

Strategies for postharvest life extension of pascuíta (*Euphorbia leucocephala* Lotsy) as a cut flower using heat treatments and silver nanoparticles

Estrategias para prolongar la vida postcosecha de pascuíta (*Euphorbia leucocephala* Lotsy) como flor de corte mediante tratamientos térmicos y nanopartículas de plata

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ABSTRACT

Pascuíta (*Euphorbia leucocephala* Lotsy) is a short-day ornamental species with potential for use as a cut flower; however, its vase life is limited due to latex-induced stem blockage, which restricts water uptake. In this study, we evaluated the effect of hot water immersion of the stem base (2.5 to 30 s) and various concentrations of silver nanoparticles (AgNPs, 1-40 mg L⁻¹), applied either as a 24 h pulse or continuously through vase water, on the postharvest performance of cut pascuíta flowers. Immersion for 15 s was the most effective treatment to reduce latex blockage. On the other hand, continuous application of AgNPs at 10 and 15 mg L⁻¹ significantly extended vase life for up to 14 days, improved water uptake, delayed leaf abscission, and enhanced visual quality. These results suggest that combining physical and nanotechnological strategies can improve postharvest quality in this species. Future studies should focus on understanding the physiological and microbiological mechanisms involved, as well as the environmental impact of AgNP use.

Keywords: Vase life; nanotechnology; xilem blockage.

RESUMEN

La pascuíta (*Euphorbia leucocephala* Lotsy) es una planta ornamental de día corto con potencial de aprovechamiento como flor de corte, sin embargo, su vida postcosecha es limitada debido a la presencia de látex en los tallos que obstruye la absorción de agua en flores cortadas. En este estudio se evaluó el efecto del tiempo de inmersión de la parte baja del tallo cortado en agua hirviendo (2.5 a 30 s) y de diferentes concentraciones de nanopartículas de plata (AgNPs, 1-40 mg L⁻¹), aplicadas como tratamiento pulso y en el agua del florero, sobre la vida postcosecha de flores cortadas de pascuíta. La inmersión durante 15 s fue el tratamiento más efectivo para evitar el taponamiento por látex. Por otro lado, el uso de AgNPs en el agua del florero, particularmente a 10 y 15 mg L⁻¹, prolongó la vida en florero hasta 14 días, mejoró la absorción de agua, retrasó la caída de hojas y mantuvo mayor atractivo visual. Estos resultados sugieren que la combinación de técnicas físicas y nanotecnológicas puede optimizar la calidad postcosecha de esta especie. Se recomienda evaluar en estudios futuros los mecanismos fisiológicos y microbiológicos involucrados, así como el impacto ambiental del uso

de AgNPs.

Palabras clave: Vida en florero; nanotecnología; taponamiento del xilema.

INTRODUCTION

Pascuíta (*Euphorbia leucocephala* Lotsy) is an ornamental species native to southern Mexico and Central America. It was described by Lotsy (1895) as a shrub that grows to a height of 60 cm to 2.1 m. Its stems are striated, thickening at the joints and becoming hairless with age, a stark contrast to their woolly appearance in youth. The lower leaves are obovate and arranged in whorls, while the upper leaves are oblong with a pointed tip and typically grow in groups of three. The plant's most notable feature is its terminal, dichasial inflorescence, which is prominent due to the numerous white, spatulate, and pointed bracts that are larger than the cyathium, the characteristic flower of the family. The cyathium itself is bell-shaped and hairy, with transverse oblong glands. The plant produces a hairless, deeply three-lobed capsule that contains seeds without a caruncle, although they may sometimes appear wrinkled.

Like poinsettia (*E. pulcherrima*), pascuíta is a short-day plant, blooming during fall and winter (Galindo-García *et al.*, 2019). Although commonly marketed as a potted ornamental, its vigorous vegetative growth often results in asymmetrical shapes and overly large aerial structures, which may reduce its commercial appeal.

Using pascuíta as a cut flower offers a promising alternative for ornamental exploitation. However, this use also presents specific challenges. Similar to other *Euphorbia* species, pascuíta produces latex in its tissues (Galindo-García *et al.*, 2019). Upon detachment, the latex rapidly coagulates in the presence of air, forming a plug that obstructs water uptake and significantly reduces postharvest life (Bredmose, 1982).

Hot water immersion of the cut end has been reported as an effective method to reduce latex-induced blockage in pascuíta and related species (Sytsema, 1966; Bredmose, 1982). However, optimal immersion duration and the effectiveness of complementary postharvest treatments remain unclear.

Silver nanoparticles (AgNPs) are metallic colloidal structures measuring 1-100 nm, known for their unique

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physicochemical properties due to high surface-area-to-volume ratio (Naing and Kim, 2020). In agriculture, AgNPs have shown positive effects on seed germination, plant growth, nutrient uptake, and pest and disease management (Khan *et al.*, 2023). In postharvest applications, AgNPs have enhanced water uptake and vase life in lily (Mahmoudian *et al.*, 2025), peony (Ma *et al.*, 2023), gladiolus (Maity *et al.*, 2019), carnation (Naing *et al.*, 2017; Park *et al.*, 2017), alstroemeria (Langroudi *et al.*, 2020), cosmos (Skutnik *et al.*, 2020), and gerbera (Solgi *et al.*, 2009).

The positive effects of AgNPs on the postharvest life of flowers are primarily attributed to these particles' potential to inhibit bacterial growth (Solgi *et al.*, 2009; Naing and Kim, 2020; Ma *et al.*, 2023). This prevents the blockage of the xylem by bacteria (which is one of the main inhibitors of cut flower postharvest life) and allows water absorption. Likewise, AgNPs have been reported to reduce ethylene synthesis in some floral species, an effect related to the inhibition of genes involved in this hormone biosynthesis (Naing *et al.*, 2017; Park *et al.*, 2017; Naing and Kim, 2020). Furthermore, they have been related with antioxidant activity by inducing enzymes that mitigate the effects of reactive oxygen species (Maity *et al.*, 2019; Mahmoudian *et al.*, 2025).

While the effects of AgNPs on cut flowers postharvest are evident, the appropriate dose to achieve positive effects depends on multiple factors, such as the nanoparticle synthesis method, size, plant species, combination with other chemical agents, and the application method (e.g., as a pulse treatment or added to vase water) (Naing and Kim, 2020). Therefore, it's crucial to design experiments that consider the use of AgNPs at different doses and application methods for each genotype.

Based on the preceding information, the present study aimed to determine the effect of immersion time of stem bases in boiling water, as well as to evaluate the impact of different doses of silver nanoparticles, applied as a pulse treatment and added to vase water, on the vase life of cut *E. leucocephala* flowers.

MATERIAL AND METHODS

Plant material

The mother plants of pasquita (*E. leucocephala*) used in this study were cultivated in a greenhouse at Universidad Autónoma Chapingo. The plants were grown in 20 L pots filled with a substrate composed of soil and perlite in a 9:1 ratio, and were fertilized once a week with Ultrasol® multipropósito (1000 mg L⁻¹).

Cutting material consisted of terminal shoots (flowers) harvested approximately one week after full development (when all cyathia were fully open). The cut was made just below the penultimate node before the flowers (Figure 1). Selected flowers had a similar size and developmental stage to ensure uniformity.

Treatments and experimental design

Phase 1. A completely randomized design was used to evaluate the effect of hot water immersion of the basal end (≈

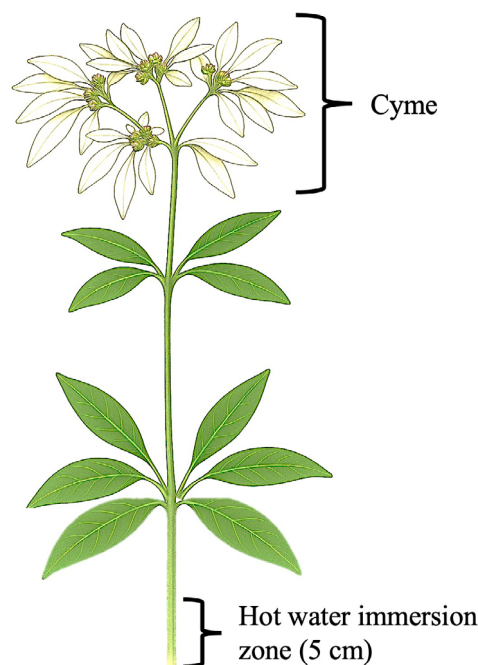


Figure 1. Structure of *E. leucocephala* used as a cut flower in the present study.

Figura 1. Estructura de *E. leucocephala* utilizada como flor de corte en el presente estudio.

5 cm) of the cut stems (Figure 1). Treatments consisted of immersing the stem base in boiling water for 2.5, 5, 10, 15, 20, or 30 s. Each treatment included four replicates. Immersion was performed immediately after harvest. The aerial portion of the plant (leaves, bracts, and cyathia) was protected from stem exposure to hot water using a cardboard shield to prevent heat damage.

Phase 2. Using the 15 s hot water immersion as a baseline treatment, a second completely randomized experiment was designed to evaluate the effect of different concentrations of silver nanoparticles (AgNPs, diameter < 20 nm; manufactured by Investigación y Desarrollo de Nanomateriales S.A. de C.V.) applied via two methods: pulse treatment (24 h exposure) or continuous treatment (direct addition to vase water). The specific treatments are listed in Table 1. Each treatment was replicated four times.

Tap water was used as the base for all treatments. Experiments were conducted under laboratory conditions, with daytime temperature and relative humidity averaging 24.01 ± 3.97 °C and 30.18 ± 8.14 %, respectively, and nighttime conditions averaging 22.58 ± 0.69 °C and 29.6 ± 2.23 %.

Measured variables

In both experimental phases, vase life was recorded by counting the number of days from 24 h post-harvest until the bracts were completely dry and/or most had abscised. Additional measurements included the number of days with leaf presence, daily water uptake, and daily loss of leaf greenness

Table 1. Silver nanoparticle treatments used to evaluate their effect on the postharvest performance of cut *E. leucocephala* flowers.

Cuadro 1. Tratamientos con nanopartículas de plata para evaluar su efecto en la postcosecha de flores cortadas de *E. leucocephala*.

Treatment	Application type	Dose (mg L ⁻¹)
T	Control	0
C01	Continuous	1.0
C05	Continuous	5.0
C10	Continuous	10.0
C15	Continuous	15.0
P10	Pulse (24 h)	10.0
P20	Pulse (24 h)	20.0
P30	Pulse (24 h)	30.0
P40	Pulse (24 h)	40.0

(SPAD values, measured with a Konica Minolta® 502-Plus). In Phase 2, daily fresh weight loss was also measured. Based on initial and final values, total weight loss, total leaf greenness loss, and total water uptake were calculated.

Statistical analysis

Data corresponding to vase life, days with leaf presence, total water uptake, total SPAD loss, and total weight loss were subjected to analysis of variance (ANOVA), followed by Fisher's Least Significant Difference (LSD) test for mean comparisons ($\alpha \leq 0.05$). Statistical analyses were conducted using SAS® System Software, version 9.0. Time-course data were graphically represented using line charts

RESULTS AND DISCUSSION

Phase 1. Effect of hot water immersion

Analysis of variance and post-hoc tests revealed statistically significant differences ($P \leq 0.05$) among treatments for all evaluated variables, except total water uptake during phase 1.

Stem-end immersion in boiling water proved to be an effective strategy to prolong the vase life of cut flowers of *E. leucocephala*. Without this treatment, latex-induced blockage was so pronounced that even the short time between harvest and transport from the greenhouse to the lab was sufficient to dehydrate the flowers, reducing postharvest life to only a few hours. Among the tested immersion times, the 15 s treatment resulted in the longest vase life, with an average of 9.67 days. Although this treatment did not differ statistically (LSD, $P \leq 0.05$) from the 5, 10, or 20 s treatments, it was clearly superior to the 2.5 and 30 s treatments (Figure 2). These results contrast with those reported by Sytsema (1966), who recommended a 1 s immersion for some poinsettia cultivars, and with Bredmose (1982), who proposed a 30 s of immersion for *E. leucocephala*.

The positive effect of boiling water is associated with two key mechanisms: the dilution of exuded latex at the cut site, and the coagulation of latex within the laticifers (Manzoor *et al.*, 2024). Short immersion times may not be sufficient to trigger these effects, whereas prolonged exposure can damage plant tissues. This is evidenced by water uptake measurements across treatments (Figure 3). In the

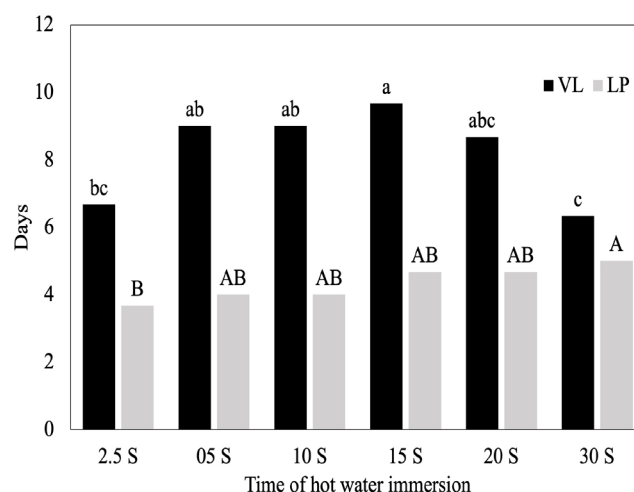


Figure 2. Effects of different immersion times of cutted *E. leucocephala* stems in boiling water on vase life and leaf persistence. VL: vase life; LP: leaf persistence. Bars of the same color sharing the same letter are not statistically different (LSD, $P \leq 0.05$).

Figura 2. Efectos de diferentes tiempos de inmersión del tallo cortado de *E. leucocephala* en agua hirviendo sobre la vida en florero y los días con presencia de hojas. VL: vida en florero, LP: presencia de hojas. Barras del mismo color con letras iguales no son diferentes estadísticamente (LSD, $P \leq 0.05$).

15 s treatment, total water uptake was highest, primarily due to the extended vase life. Furthermore, on day 9 (when most stems in other treatments had ceased absorbing water), the 10 and 15 s treatments still showed the highest daily water uptake values (Figure 3).

Regarding leaf retention, none of the treatments maintained leaf presence for more than five days (Figure 2), and SPAD-measured greenness loss was rapid under all treatments (Figure 4). Only the 30 s immersion showed a statistically lower total SPAD loss in the leaves, although this was not visually perceptible.

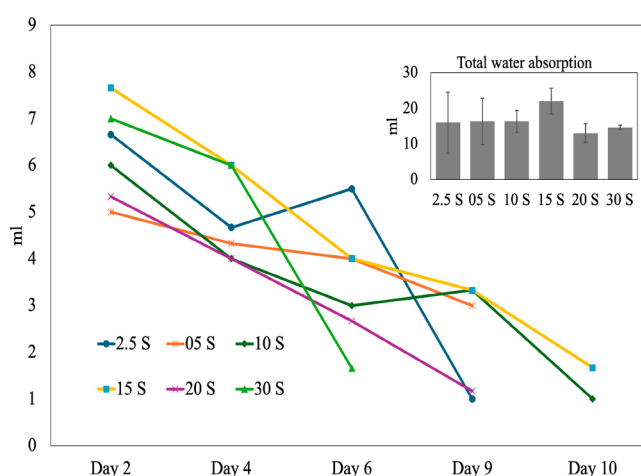


Figure 3. Effects of different immersion times of the cutted stem in boiling water on water uptake during the vase life of *E. leucocephala*.

Figura 3. Efectos de diferentes tiempos de inmersión del tallo cortado en agua hirviendo sobre la absorción de agua durante la vida en florero de *E. leucocephala*.

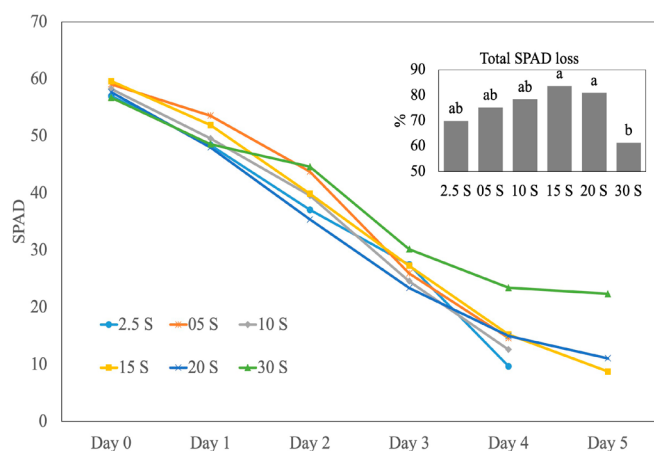


Figure 4. Effects of different immersion times of the cutted stem in boiling water on SPAD unit loss during the vase life of *E. leucocephala*. Bars with the same letter are not statistically different (LSD, $P \leq 0.05$).

Figura 4. Efectos de diferentes tiempos de inmersión del tallo cortado en agua hirviendo sobre la pérdida de unidades SPAD durante la vida en florero de *E. leucocephala*. Barras con letras iguales no son diferentes estadísticamente (LSD, $P \leq 0.05$).

Figure 5 illustrates the visible effects of the different immersion treatments on pasquita flowers five days after the beginning of the experiment. The negative effects of both 2.5 and 30 s immersions were evident. In the first one, insufficient water absorption led to rapid dehydration, while in the last one, signs of accelerated senescence were observed. The 5, 10, and 15 s treatments resulted in flowers with the best overall visual appearance.

Phase 2. Silver Nanoparticle Treatments

The application of AgNPs as a continuous treatment (added directly to the vase water) had a more pronounced positive effect on the postharvest life of *E. leucocephala* flowers compared to both the control and the pulse treatments (Figure 6). Under treatment with 15 mg L⁻¹ of AgNPs in the vase water, postharvest life was extended to 14 d, representing a five-day advantage over the control.

Water uptake in the first few days postharvest is one of the main determinants of vase life. In this study, treatments with AgNPs added to the vase water showed greater water absorption on the second day than both the pulse treatments



Figure 5. Effects of different immersion times of the cutted stem in boiling water on the *E. leucocephala* visual appearance five days after the start of the experiment.

Figura 5. Efectos de diferentes tiempos de inmersión del tallo cortado en agua hirviendo sobre el atractivo visual de *E. leucocephala* a los cinco días de iniciado el experimento.

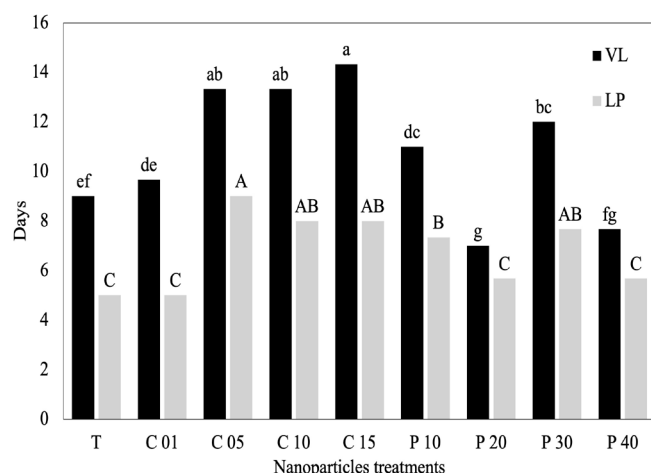


Figure 6. Effects of different doses and application methods of AgNPs on vase life and leaf retention in *E. leucocephala* cut flowers. Bars of the same color sharing the same letter are not significantly different (LSD, $P \leq 0.05$).

Figura 6. Efectos de diferentes dosis y métodos de aplicación de AgNPs sobre la vida en florero y los días con presencia de hojas en flores cortadas de *E. leucocephala*. Barras del mismo color con letras iguales no son diferentes estadísticamente (LSD, $P \leq 0.05$).

and the control (Figure 7). Although this trend reversed by day four, cumulative water uptake was highest under the 5, 10, and 15 mg L⁻¹ continuous AgNP treatments, likely due to their longer vase life.

The positive effect of AgNPs on water uptake in cut flowers has been associated with their ability to inhibit stem blockage caused by bacterial colonization. In species such as carnation (Naing *et al.*, 2017; Park *et al.*, 2017), cosmos (Skutnik *et al.*, 2020), peony (Ma *et al.*, 2023), gladiolus (Maity *et al.*, 2019), and alstroemeria (Langroudi *et al.*, 2020), AgNPs have been shown to reduce bacterial growth both in the vase solution and inside the xylem, thereby improving water conductivity and hydration. Although microbial growth were not quantified in the present study, we do not rule out that the improved water uptake observed under AgNP treatments may be due in part to this antimicrobial activity.

Beyond their antimicrobial effects, AgNPs also interact with ethylene biosynthesis pathways due to the release of silver ions, which inhibit key genes in ethylene production. This interaction can mitigate several ethylene-induced postharvest symptoms in cut flowers, such as petal drop, leaf yellowing, chlorophyll degradation, and increased respiration (Naing *et al.*, 2017; Park *et al.*, 2017; Naing and Kim, 2020; Skutnik *et al.*, 2020).

In the present study, leaf retention time was highest under the 5 mg L⁻¹ continuous AgNP treatment, although it was not significantly different ($P \leq 0.05$) from the 10 and 15 mg L⁻¹ treatments or the 30 mg L⁻¹ pulse treatment (Figure 6). Leaf greenness, as measured by SPAD, declined rapidly in the control and C01 treatments (Figure 8). Interestingly, the highest total SPAD loss occurred in the 10 mg L⁻¹ continuous treatment. This can be attributed to the extended presence of leaves under this treatment, allowing for a more prolonged degradation of chlorophyll before senescence and abscission.

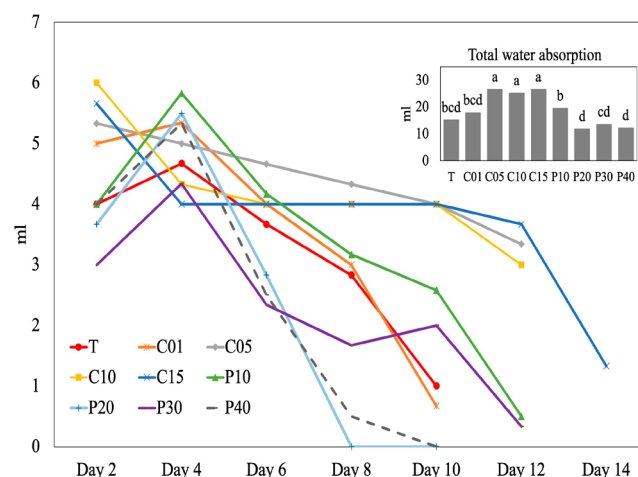


Figure 7. Effects of different doses and application methods of AgNPs on water absorption in *E. leucocephala* cut flowers. Bars sharing the same letter are not significantly different (LSD, $P \leq 0.05$).

Figura 7. Efectos de diferentes dosis y métodos de aplicación de AgNPs sobre la absorción de agua en flores cortadas de *E. leucocephala*. Barras con letras iguales no son diferentes estadísticamente (LSD, $P \leq 0.05$).

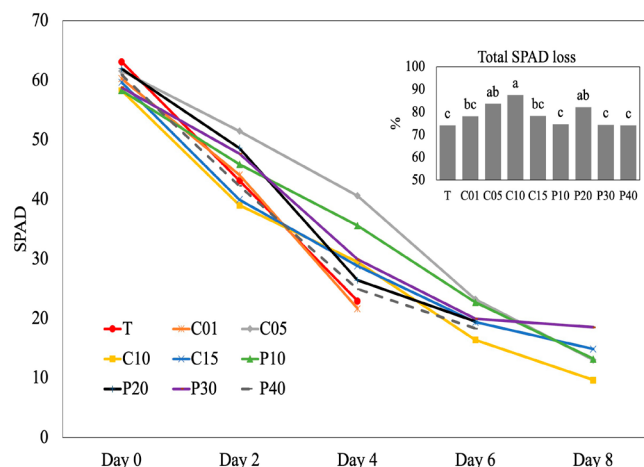


Figure 8. Effects of different doses and application methods of AgNPs on greenness leaves loss in *E. leucocephala* cut flowers. Bars sharing the same letter are not significantly different (LSD, $P \leq 0.05$).

Figura 8. Efectos de diferentes dosis y métodos de aplicación de AgNPs sobre la pérdida de verdor de las hojas en flores cortadas de *E. leucocephala*. Barras con letras iguales no son diferentes estadísticamente (LSD, $P \leq 0.05$).

Weight loss during vase life is a useful indicator of physiological deterioration, influenced by dehydration, leaf and bract drop, and the respiration-driven depletion of carbohydrate reserves. In this study, the highest total weight loss was recorded under the continuous AgNPs treatments (Figure 9). Rather than indicating damage, this reflects the longer vase life of flowers in these treatments, leading to extended respiratory activity and gradual loss of plant tissue. In contrast, the control and pulse-treated stems senesced earlier and therefore lost less weight overall.

While the variables discussed above help clarify the physiological responses of pasquita during postharvest, the most commercially relevant trait is visual quality. In this study, all AgNPs treatments improved the visual appearance of cut

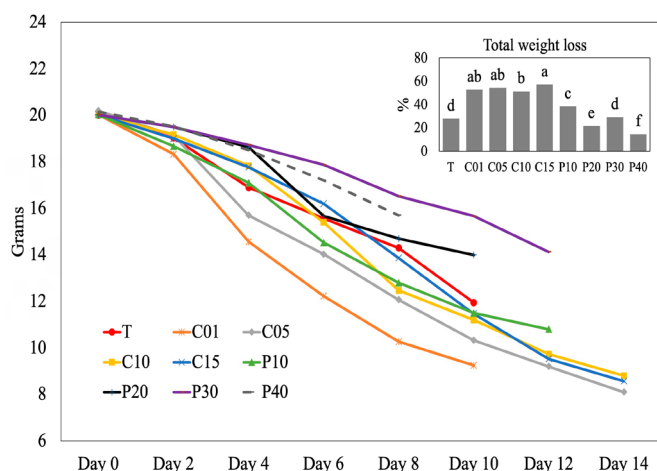


Figure 9. Effects of different doses and application methods of AgNPs on weight loss in *E. leucocephala* cut flowers. Bars sharing the same letter are not significantly different (LSD, $P \leq 0.05$).

Figura 9. Efectos de diferentes dosis y métodos de aplicación de AgNPs sobre la pérdida de peso en flores cortadas de *E. leucocephala*. Barras con letras iguales no son diferentes estadísticamente (LSD, $P \leq 0.05$).

flowers compared to the control (Figure 10). However, continuous treatments (AgNPs in vase water) maintained superior visual quality for a longer duration than pulse treatments. Among these, the 10 and 15 mg L⁻¹ doses stood out as the most effective.

This study demonstrates the potential use of pasquita as a cut flower and the positive impact of silver nanoparticles on the vase life of cut *E. leucocephala* flowers. Future research should focus on understanding the physiological and microbiological mechanisms involved, particularly those affecting xylem blockage and tissue senescence.

While the findings align with previous reports in other ornamental species, it is important to emphasize the environmental risks associated with AgNPs use. These particles ultimately release silver ions, which can be toxic at high concentrations and tend to persist in the environment (Naing and Kim, 2020). Their bioaccumulation and potential

for ecosystem contamination must be considered. Therefore, future research should aim to define safe and effective doses and explore technologies for neutralizing residual silver ions before disposal.

CONCLUSIONS

Immersing the basal portion of the stem in boiling water is an effective technique to enhance the postharvest life of cut flowers of *E. leucocephala*, with 15 s being the most suitable immersion time among those tested. The use of silver nanoparticles (AgNPs) applied as a continuous treatment (added to the vase solution) at concentrations of 10 and 15 mg L⁻¹ significantly extended vase life, improved water uptake, delayed leaf abscission, and preserved visual quality compared to both the pulse treatments and the control. Altogether, these findings indicate that the combination of thermal and nanotechnological strategies represents a promising approach for optimizing the ornamental value and commercial potential of *E. leucocephala* as a cut flower.

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CONFLICTS OF INTEREST

Authors declare no conflicts of interest

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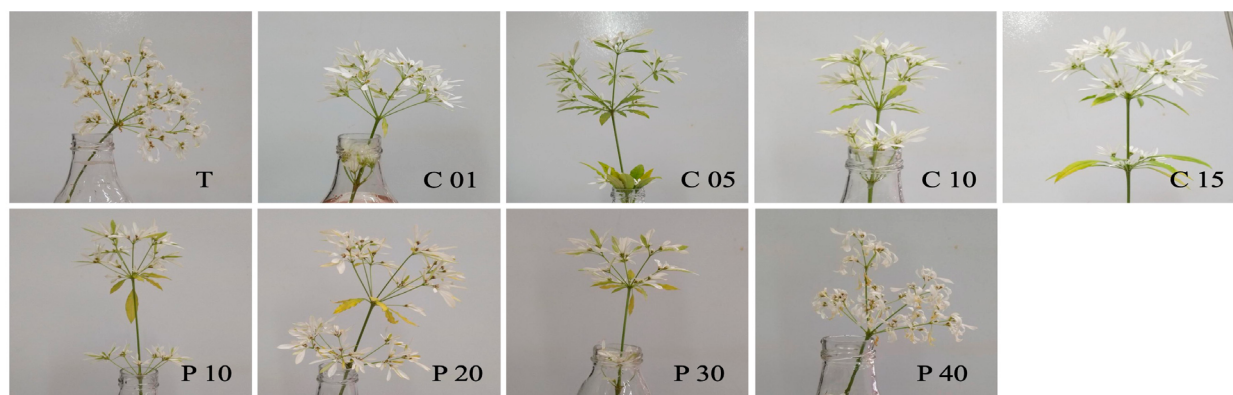


Figure 10. Effects of different doses and application methods of AgNPs on the *E. leucocephala* visual appearance seven days after the start of the experiment.

Figura 10. Efectos de diferentes dosis y métodos de aplicación de AgNPs sobre el atractivo visual de *E. leucocephala* a los siete días de iniciado el experimento.

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