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Article

Glucose concentration and the longevity of cut roses: sugar-induced senescence

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SUMMARY

Ensuring optimal cut flower longevity is a central objective in the floriculture industry, as it profoundly influences visual quality, commercial value, and end-user satisfaction. Keeping the costliest ornamental flower to purchase, the cut rose, fresh is especially valuable to florists, retailers, and consumers who would like to extend the vase life of roses. This study examines the influence of varying glucose concentrations on the post-harvest longevity of cut roses. We hypothesized that exposure to higher glucose levels would enhance the flowers' freshness and overall vase life by providing additional metabolic energy. To test this hypothesis, we placed cut roses in solutions containing 5%, 10%, and 15% glucose, alongside a control group in tap water. Contrary to expectations, roses in higher glucose concentrations showed accelerated wilting, with the most pronounced signs of senescence observed in the 15% glucose solution. Conversely, roses in tap water retained freshness for a longer period. The observed rapid decline in floral longevity at higher glucose concentrations may be linked to increased microbial activity and cell death. These results suggest that elevated glucose levels may have unintended adverse effects on flower preservation. This study has practical implications for florists and consumers interested in optimizing post-harvest care. Further research should explore the efficacy of alternative sugars, plant hormones, and natural preservatives to enhance the longevity of cut flowers.

INTRODUCTION

Cut flowers, especially roses, are among the most economically significant products in ornamental horticulture due to their extensive use in cultural, social, and commercial contexts, such as weddings, holidays, and other ceremonial events (1, 2). Despite their popularity, preserving the aesthetic quality and freshness of cut flowers after harvest presents a substantial challenge, as they are highly perishable and begin the senescence process — developmental programmed aging characterized by cellular breakdown and tissue deterioration — almost immediately upon separation from the parent plant. This rapid onset of wilting occurs because severed flowers lose access to essential nutrients, particularly carbohydrates, which are produced via photosynthesis and are critical for sustaining cellular metabolism and delaying the senescence process (3, 4). Thus, effective post-harvest care practices are essential not only for extending the vase life of these flowers but also for enhancing their marketability and appeal.

Vase life is defined as the time when a cut flower remains attractive and holds its shape until it wilts, turns color, or sheds its petals (5). Unlike senescence, which is the internal, cellular aging process, vase life is the external, observable period during which flowers remain commercially acceptable. In the commercial flower industry, chemical treatments with sugar solutions have become common practice to prolong the post-harvest life of cut flowers, with sucrose being the most frequently used sugar (6). Sucrose is added to preservative solutions as an external energy source to compensate for the loss of endogenous carbohydrate production once the flowers are cut (7). By providing an alternative energy source, sucrose helps sustain the metabolic processes that maintain petal structure and color, delaying wilting and extending the visual appeal of cut flowers (8). However, while sucrose has been extensively studied as a flower preservative, less research has been conducted on the effects of simpler sugars, such as glucose, on the post-harvest longevity of cut flowers.

Glucose, a monosaccharide and direct photosynthetic product, serves as the primary energy source for cellular processes in plants (9). Unlike sucrose, glucose does not require additional metabolic breakdown, which theoretically makes it a more readily available energy source for cut flowers (10). However, the concentration and type of sugar used in flower preservation solutions are known to impact flower longevity in complex ways. High sugar concentrations, such as those 3 % (w/v) or greater, while potentially beneficial in providing energy, can encourage microbial growth in the vase solution, clogging xylem vessels in flower stems and impairing water uptake (11). This microbial blockage can lead to dehydration and accelerated wilting of the flowers (12, 13). Additionally, high sugar levels can create osmotic stress, further exacerbating flower senescence (14). Therefore, the balance between providing sufficient energy and avoiding detrimental effects from sugar treatments is crucial in optimizing post-harvest flower care.

Most research to date has focused on sucrose as a preservative. Whether glucose can serve as an equally effective or even superior alternative for extending cut flower longevity remains unknown. Given its structural simplicity and ease of metabolism, glucose has the potential to be a more effective energy source to sustain floral freshness without the negative effects associated with higher concentrations of sucrose (15, 16). In this study, we aimed to address this gap by examining how different glucose concentrations (5%, 10%, 15%) influence the vase life of cut roses. Specifically,

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we hypothesized that glucose, due to its simpler composition and direct role in cellular energy pathways, would enhance flower longevity without the adverse effects observed at high sucrose concentrations (17). Furthermore, we investigated the relationship between glucose concentration, water uptake, microbial activity, and the visual quality of cut roses (18).

Our results did not support this hypothesis. We noted that elevated glucose levels (10% and 15%) triggered senescence more quickly, which yielded significantly decreased vase life compared to both the control (tap water) and the 5% glucose treatment ($p < 0.01$ for all comparisons). These findings indicate that although glucose has some energy advantages at low levels, elevated glucose levels might exert unforeseen detrimental effects on flower preservation, possibly because of microbial development and osmotic stress. By investigating how glucose functions in cut flower preservation, this research can provide insights that could lead to improved post-harvest care practices and inform the floral industry on optimal vase solutions for maximum flower quality retention.

RESULTS

We aimed to determine the effects of varying glucose concentrations on cut roses post-harvest. Specifically, we evaluated whether adding increasing concentrations of glucose to vase solutions would enhance cut flower vase life by providing supplemental metabolic energy. There were four treatment groups: tap water control, 5%, 10%, and 15% glucose solutions. Each treatment had four replicates, and we allocated roses randomly to different experimental groups to minimize source bias (**Figure 1**).

Flower freshness was quantified as the elapsed time (in days) until the first evidence of petal discoloration became apparent. Analysis revealed a statistically significant difference in the mean duration of freshness among treatments (**Figure 1**). Roses held in tap water maintained the longest mean vase life (10.75 ± 0.50 days), outlasting those in 5 % glucose (9.25 ± 0.96 days) (Tukey's HSD, mean diff = 1.50 days, $p = 0.0054$). Freshness declined in a concentration-dependent fashion across the glucose treatments, with all pairwise comparisons among tap water, 5 %, 10 % and 15 % glucose reaching statistical significance (Tukey's HSD, $p \leq 0.01$). Petal wilting, petal color change and loss of turgidity likewise occurred progressively earlier in glucose-treated flowers, showing a trend toward more rapid senescence at higher glucose levels (Tukey's HSD, $p < 0.05$ for all comparisons) (**Figures 1, 2**).

Mean vase life declined with increasing glucose concentration, that is roses in tap water lived the longest (10.75 ± 0.50 days), followed by 5 % glucose (9.25 ± 0.96 days), 10 % glucose (7.25 ± 0.80 days) and 15 % glucose (5.25 ± 0.75 days) (**Figure 2A**). Freshness in 5 % versus tap water differed by 1.50 days (Tukey's HSD, $p = 0.0054$), and all other pairwise comparisons among the four treatments were also statistically significant (Tukey's HSD, $p \leq 0.001$). This demonstrates a clear, concentration-dependent decline in visual freshness with increasing glucose levels.

Mean time to first visible wilting progressively also shortened as glucose concentration increased: 7.75 ± 0.37 days in tap water, 6.25 ± 0.40 days in 5 % glucose, 5.00 ± 0.35 days in 10 % glucose, and 2.50 ± 0.30 days in 15 % glucose (**Figure 2B**). Petal wilting started significantly earlier in flowers held in high versus low glucose (Tukey's HSD, $p = 0.0294$ for 10 % vs. 5 %; $p < 0.0001$ for all others) and in all glucose treatments versus tap water (Tukey's HSD, $p < 0.001$). Flowers held in higher glucose concentrations wilted earlier than those in lower concentrations, suggesting accelerated turgor loss at elevated sugar levels.

Additionally, the interval to 50 % petal drops mirrored wilting trends: 9.50 ± 0.45 days in tap water, 7.50 ± 0.50 days in 5 % glucose, 6.00 ± 0.55 days in 10 % glucose, and 3.25 ± 0.40 days in 15 % glucose (**Figure 2C**). Pairwise comparisons (Tukey's HSD) showed faster petal abscission at higher glucose concentrations (10% vs 5%, $p = 0.0039$; all other pairwise comparisons $p < 0.0001$). This pattern is consistent with an increase in petal abscission at elevated glucose levels, although a formal trend test would be required to demonstrate a dose–response relationship.

Alongside this, the mean time to noticeable loss of stem turgidity was 8.00 ± 0.60 days in tap water, 6.25 ± 0.50 days in 5 % glucose, 5.00 ± 0.45 days in 10 % glucose, and

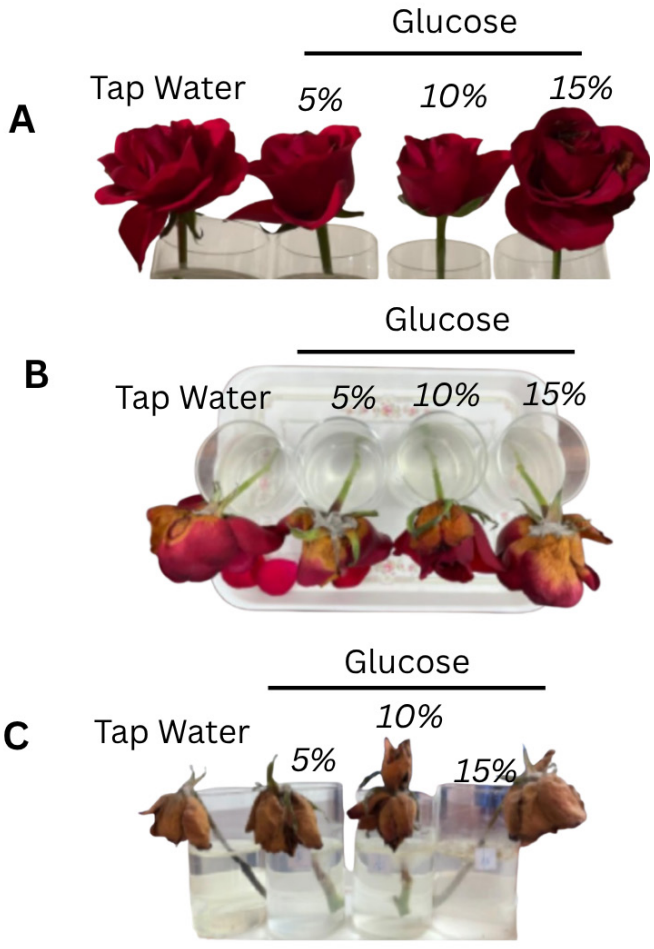

Figure 1: Progression of wilting in cut roses across glucose concentrations. (A) Photo of the fresh cut roses from day, immediately after placement in vase solutions (tap water, 5%, 10%, 15% glucose). (B) Photo from day 10. We observed the onset of wilting and petal drooping, with more pronounced symptoms in lower-glucose treatments. (C) Photo from day 15. We observed advanced senescence— noted as discoloration, petal drop, and stem softening, which was most severe in the tap water control.

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3.75 ± 0.40 days in 15 % glucose (**Figure 2D**). Softening occurred earlier in the 15% glucose treatment than in tap water and 5% (Tukey's HSD, $p < 0.001$ for both comparisons), and earlier in 10% than in tap water ($p = 0.0025$). There was no difference between 10% and 5% ($p = 0.0919$). Higher glucose concentrations in essence therefore promoted an earlier loss of stem rigidity, with the most pronounced effect at 15 % glucose.

By day 3, the 15% glucose solution had turned cloudy, and flowers in that group showed severe wilting and petal breakdown. Petal wilting began as early as day 4, and by day 6, flowers in this group exhibited complete wilting and petal drop. A similar but slightly delayed pattern was observed in the 10% glucose treatment, where cloudiness in the solution was accompanied by a significant reduction in water uptake and widespread senescence by day 6–7. In contrast, flowers in the 5% glucose solution remained turgid until day 7–8, after which wilting began gradually. Tap water (control) showed the slowest progression of senescence, with flowers maintaining freshness until approximately day 10–11 (**Figure 2**). Petal wilting and senescence occurred earlier in flowers treated with 10% and 15% glucose than in tap water (one-way ANOVA followed by Tukey's HSD, $p < 0.01$ for both comparisons). Treatment with 5% glucose also reduced vase life relative to control ($p = 0.0054$). These results demonstrate that high glucose concentrations in a way accelerate senescence, while even moderate glucose levels significantly affect floral longevity across all measured variables — freshness duration, petal wilting, petal drop, and stem softness.

DISCUSSION

Treatments with 10% and 15% glucose were associated with shorter vase life and more rapid senescence than tap water; however, a formal trend or correlation analysis would be required to demonstrate a concentration-dependent effect. In contrast to our initial hypothesis that increased availability of glucose would prolong flower lifespan by serving as an additional source of metabolic energy, the experiment showed that increased concentrations of glucose resulted in faster wilting and petal drop compared to water alone. The longest vase life was seen in the control (tap water), followed by flowers treated with 5% glucose, while flowers treated with 10% and 15% glucose solutions had noticeably shorter longevity.

Osmotic stress and dehydration may explain the elevated senescence in the 10% and 15% glucose treatment. Flowers maintain a delicate balance between water uptake and transpiration to achieve turgidity and enable cellular metabolism. With a high concentration glucose solution, the osmotic potential of the external environment is higher, such that water may be removed from cells instead of being absorbed (19). This effect may have been responsible for the wilting and petal softening seen earlier in the high-glucose treatments.

While microbial growth was not quantified in this study, reduced water clarity and resultant floral deterioration indicate

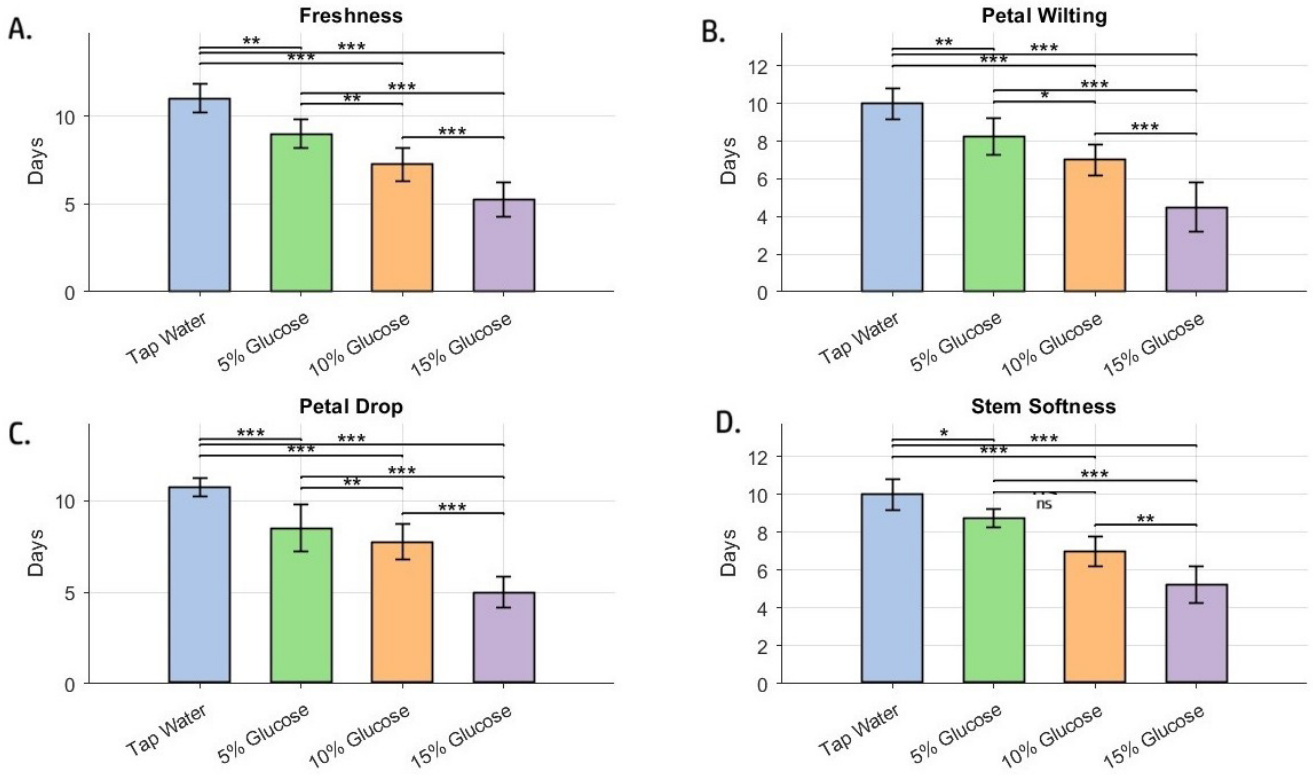

Figure 2: Effect of glucose treatments on flower longevity parameters. Bar plots show the average number of days (± standard deviation, SD) that flowers (A) maintained freshness, or until flowers experienced (B) petal wilting, (C) petal drop, and (D) stem softness under four different treatments: tap water, 5% glucose, 10% glucose, and 15% glucose. Each treatment group included four replicates. Post hoc comparisons among treatment groups were made using Tukey's honestly significant difference (HSD) test. Statistical significance is indicated as follows: $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***) and $p \geq 0.05$ (ns or non-statistically significant).

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that microbial growth may have contributed to vascular tissue clogging and interference with water uptake and leading to reduced vase life. This should be tested more accurately in future studies, for example, through tracking flower mass loss as a surrogate for dehydration over time. Furthermore, water absorption efficiency (vase volume absorbed throughout the experiment) should be measured to validate the effect of glucose concentration on the ability of the cut flower to absorb water. This would test the hypothesis that microbial growth and/or osmotic stress in higher concentrations of glucose could cause premature senescence. That could have been the reason for the reduced longevity found in flowers undergoing the high glucose treatments. Microbe growth could have been prevented by increasing water absorption since microbe build-up could clog xylem vessels. Cloudiness noticed in 10% and 15% glucose solutions following the first few days of the experiment may be a sign of the growth of microbes but may also be due to other reasons like the release of plant exudate from cut stems. The origin of microbial contamination may be either the plant tissue or water since naturally-occurring microorganisms in tap water or stem and petal surfaces have the ability to grow in nutrient-rich solutions. To prevent any form of microbial contamination, florists and consumers may use sterilized or distilled water, change vase solutions periodically, or add mild antimicrobial agents. Flower freshness possibly decreased with increased concentrations of glucose, likely due to a combination of microbial growth, osmotic stress, and decreased uptake of water.

To determine whether microbial growth is the cause of premature senescence experienced under high-glucose conditions, a second experiment measuring bacteria would be valuable. Vase solution samples could be cultured on nutrient agar plates to measure bacterial colony-forming units over time. If solutions exposed to high-glucose conditions are found to have measurably higher bacterial counts than control and low-glucose solutions, this would suggest that microbial growth may play a role in the reduced floral lifespan observed.

A controlled antibiotic treatment could also be used to distinguish the effect of glucose concentration and bacterial growth. If the addition of an antimicrobial agent (e.g., bleach, silver nitrate, or hydrogen peroxide) to 10% or 15% glucose solutions significantly prolongs flower longevity, this would suggest that bacterial growth, rather than glucose itself, is the primary factor triggering early flower aging. This phenomenon, known as precocious senescence, refers to the premature onset of the aging process in flowers, leading to earlier wilting, discoloration, and petal drop. Such findings would represent an important step toward identifying effective antimicrobial preservatives for use in the commercial cut flower industry.

However, to be able to distinguish direct phytotoxicity of the antimicrobial agent from its bactericidal effect, another control set would be needed. This could be done by first keeping flowers in sterile glucose solutions containing the antimicrobial but leaving out any bacterial inoculum. Herein, any vase life reduction under these conditions would be a sign of phytotoxicity. Second, controls where flowers are placed in plain water with the antimicrobial to measure effects without elevated glucose could be added. Comparison of flower longevity and senescence-associated physiological markers (e.g., membrane leakage, ethylene production) between (i) bacteria-only, (ii) antimicrobial-only, and (iii) bacteria + antimicrobial treatments, longevity improvements can be credited solely to the inhibition of bacteria. Lastly, concurrent quantitation and determination of microbial burden (e.g., by colony-forming unit test) will permit correlation of the loss of bacteria with aging floral changes and thereby distinguish between any indirect effect of microbial management from any direct effect of antimicrobial on the cut flower.

Trials using sucrose-rich preservation solutions have also shown that moderate levels of sugar (usually 2–5%) delay senescence by supporting cellular metabolism, but higher levels of sugar cause microbial infection and inhibit water absorption (20, 21). The results obtained through this study parallel those studies by showing that even though sugars could provide energy for cut flowers, higher concentrations prove to be deleterious according to osmotic stress and microorganism development. Glucose, to date, has not been the focus of flower preservative research. Our results demonstrate that glucose behaves in the same manner as sucrose —useful at low but toxic at high levels. Whether glucose can serve as a sufficient alternative to sucrose in flower preservation has yet to be determined. These alternative sugars, like sucrose or fructose, may possess varying physicochemical properties to repress microbial growth, compared to glucose (22). In addition, the incorporation of natural preservatives (e.g., citric acid) will repress microbial growth, while plant hormones (e.g., gibberellins and cytokinins) are capable of postponing senescence through the promotion of cell stability and reduction of breakdown, subsequently leading to the extended vase life of cut flowers (23, 24). Additionally, although the measurements of our study are not quantitative, they are reproducible and consistent criteria for measuring floral senescence. Subsequent research should utilize more specific quantitative techniques, like texture analysis or image-based tracking, to further refine these measures (25, 26).

Moreover, our results contradict the common belief that all sugars guarantee floral longevity. Although florists and consumers have been using sugar solutions for decades to preserve the freshness of cut flowers, our results show that the concentration and type of sugar used need to be considered. Our results in this case indicate that roses held in high-glucose solutions exhibited a more rapid decline in freshness than those kept in water alone, demonstrating that elevated glucose levels can impair post-harvest preservation.

MATERIALS AND METHODS

The glucose utilized for this research work was laboratory-grade anhydrous glucose from Lab Solutions, Jorhat. Four beakers were used, all containing 400 mL solution: three with glucose concentrations of 5%, 10%, and 15%, and one for tap water to serve as a control (**Figure 2**). All glucose concentrations were measured by a precision scale for uniform solution preparation. Four replicates per treatment were performed for statistical reliability. The study roses were the hybrid rose ‘Mister Lincoln’, which is used extensively because of its large, fragrant flowers and long vase life (21, 24). Roses of uniform size and condition were selected from a local garden and a local nursery. Approximately 5 cm was trimmed from the end of each stem under water to prevent air embolism in the xylem, which could inhibit water absorption. The flowers were placed in a room with a consistent

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temperature (20–22°C) and natural light.

We assessed relative vase life compared to four relevant parameters: (i) time of freshness duration, as days to visible browning or discoloration of the petals; (ii) petal wilting, expressed as clear petal curl or sagging by more than 45° from the vertical stem; (iii) petal drop, quantified when a first petal dropped from the flower stem; and (iv) stem softness, noted as the shift in stem firmness to becoming soft or mushy, the sign of architectural breakdown. All these factors overall represent flowering period duration indicators and collectively represent a general estimate of post-harvest preservation efficiency. The flowers were observed daily for freshness, petal wilting, petal drop and stem softness (**Figure 1**). The "number of days fresh" (freshness) was the time from the beginning of the experiment to when discoloration was first evident, i.e., when petals began to brown. "Petal wilting" was noted when the petals exhibited noticeable curling or sagging, usually at an angle of approximately 45°. "Petal drop" was recorded as the day on which the first petals fell from the stem of the flower, without specifying the number of petals dropped per day. "Stem softness" was recorded when the stem had an easily noticeable change in texture, from hard to soft or mushy, consistent with deterioration.

Statistical analysis was performed using one-way ANOVA to assess the effect of glucose concentration on each of the four variables: freshness, petal wilting, petal drop, and stem softness. When the ANOVA indicated significant differences among groups ($p < 0.05$), a post-hoc Tukey's Honest Significant Difference (HSD) test was conducted to identify which treatment groups differed. All analyses were conducted using Python (version 3.10), with statistical functions from the scipy.stats and statsmodels libraries.

Water levels were monitored and refreshed every 48 hours to prevent microbial growth. It should be noted that water in the beakers was not completely replaced every 48 hours; instead, additional water was added to compensate for evaporation and maintain the original 400 mL volume. This method ensured that the same vase solution was used throughout the experiment, allowing us to observe the natural progression of microbial growth over time. The longevity of each flower was recorded, along with any notable differences in the solutions, such as cloudiness, which might indicate microbial proliferation.

Alongside typical signs of senescence, the glucose solutions were checked for cloudiness, which may indicate bacterial growth that could block the stems and reduce water absorption (27).

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