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Scientific Article

Harvest stages and pulsing in ornamental sunflower 'Sunbright Supreme'

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Abstract

The use of ornamental sunflower as a cut flower has been increasing due to the advent of new cultivars and the demand of the flower-growing market for new products. However, there are few studies related to postharvest of this species. The objective of this research was to evaluate the water balance and durability of 'Sunbright Supreme' sunflower collected at three different harvest stages and submitted or not to a pulsing with sucrose. The flower stalks were collected fully open, at an intermediate opening stage and also closed; they were then standardized at 50 cm and stored in water or 4% sucrose solution during 24 hours. After this period, stalks were maintained in sealed bottles containing 500 mL of water. Fresh matter, water consumption, flower opening, complete durability and visual quality of stems were evaluated every three days, considering a rating scale of color, turgescence and stalk bending. Rates of absorption and transpiration were calculated considering the fresh matter and variation in water volume. There was an increase in fresh matter and high water consumption in inflorescences until the seventh day; after this period, there was a reduction in weight and increased transpiration rates. Stems collected closed, closed with pulsing and at an intermediate stage treated with pulsing were maintained in commercial quality about four days longer than the open harvested (with and without pulsing) and intermediate without pulsing. Sucrose pulsing leads to flower opening of stalks collected at all harvest stages. The positive water balance was observed until the seventh day and contributes to the maintenance of commercial quality in ornamental sunflower. The early harvest of ornamental sunflower 'Sunbright Supreme' is recommended, besides the application of 4% sucrose pulsing.
Keywords: *Helianthus annuus*, postharvest, floriculture, sucrose.

Resumo

Efeito do pulsing em hastes cortadas de girassol ornamental 'Sunbright Supreme' em diferentes estádios de desenvolvimento

A utilização do girassol ornamental como flor de corte vem crescendo devido ao surgimento de novas cultivares e a demanda do mercado de floricultura por novos produtos, no entanto, são escassos os trabalhos relacionados à pós-colheita dessa espécie. Assim, objetivou-se avaliar as relações hídricas e durabilidade de inflorescências da cultivar Sunflower 'Sunbright Supreme' coletadas em três diferentes pontos de colheita e submetidas ou não ao pulsing de sacarose. As hastes florais foram coletadas com as inflorescências totalmente abertas, em um estágio intermediário de abertura ou fechadas e, em seguida, foram padronizadas em 50 cm e mantidas armazenadas em água ou em solução de 4% de sacarose durante 24 horas. Após esse período, as hastes foram dispostas em frascos vedados contendo 500 mL de água. A cada três dias, as hastes foram avaliadas quanto a massa fresca, volume de solução consumida, abertura floral, durabilidade total e qualidade visual considerando-se uma escala de notas que considera padrões de coloração, turgescência e curvatura do pedúnculo. Os cálculos das taxas de absorção e transpiração foram realizados considerando-se os valores de massa fresca e variação no volume de água consumido. Foi observado aumento na absorção de água e ganho de massa fresca pelas inflorescências até aproximadamente o sétimo dia de avaliação sendo que, após esse período, houve redução de massa e aumento nas taxas de transpiração. Hastes coletadas fechadas, fechadas com pulsing e no estágio intermediário com pulsing mantiveram-se na qualidade comercial cerca de quatro dias a mais que as colhidas abertas (com e sem pulsing) e em estádio intermediárias, sem a realização de pulsing. O pulsing de sacarose favorece a abertura floral de hastes coletadas em todos os estágios de colheita. O balanço hídrico positivo foi observado até o sétimo dia de avaliação e contribui para a manutenção da qualidade comercial de girassol ornamental. Recomenda-se a colheita precoce de inflorescências de girassol ornamental 'Sunbright Supreme' e aplicação de pulsing de sacarose a 4%.
Palavras chave: *Helianthus annuus*, pós-colheita, floricultura, sacarose.

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Introduction

As a result of breeding programs, new varieties of ornamental sunflower have been made available to the flower market, presenting reduced size and different shades. These varieties have made the sunflower a prominent product in the composition of arrangements, due to its exotic shape and the different shades of flowers, which add life and dynamism to the environments (Andrade et al., 2012). As it is a new product in the floriculture market and since sunflower is normally produced for food or energy purposes, there is little research on procedures and postharvest for this species, when produced with ornamental purposes.

After harvesting, several physiological processes occur, causing the deterioration of plant products, the exhaustion of reserves by the breathing process and the wilt of the floral structures due to water loss by transpiration and reduction in absorption due to the occlusion of conducting vessels, deposition of chemicals or bacterial proliferation (Nowak and Rudnicki, 1990, Sonego and Brackmann, 1995). In this context, the optimization of water relations is one of the factors that most contribute to the control of senescence and increase the post-harvest durability of cut flowers (Finger et al., 2004; Sales et al., 2015), being influenced by the post-harvest procedures adopted. Water balance is based on the relationship between transpiration and water absorption by the flower stems (Bellé et al., 2004) and is related to the visual quality of the flowers, since it reflects the turgescence characteristic of the flower stems.

The development stage influences the total durability of cut flowers (Gupta and Dubey, 2018). The harvest stage varies according to the market and, mainly, the physiological maturity of the flowers (Curti et al., 2012). Flowers collected at a more advanced development stage frequently exhibit lower durability, since the catabolic processes leading to senescence are at more advanced stages (Gupta and Dubey, 2018; Nowak and Rudnicki, 1990). On the other hand, the early harvest of some flower species is not recommended, since the flowers could not reach full opening due to low carbohydrate reserves, or they would not reach the point of physiological maturity (Gorsel, 1994). (Naik, et al., 2008), but the feasibility of harvesting some species at early stages has been shown, unlike the traditional harvest stages, with flowers and ligules still closed (Çelikel and Reid, 2002; Sales et al., 2015; Naik, et al., 2018).

One of the main causes of flower senescence is the exhaustion of carbohydrate reserves; in this context, the supply of exogenous sugars in the form of sucrose pulsing can extend the durability of the flowers, besides yielding the opening of flowers collected early (Bellé et al., 2004; Carneiro et al., 2014). Pulsing is a form of conditioning in which tissue saturation occurs by substances such as solutions of sugars, organic acids, inhibitors of the synthesis or action of ethylene and bactericides, immediately after collection, for a maximum period of 48 hours (Dias-Tagliacozzo et al., 2005).

For the ornamental sunflower, the usual harvest stage is the intermediate, with the pseudanthium partially open and the pulsing of 4% sucrose is indicated for a period of 24 hours (Rodrigues et al., 2012; Naik et al., 2018). However, there is no information on the possibility of harvesting at other stages, nor any specifications for 'Sunbright Supreme' sunflower. Therefore, the objective of this research was to evaluate the quality of stems collected at different harvest stages and the application or not of sucrose pulsing.

Material and Methods

'Sunbright Supreme' ornamental sunflower seeds (Sakata®) were arranged in 8 x 3 m beds, under full sun, spaced 50 x 20 cm. The soil of the experimental area was classified as Oxisol, with average fertility in the layer of 0 to 20 cm. Soil analysis and fertilization were performed according to indications for grain sunflower (Ribeiro et al., 1999). Initial fertilization with 2.5 kg/m^2 of tanned manure and 50 g/m^2 of 10:10:10 NPK/m^2 was performed. At 30 days, cover fertilization was performed with 80 g of NPK (10:10:10) and 300 g of Yoorin master® 1S fertilizer per growing line. The plants were irrigated daily until field capacity and the control of invasive plants was done manually.

The stems were harvested when the collection points were closed, partially open (intermediate or commercial point) and open. These points were determined by the expansion of flower pseudanthium ligules, slightly expanded, intermediate opening or fully expanded (Figure 1). The stems were collected early in the morning, immediately arranged in water and transported to the postharvest laboratory. All leaves were removed and the stems were standardized at 50 cm in height. The stems were immersed in 0.2 g L^{-1} sodium hypochlorite solution for 30 min and then conditioned for 24 h in tap water or pulsing solution with 4% sucrose (Rodrigues et al., 2012), according to the treatments.

Figure 1. Harvest stages: closed (A, B), intermediate (C, D) and open inflorescences (E, F).

After 24 hours, the stems were evaluated, packed in sealed vials containing 500 mL of water and stored under refrigeration at an average temperature of 18 °C.

The flower stems were evaluated every three days for fresh matter (g) and the volume of solution consumed (mL) was determined. All inflorescences were photographed during the evaluations. The images were used to evaluate flower opening through the measurement of the diameter of the floral pseudanthium, which was done using the Image Tool® software.

The visual quality of the inflorescences was measured by a score scale assigned by three evaluators, every three days, considering parameters of coloration, brightness, turgescence and slope of the floral pseudanthium.

In order to classify the visual quality of 'Sunbright Supreme' ornamental sunflower inflorescences, a score scale was established, as is the case for other species such as calla lily (Sales, et al., 2015; Sales, et al., 2018), based on turgescence, brightness, coloration and slope parameters of the pseudanthium (Table 1). Commercial durability was estimated based on the number of days the stems remained in scores 4 and 3.

Table 1. Score scale for the evaluation of visual quality of 'Sunbright Supreme' ornamental sunflower inflorescences.

Score	Peripheral ligulated flowers	Pseudanthium	General aspect
4	Turgid, bright, absence of spots	Turgid, without slope	Excellent
3	Turgid, bright, absence of spots	Turgid, slope lower than 30°	Good
2	Slightly wilted and opaque, appearance of dimming points	Slightly wilted, slope between 30° and 45°	Medium
1	Wilted and opaque, presence of dimming points	Wilted, slope between 45° and 60°	Bad
0	Totally wilted and dull, totally darkened	Wilted, slope higher than 60°	Discard

The transpiration rate was estimated according to the formula T = V - (PHf - PHi) mg g^{-1}MF day^{-1}; where, T: transpiration rate; V: volume of solution absorbed; PHi: stem mass at the beginning; PHf: stem mass at the end. The water absorption rate was determined by V= (PSi - PSf)/PH mg g^{-1}MF day^{-1}; where, V: volume of solution absorbed, PSi: initial mass of the solution, PSf: final mass of the solution, PH: final stem mass (Van Doorn and Vaslier, 2002).

The experiment consisted of a factorial 2 x 3; 3 harvest stages were tested, as well as the application or not of sucrose pulsing. The experimental design was completely randomized with 6 treatments, 4 replicates and 2 plants per plot. The data obtained were evaluated using the Sisvar® software (Ferreira, 2011).

Results and Discussion

Physiological analyses

In the fresh matter analysis, the effect of the interaction between the harvest stages and the sucrose pulsing application was identified (Figure 2).

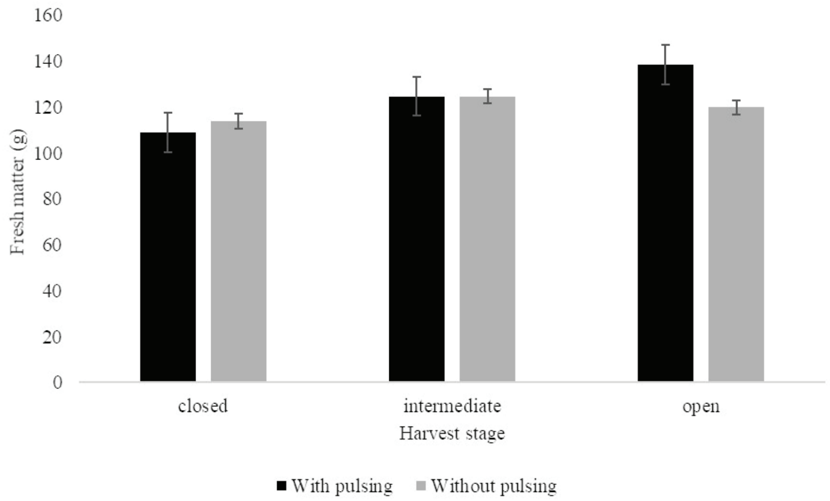

Figure 2. Mean values for fresh matter (g) for ornamental ‘Sunbright Supreme’ sunflower inflorescences harvested at different harvest stages and sucrose pulsing (0 or 4%). Values followed by the same lowercase letter do not differ for the variable harvest stage and, by the same capital letter, they do not differ for pulsing or not by the Tukey test at 5% probability. CV=16.13%

The use of sucrose pulsing affected the fresh matter of stems collected at the open stage, which showed superiority to those that did not receive this treatment (Figure 2). The use of sucrose at post harvest tends to contribute to the water balance of the stems, maintenance of turgidity and improvement in water absorption, due to the reduction in the osmotic potential of the stems and to the aid in stomatal closure (Moraes et al., 1999). Increased longevity is another beneficial effect, already observed in sunflower (Gonzaga et al., 2001).

Comparing the fresh matter of stems collected at different harvest stages, no variation was observed for the stems harvested closed, at the commercial stage or open, when no pulsing was applied. However, as a consequence of the more advanced maturation stage, the fresh matter is higher in stems harvested open and at the commercial point, due to the longer period for the accumulation of reserves.

Analyzing water absorption and transpiration rates, they varied according to the time after harvest, regardless of the treatment applied (Figure 3), with a marked reduction occurring after seven days of harvest. The durability of cut flowers is influenced by absorption, retention capacity, transport and loss of water in the tissues (Gupta and Dubey, 2018); thus, the reduction in water in the tissues is directly related to their durability.

For the visual quality of ornamental sunflower, the interaction between harvest stages and the application of sucrose pulsing was observed (Table 2).

Throughout the experimental period, loss of color, brightness and turgescence of ligulated flowers was observed (Table 3).

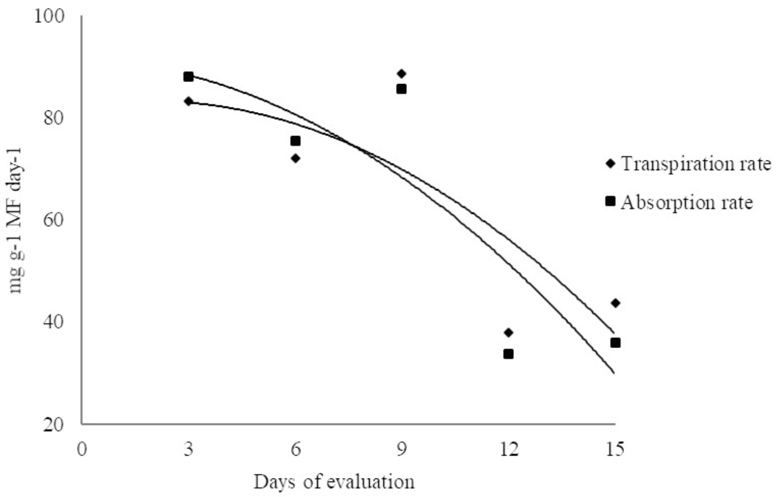

Figure 3. Water absorption and transpiration rates (mg g^{-1} MF day^{-1}) of ornamental ‘Sunbright Supreme’ sunflower stems during storage.

Table 2. Visual quality of ornamental 'Sunbright Supreme' sunflower stems as a function of harvest stage and pulsing (sucrose at 4%) (0 to 4 where, 0 = discard and 4 = excellent).

	Harvest stage		
	Closed	**Intermediate**	**Open**
Pulsing	3.13aA	2.79aA	2.07aB
Without pulsing	3.02aA	2.64aB	1.58bC

Values followed by the same lowercase letter in the column and by the same uppercase letter in the rows do not differ by the Tukey test at 5% probability. CV=20.78%

Table 3. Visual aspect of ornamental sunflower inflorescences collected at different harvest stages and submitted or not to sucrose pulsing.

	Closed	**Intermediate**	**Open**	**Closed**	**Intermediate**	**Open**
	Without Pulsing			**Pulsing**		
1st day						
9th day						
15th day						

Flower stems treated with sucrose pulsing had higher mean visual quality values than those that did not receive the treatment at all harvested stages evaluated. This positive effect of pulsing on maintaining post-harvest quality has been observed in other ornamental species such as Aster (Pivetta et al., 2018; Prakash et al., 2018), chrysanthemum (Bellé et al., 2004), costus (Maithong et al., 2018) and calla lily (Almeida et al., 2011), thus demonstrating that its use is also favorable in sunflower. The maintenance of quality for a longer period as a consequence of the treatment with sucrose can be attributed to the reduction in transpiration associated to the increase in osmotic potential by the energy supply to maintain the cellular homeostasis (Van Doorn and Woltering, 2008), thus contributing to the maintenance of the visual characteristics of flowers. However, in the evaluation of transpiration (Figure 3), it was not affected by the applied treatments; therefore, the extension of the period of higher quality is only attributed to energy supply.

The durability of sunflower maintained at 20 °C is 6.3 days, when harvested open (Çelikel and Reid, 2002) and this was confirmed for 'Sunbright Supreme' (Table 4). Comparing the harvest stages of the stems, it was observed that the stems collected still closed showed no difference, compared to the stems collected at the intermediate point and treated with pulsing (Table 4). In general, stems harvested at the open stage showed less commercial durability (scoes 3 and 4) since, even at maximum harvest quality, they were already at a more advanced development stage and closer to senescence. Early harvest is interesting precisely as it enables greater durability, which allows a longer period of transport and commercialization, and this has been indicated for other species traditionally harvested at the open stage, such as torch ginger (Carneiro et al., 2014) and calla lily (Castro et al., 2014). Early harvest also contributed to the maintenance of the quality of the flower stems for a longer period.

Table 4. Durability (days) of the commercial quality of ornamental ‘Sunbright Supreme’ sunflower stems as a function of harvest stage and pulsing (sucrose 4%).

	Harvest stage		
	Closed	Intermediate	Open
Pulsing	12.45 aA	10.95 aA	6.0 aB
Without pulsing	12.00 aA	8.7 bB	7.5 aB

Means followed by the same lowercase letter in the column and by the same uppercase letter in the rows do not differ by the Tukey test at 5% probability. CV=12.67%

Stems harvested closed and intermediate added with sucrose pulsing remained in scores 4 and 3 until the tenth and twelfth days, respectively, while the stems collected open (with and without sucrose pulsing) and those collected at the intermediate point without the application of pulsing, showed loss of quality from the seventh day of evaluation (Figure 4).

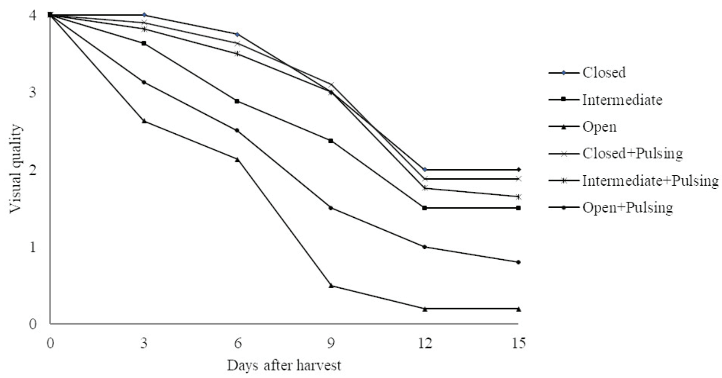

Figure 4. Visual quality of ornamental ‘Sunbright Supreme’ sunflower stems as a function of days after harvest.

The visual quality of the flower stems is directly related to the water balance since, after the seventh day, with the marked reduction in water absorption and transpiration, there was also a marked reduction in the observed visual quality. From that period, there was also loss of turgescence of ligulated flowers, which is probably related to the increase in transpiratory rates and the consumption of respiratory substrates of the flower stem. The longer durability of stems harvested early and treated with sucrose pulsing can be attributed to the fact that the treatment with exogenous sugars provided respiratory substrates for the flower stems for a longer period, delaying the consumption of the plant endogenous reserves.

Differences were observed for flower opening as a function of sucrose pulsing treatment and different harvest stages (Table 5). Therefore, plants that received sugar addition had higher average values of final inflorescence diameter, and a statistical difference for stems harvested at intermediate and open stages was observed, when comparing the application or not of pulsing.

Table 5. Opening of ornamental sunflower inflorescences (cm), as a function of harvest stage and pulsing.

	Harvest stage		
	Closed	**Intermediate**	**Open**
Pulsing	16.58aA	16.41aA	16.40aA
Without pulsing	15.78aA	15.20bB	15.41bA

Means followed by the same lowercase letter in the column and by the same uppercase letter in the rows do not differ by the Tukey test at 5% probability. CV=11.18%

The addition of exogenous sugars during flower opening is beneficial, since they act as substrates for the metabolism and also tend to cause increased concentration of sugars in the flowers. The sugars probably propitiate an osmotic potential favorable to the expansion of the cells that form the petals, stimulating the opening of floral buds (Cho et al., 2001). The positive effect on flower opening has already been observed in chrysanthemum (Spricigo et al., 2010), snapdragon (Ichimura and Hisamatsu, 1999) and calla lily (Almeida et al., 2011). The supply of sucrose also contributes to better maintenance of reserve substances in the stem and increased pot life (Spricigo et al., 2010; Almeida et al., 2011). Another effect is to lead to the complete development of flowers harvested early (Bellé et al., 2004; Spricigo et al., 2010; Almeida et al., 2011), besides increasing the color intensity of the petals (Ichimura and Hisamatsu, 1999).

A difference was observed in flower opening as a function of time and the harvest stage of the stems (Figure 5). For all treatments, an increase in flower opening was observed, followed by a decrease due to the senescence of the inflorescence. It took longer for stems harvested closed to reach the estimated maximum opening stage (8.3 days), in addition to reaching the highest total inflorescence diameter (18.5 cm).

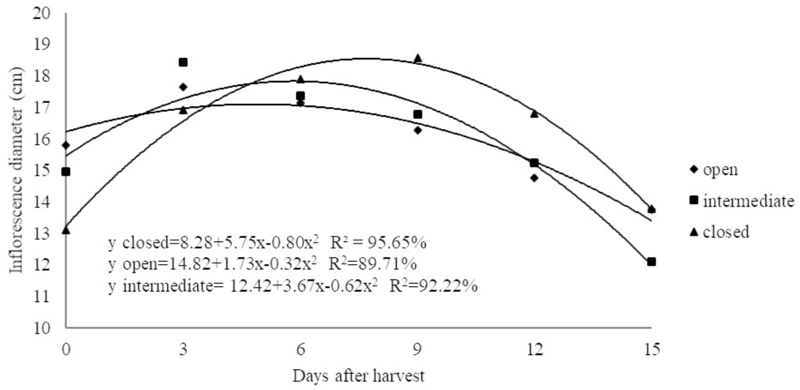

Figure 5. Opening of ornamental sunflower inflorescences (cm) as a function of days after harvest.

Many species harvested early do not complete their flower opening process. Thus, it is important to note that the use of sucrose does not increase its openness due to carbohydrate depletion and proteolysis (Rocancio et al., 1995) and to the precarious water balance and low turgidity power (Halevy, 1976). However, it was observed that the ornamental sunflower collected early, continues its opening process and presents desirable commercial characteristics for a longer period.

For ornamental 'Sunbright Supreme' sunflower, it was observed that the period of greatest flower opening coincided with the period when there was greater water absorption. This can be attributed to the fact that flower opening is a process that involves high rates of cell division and expansion and requires high levels of water. With the reduction in transpiration (from day 7), the ligulated flowers began a process of loss of turgescence that led to the reduction in flower diameter, natural in senescence processes.

The ideal harvest stage varies as a function of species, market requirement and logistics. Early harvesting frequently has advantages for distant consumer markets, enabling quality maintenance for longer, facilitating transportation, taking up less space and preventing damage (Castro et al., 2014), and is a viable alternative to extend durability.

Conclusions

It is recommended to harvest 'Sunbright Supreme' ornamental sunflower inflorescences at closed or intermediate stages and the treatment with 4% sucrose pulsing is recommended for greater commercial durability and flower bud opening.

Author Contribution

AMPN 0000-0002-2846-3272: perform the idea, experiment installation, condut and evaluations; writing the text. PDOP 0000.0001.7997.8420: perform the idea, participation in the experiment conduct, writing and corrections the article. GMM 0000-0001-8883-1471: experiment condut and evaluations. TSS 0000-0002-6558-6896: experiment condut and evaluations

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