Ornamental Horticulture
ISSN 2447-536X | HTTPS://ORNAMENTALHORTICULTURE.EMNUVENS.COM.BR/RBHO
SBFPO Sociedade Brasileira de Floricultura e Plantas Ornamentais

REVIEW ARTICLE

Meta-analysis of new technologies in post-harvest of tropical flowers

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Abstract

The ornamental plant sector is growing due to the development of new species and technologies. The focus of research is to extend the shelf life of cut flowers to maintain quality and customer satisfaction. Techniques such as storage at low temperatures, use of preservative solutions, and new technologies such as nanotechnology can help maintain the quality of the floral stem. The present review aims to analyze various techniques used to extend the post-harvest shelf life of floral stems. For this purpose, a systematic search was conducted on major indexing platforms for studies published in 2023, which were subjected to a meta-analysis. The global effect size and moderator effects were calculated to assist in decision-making for future studies in floriculture. The results indicated that the addition of preservatives to solutions, variations in storage temperature, and the use of electromagnetic fields were the most effective techniques in extending the shelf life of cut flowers. However, techniques such as dry conditioning and the use of coating films did not show significant results in maintaining commercial quality. It was found that conservative solution research is still the main focus of research at major cut flower technology centers. The meta-analysis highlights the importance of further deepening and/or improving research on techniques that have shown less effective results, and developing new technologies to prolong the vase life of floral stems in order to improve post-harvest quality.
Keywords: cut flowers, floral stem, floriculture, indexing platform, vase life.

Resumo

Meta-análise das novas tecnologias em pós-colheita de flores tropicais

O setor de plantas ornamentais está crescendo devido ao desenvolvimento de novas espécies e tecnologias. O foco da pesquisa é estender a vida útil das flores cortadas para manter a qualidade e a satisfação do cliente. Técnicas como armazenamento em baixas temperaturas, uso de soluções conservantes e novas tecnologias como a nanotecnologia podem ajudar a manter a qualidade da haste floral. A presente revisão tem como objetivo analisar diversas técnicas utilizadas para prolongar a vida útil de hastes florais pós-colheita. Para tal, foi realizada uma busca sistemática nas principais plataformas indexadoras de estudos publicados em 2023, os quais foram submetidos a uma meta-análise. Calculou-se o tamanho do efeito global e o efeito por moderadores, com o intuito de auxiliar na tomada de decisão para futuros estudos na floricultura. Os resultados indicaram que a adição de conservantes nas soluções, variações nas temperaturas de armazenamento e o uso de campos eletromagnéticos foram as técnicas mais eficazes para prolongar a vida útil das hastes florais em vasos. No entanto, técnicas como o condicionamento a seco e o uso de filmes de revestimento não apresentaram resultados significativos em manter a qualidade comercial. Foi verificado que as pesquisas com soluções conservantes ainda são o principal foco dos trabalhos de grandes centros de tecnologia de flores de corte. A meta-análise destaca a importância de aprofundar e/ou aperfeiçoar as pesquisas em técnicas que apresentaram resultados menos eficazes e desenvolver novas tecnologias para prolongar a vida útil das hastes florais, a fim de melhorar a qualidade pós-colheita.
Palavras-chave: floricultura, flores de corte, haste floral, plataforma de indexação, vida de vaso.

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https://doi.org/10.1590/2447-536X.v29i2.2643
Received Mar 23, 2023 | Accepted May 1st, 2023 | Available online May 23, 2023

Area Editor: Márkilla Zunete Beckmann-Cavalcante

Introduction

The ornamental plant sector is rising, driven by factors such as the improvement and diversification of species and the development of new technologies throughout the production chain (Botini et al., 2023). Among the products, cut flowers stand out for their use in arrangements and bouquets and, to ensure their quality, there are several studies focusing on new technologies to extend vase life (Alam et al., 2023). These technologies are implemented with the aim of extending the shelf life of cut flowers or potted plants, thereby ensuring their commercial quality after being harvested or purchased (Almeida et al., 2009), while reducing losses and increasing customer satisfaction through the maximization of the flowers' shelf life.

During the transport and storage, factors such as inadequate temperatures, improper conditioning or use of conservative solutions can result in loss of quality and reduction in vase life of cut flowers (Botini et al., 2023). The factors related to the visual aspect are the most important attributes for quality in flowers and ornamental plants (Almeida et al., 2009).

The use of appropriate techniques helps to maintain the quality of the floral stem by increasing vase life, reducing metabolic processes, transpiration, decreasing ethylene levels in plant tissues and, consequently, reduction of leaf abscission and senescence (Sonego and Brackmann, 1995; Paula et al., 2021). These include storage at low temperatures, use of preservative solutions, use of coating films, as well as new technologies such as inducing of electromagnetic fields in the water (Almeida et al., 2009; Pizetta et al., 2022) and nanotechnology (Jena et al., 2022). The response of the use of these technologies depends on the species/ variety, requiring research to confirm efficiency and suitability (Almeida et al., 2009).

To understand the importance and results already obtained in previous research, helping on decision-making for new action, one technique that may help is the meta-analysis. This technique analyses research results using quantitative statistics. With the introduction in the 1970s of the term and modern approaches to scientific methodology, meta-analysis had a revolutionary effect in several areas of knowledge, helping to establish evidence-based practices and resolve seemingly contradictory research results (Gurevitch et al., 2018).

In view of the above, the objective was to analyse, through meta-analysis, the efficiency of post-harvest techniques to increase the durability of floral stems, considering some tropical species. In this way, it is intended to clarify some questions: Are there post-harvest conservation techniques already determined by research effective in increasing the vase life of floral stems? For which species does the use of post-harvest techniques provide significant results? What are the new technologies in development?

Material and Methods

To perform the meta-analysis, studies published in 2023 were selected through a systematic search on indexing platforms such as "Web of Science," "Scopus," "Google Scholar," and "Periódicos Capes." For that the Keywords used included "Flower postharvest"; "Tropical flowers"; "Postharvest vase life"; "Postharvest technologies"; "Floral stem conservation," among other related terms and possible variants.

As inclusion criteria for the case studies, those that presented results of postharvest durability of floral stems using visual quality analysis on daily scales were selected. The need for studies to present standard deviation values was also a criterion for inclusion. As an exclusion criterion, studies that did not meet these requirements were removed from the study, so that the meta-analysis could be performed.

The moderators having been defined, a test of heterogeneity was performed on the cases obtained. The aim was to the type of effect (fixed or random) to be used in calculating the overall effect size and effect by moderators (Gurevitch et al., 2018). The overall effect size was calculated for each case by performing the standardized mean difference (d) obtained from equation (1):

(Eq 1) $d = (X1 - X2) / Swithin$

Where X1 is the mean of the treatment, X2 is the mean of the control, and Swithin is the standard deviation parameter that considers the values of the standard deviation and the number of replicates in the control and treatment.

The variance (Vd) of d was calculated by equation 2, where n1 is the treatment error and n2 is the control error.

(Eq 2) $Vd = [(n1+n2) / (n1n2)] + [d^2 / 2(n1+n2)]$

Positive values of d indicate that the treatments were beneficial in promoting an increase in vase life of post-harvest floral stems, while negative values indicate the opposite effect. Minimum and maximum values were obtained for each case to indicate if the study was significant. The entire methodology described was performed using Launch Open Meta Analyst software, with a significance level of 5% (Cunha Neto et al., 2020).

Results and Discussion

Postharvest vase life

The heterogeneity test was significant for both the global effect and the effect by moderators, thus a random effects model was applied. From the systematic search considering the year 2023, 88 case studies were found. The different forms of techniques and/or technologies were significant for the global effect (d = 2.012; minimum value = 1.443; maximum value = 2.582) in a positive way, indicating an extension of vase life of up to two days.

Cut flowers are highly perishable products. Therefore, operations along the production chain must be carried out carefully to ensure quality and longevity, reducing respiration and transpiration. Postharvest durability will depend on factors such as species or cultivar and the stage of opening used for harvest (Lima and Ferraz, 2008; Carneiro et al., 2014; Sales et al., 2021).

Indeed, the post-harvest senescence can start prematurely depending on the opening stage, caused by the production of ethylene. Moreover, bacteria can accumulate in the area of the stem where the cut was made. The harvesting process triggers extracellular production of polysaccharides that clog the xylem vessels, increasing hydraulic resistance and ultimately leading to a reduction in water uptake by the stem (Lou et al., 2020). The vase life is commonly used as an indicator of the longevity of cut flowers, being determined in days, from harvest until senescence (Girardi et al., 2015).

Post-harvest vase life of tropical flowers

One of the moderators identified in this meta-analysis was the grouping of tropical flowers, in which the influence of new technologies was also significantly beneficial (Table 1). There was an increase of 2.925 days (minimum value = 2.379; maximum value = 3.471) in post-harvest vase life, which is longer than that obtained by the overall effect.

Table 1. Tropical species found in the case studies and the tested technologies.

Species	Postharvest technology tested
Alstroemeria sp.	Conservative solutions
Dendrobium sp.	Dry conditioning
Etlingera elatior (Jack) R.M. Sm.	Coating films Conservative solutions Dry conditioning Storage temperature
Gerbera jamesonii Bolus *ex* Hook. f.	Conservative solutions
Heliconia bihai (L.) L. f.	Storage temperature
Heliconia rauliniana	Storage temperature

The vase life of floral stems is determined by several factors during plant cultivation, harvest and postharvest, also being related to the genetic, anatomical, and physiological characteristics of each species and cultivar (Botini et al., 2023).

The aesthetic characteristics in tropical flowers are often due to bracts and not necessarily to the flowers themselves, however, it is assumed that they are also subject to factors that reduce commercial quality similar to the flowers (Lima and Ferraz, 2008).

In this context, these new technologies that extend vase life have already been studied for this plant group, and as a result of the meta-analysis performed, a longer durability time was observed compared to flowers in general. It should be noted that this result refers to the behaviour of the tropical plant population, and different results may be found when species are individualized.

Postharvest durability of different flowers

Among the diversity of flowers, it was possible to obtain results for some selected the species torch ginger (*Etlingera elatior* (Jack) R.M. Smith), gerbera (*Gerbera jamesonii* Bolus ex Hook.f.), and alstroemeria (*Alstroemeria* sp). Other species such as anthurium, alpinia, strelitzia, among others, were not found due to the limited time range of articles published in 2023. The results obtained through the studies was not significant for torch ginger (Figure 1), indicating that the new technologies applied to this species do not influence the vase life of the stems.

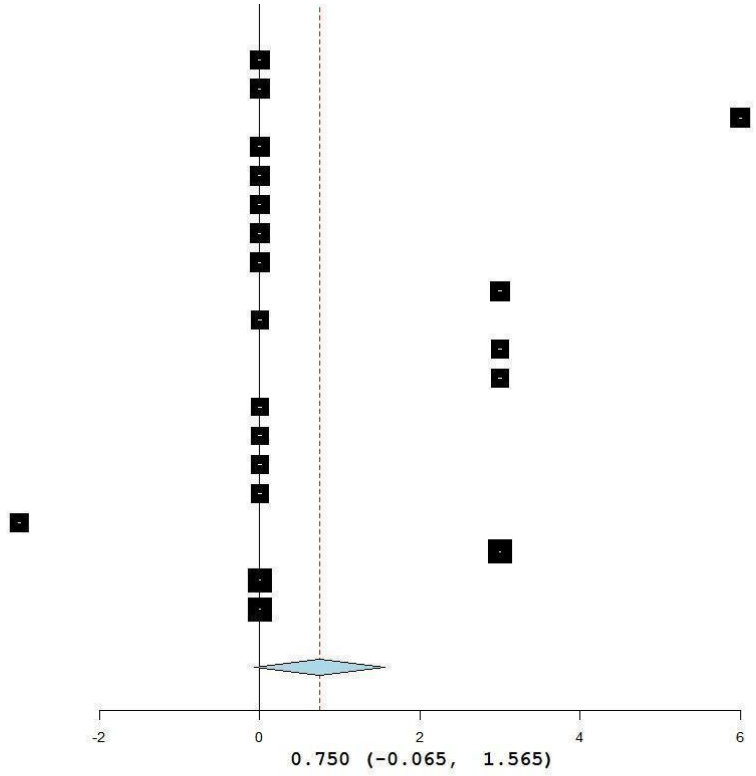

Figure 1. Effect size for the moderator torch ginger, minimum and maximum v alues in parentheses at 5% significance.

Etlingera elatior, commonly known as torch ginger or red ginger lily, is a species of the Zingiberaceae family, found mainly in tropical and high humidity forests. Due to its exotic appearance, it is widely commercialized, and the increasing demand from customers for the versatility and durability of cut inflorescences has led horticultural industry producers to seek new cultivars (Yunus et al., 2021).

The vase life of *Etlingera elatior* varies among cultivars and production locations. On average, cultivars produced in Australia have a vase life between 3-10 days, Malaysia up to 6 days, and Latin America ranges between 5-8 days, depending on the cultivar (Araújo et al., 2018).

Studies showed that this inflorescence, as a cut flower, provides an energy supply from the stem to the cell wall of the bract that stimulates its opening and strengthens the peduncle. During the opening of the inflorescence, there is degradation of cellulose in the involucral and floral bracts indicating the onset of the senescence process (Nogueira et al., 2023).

Senescence is linked to the point of opening at the time of harvest. With the sequential opening of the true flowers of the torch ginger, the outer bracts and the upper part of the peduncle darken due to the consumption of reserve molecules. Thus, to ensure the quality and longevity of the stems, they must be harvested at closed or semi-open points (Araújo et al., 2018). Given these characteristics associated with the short vase life, it justifies the need and limitations related to new technologies to increase the postharvest longevity of this species (Nogueira et al., 2023)

A similar result to the torch ginger also occurred for the alstroemeria, for which the use of technologies to increase vase life was also not significant (Figure 2).

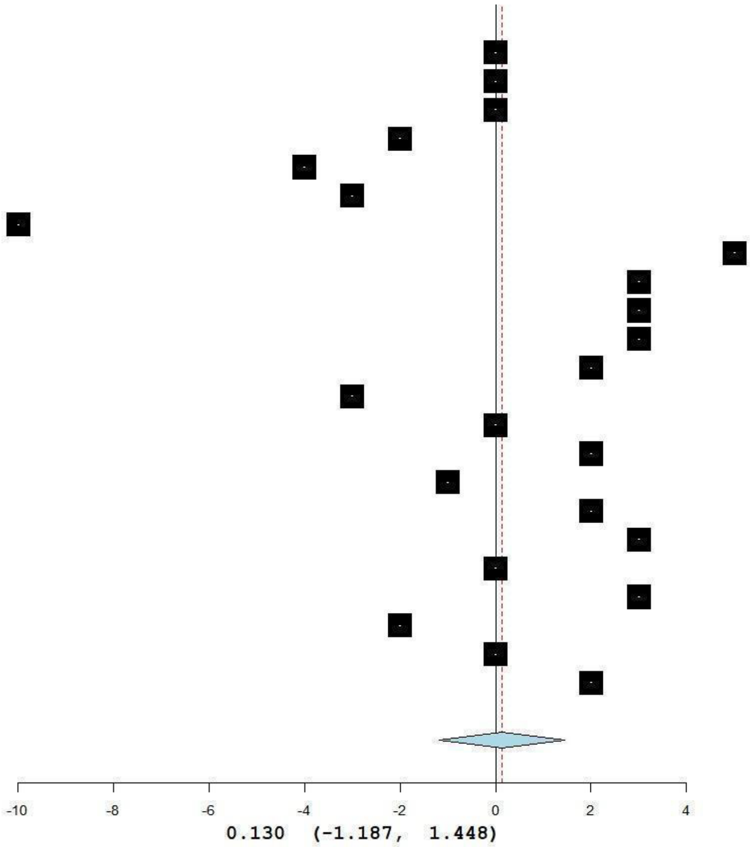

Figure 2. Effect size for the moderator alstroemeria, minimum and maximum values in parentheses at 5% significance.

Alstroemeria is an herbaceous plant native to South America that has a long floral stem, with a great variety of flowers and spots on the petals. It is used as a cut flower in the making of arrangements and bouquets (Girardi et al., 2015).

The vase life of this species is estimated to be between 10 to 14 days. Maintenance or increase in vase life of the floral stems is influenced by the supply of water and reserve molecules that preserve active metabolism (Carneiro et al., 2014). For alstroemeria, storage temperature of up to 5 ºC is one of the most efficient and less expensive techniques that help in post-harvest maintenance of floral stems (Girardi et al., 2015).

For this species, even with refrigerated storage, each cultivar has its own characteristics that must be evaluated, thus defining the best post-harvest technique for maintaining quality and extending vase life (Ershad Langroudi et al., 2020).

Differently from alstroemeria and torch ginger, in gerberas, studies on the use of different technologies presented a significant effect. The effect obtained for this moderator was positive, resulting in an increase in vase life of 4.766 days (Figure 3).

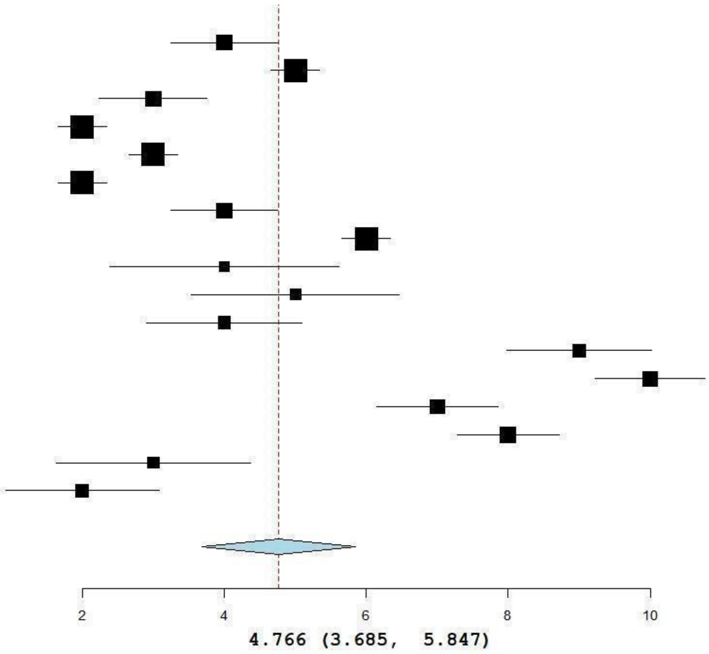

Figure 3. Effect size for the gerbera moderator, minimum and maximum values in parentheses at 5% significance level.

Gerbera exhibits a prolonged vase life and good durability, and is commonly used in floral arrangements and bouquets (Milani et al., 2021). As it ranks fourth in the global market trend among cut flowers, there is a need to develop new technologies to extend its post-harvest vase life (Alikhani et al., 2021; Timalsina et al., 2023).

For this species, it is common to use different preservative solutions, associated or not with storage temperature. It should also be noted that gerbera is susceptible to microbial contamination in the xylem that causes an imbalance in the water balance (Alam et al., 2023).

Preservative solutions act to maintain the turgor of gerberas, as this species loses its market quality when the length of the floral stem is inadequately cut and hydration is also done incorrectly (Timalsina et al., 2023). Due to lack of hydration, changes occur in cell wall components such as phenolic compounds and lignin degradation, causing loss of mechanical resistance, thus facilitating stem breakage (Çelikel et al., 2002; Piroli et al., 2019).

The increase of up to 5 days in post-harvest vase life for gerberas obtained through meta-analysis validates the efficiency of new technologies that are being developed for this species, highlighting research on different preservative solutions.

Electromagnetic fields to extend vase life

In general, promising solutions aiming to improve postharvest conservation have been developed, and there are different methods being improved in the global floriculture industry. However, these techniques need adaptations for postharvest of ornamental tropical flowers and plants. Some of these technologies include the use of electromagnetic fields, nanotechnology, and new preservative solutions.

When individualizing moderators by technology type, it was found that studies evaluating the use of electromagnetic fields were significant in extending vase life of flower stems (Figure 4).

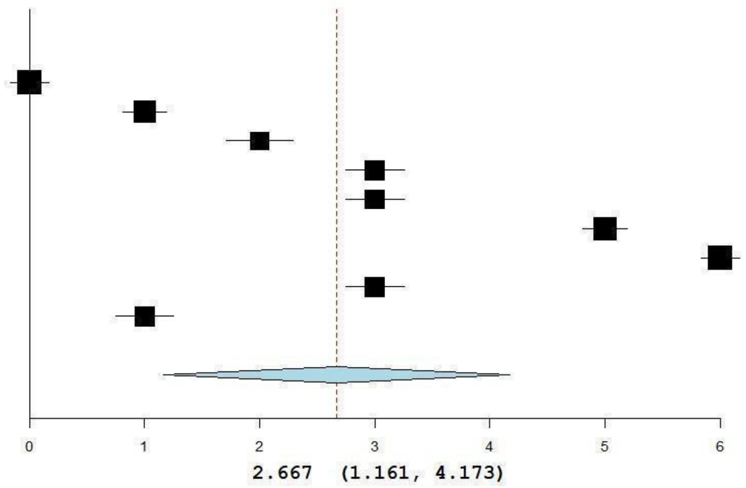

Figure 4. Effect size for the electromagnetic field moderator, minimum and maximum values in parentheses at 5% significance level.

One of the new technologies for extending the vase life of cut flowers is the use of water or solutions subjected to treatment by electromagnetic field. This technique consists of exposing the liquid to a magnetic field, which can alter some of its physical and chemical parameters (Pizetta et al., 2022). Electromagnetism can have a varied effect on the plant, depending on the equipment used, type of electromagnetic field, its frequency, intensity, and duration of exposure (Judickaitė et al., 2022).

Electromagnetic fields are capable of penetrating biological tissues due to the presence of essential elements with different magnetic behaviours, which gives plants the ability of magnetoreception (Ayesha et al., 2023). The change in the orbital motion of electrons around the atoms of essential elements is the premise of the interaction between plants and external magnetic fields (Upadhyaya et al., 2022). Thus, electrons are aligned and polarize the dipoles of cells, promoting increased gene expression, water ion uptake, and enzyme activation, leading to changes in plant growth and development, and in some cases, early flowering onset has been observed (Tang et al., 2018).

Although prolonged exposure has negative consequences, resulting in tissue deterioration, reduction in phenolic compounds, flavonoids, and vitamin C content, the effect of low-frequency magnetic field in short post-harvest exposures in flowers generates an increase in antioxidant system activity. Also, the low-frequency magnetic field improves membrane integrity, resulting in a reduction in ethylene gas emission (Ayesha et al., 2023).

Other studies report that these electromagnetic fields interfere with plant formative processes at the cellular level, affecting the mitotic index, causing genotoxic effects, chromosomal aberrations, and damaging cells where DNA would act as a fractal antenna collecting electromagnetic waves (Tang et al., 2018). These variations in cellular development occur as a result of a combination or disconnection of the external magnetic field with the phase of cellular oscillators, which can reduce vase life (Upadhyaya et al., 2022).

Dry conditioned flower stems

Unlike what is indicated for the moderate electromagnetic field, the technique that uses dry conditioning was significant, since it may cause damage to flower stems and reduce vase life in two days (Figure 5).

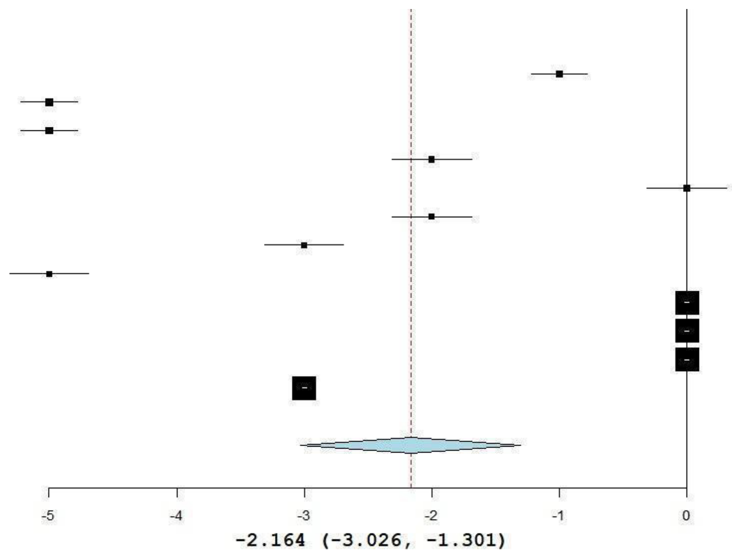

Figure 5. Effect size for moderate dry conditioning, minimum and maximum values in parentheses at 5% significance level.

Some species, particularly the tropical, have some tolerance to dry conditioning. The *Dendrobium* orchid has a tolerance of up to 24 hours dry conditioning, with maintenance of quality and vase life (Sukpitak and Seraypheap, 2023). The calla lily is another species that tolerates dry conditioning for a period of up to 6 days (Almeida et al., 2011).

Water relations are one of the main factors that affect the vase life of flower stems. A limiting factor for post-harvest longevity, it results in the reduction of the water potential and, consequently, in wilting due to stomatal changes (Dias et al., 2016).

Dry conditioning may cause several physiological changes in flower stems, such as the reduction of stomatal functionality, ethylene production, and modifications of the membrane that impair the cellular structure and accelerate flower senescence (Sales et al., 2021).

This practice generates reactive oxygen species such as superoxide radical, hydroxyl radical, and hydrogen peroxide. Moreover, excessive production of reactive oxygen species can cause oxidative damage to the lipid membrane (Fanourakis et al., 2022). To minimize the stress caused by dry conditioning, flower stems activate the enzymatic and non-enzymatic antioxidant system as defense mechanisms for the elimination of these reactive oxygen species (Sukpitak and Seraypheap, 2023).

Dry conditioning generates anatomical problems such as cavitations and embolisms in the xylem vessel. If adequately hydrated, hydraulic conductance and water potential are partially restored, allowing for the dissolution of air into the water being transported along the stem (Lima and Ferraz, 2008; Sales et al., 2021).

Another possible defense mechanism that can occur in floral stems after harvest is osmotic adjustment with the accumulation of compatible solutes or osmolytes that maintain turgor and stabilize cellular structure. Among the osmolytes, proline helps in adjusting the osmotic potential of plant cells, inducing tolerance to water restriction (Lu et al., 2020).

Postharvest coating films

Coating films are technologies that have an advanced history in research with fruits and other products. For flowers, the use of these films is still recent and, for this meta-analysis, their application to increase vase life of stems was not significant (Figure 6).

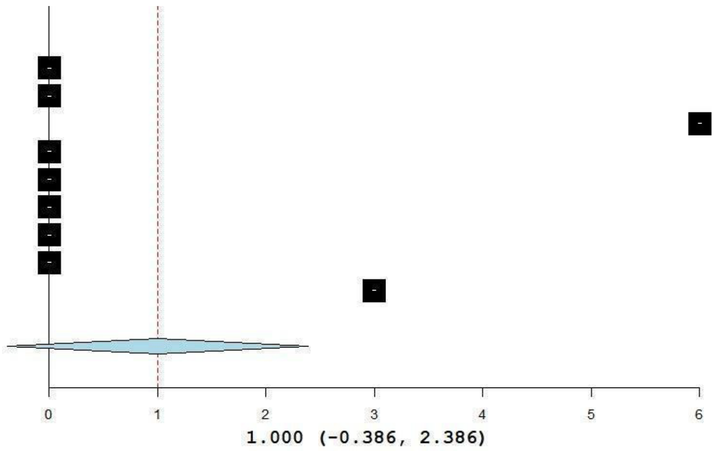

Figure 6. Effect size for the moderator coating films, minimum and maximum values within parentheses at 5% significance level.

Although the meta-analysis did not find significant effects of coating films as a moderator in extending vase life of cut flowers, this technology is extremely useful and has shown positive results in postharvest conservation of fruits with delayed senescence (Romanazzi and Moumni, 2022). This demonstrates that, although promising, this technology still faces several challenges in the floriculture industry.

One of the main problems in the commercialization of cut flowers is the reduction in vase life due to senescence and wilting (Sonego and Brackmann, 1995). Wilting results from water stress caused by transpiration rates exceeding water absorption rates, leading to loss of visual appeal (Mattos et al., 2018). Therefore, given the success of various coating films in fruit conservation (Romanazzi and Moumni, 2022), the possibility of using this technology in the conservation of cut flowers has been sought.

The use of coating films consists of applying a layer of product on the surface of the flower or inflorescence (Romanazzi and Moumni, 2022). Among the materials employed, films made of biological material stand out for being biodegradable and are generally made of materials such as starch, protein, cellulose, and chitosan (Paula et al., 2021). This layer has the ability to prolong the shelf life by reducing water loss, delaying the process of maturation and/or senescence, and providing protection against mechanical and microbiological damage.

In post-harvest of cut flowers, the use of coatings aims to prolong durability, preserving colours, texture, and aroma, and can increase their shine, ensuring commercial quality (Mattos et al., 2017). Coatings help to reduce water loss and delay the senescence process. Coatings also modify the gas concentration in the free space around the product, leading to a decrease in O_2 concentration and an increase in CO_2 (Sonego and Brackmann, 1995). The reduction in respiration, transpiration, ethylene biosynthesis, and microbial growth helps maintain the quality and longevity of cut flowers. This effect can be enhanced when associated with antioxidant, antimicrobial, and other beneficial substances for the vase life of cut flower stems (Mattos et al., 2018).

Although some types of coating, such as wax, are commercially used by flower growers, their post-harvest effectiveness is still not well established (Mattos et al., 2017). Post-harvest quality is related to the maintenance of plant metabolism and the delay of senescence, requiring an analysis of physiological and biochemical aspects to improve its techniques. However, for some species, the most appropriate procedures are still unclear (Mattos et al., 2017). Thus, results on the use of coatings in floriculture become promising, especially aiming to ensure visual characteristics and not just to prolong vase life.

Storage of floral stems

In relation to storage temperature evaluation, the meta-analysis was significant, indicating an increase of 5 to 6 days in the postharvest vase life of the stems (Figure 7).

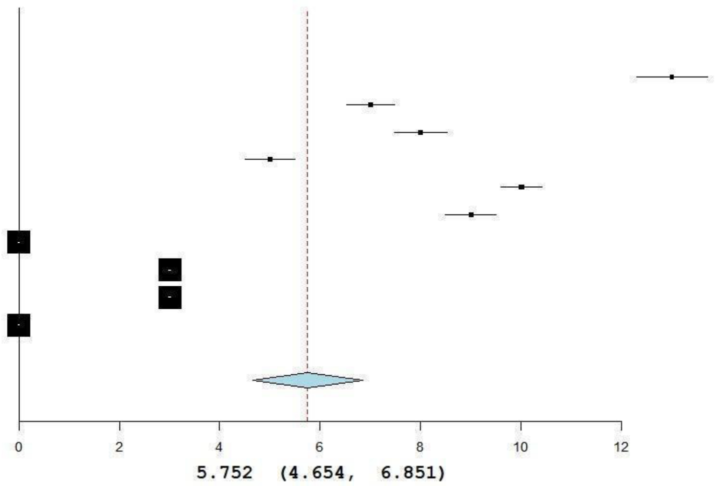

Figure 7. Effect size for the moderator storage temperature, minimum and maximum values in parentheses at 5% significance level.

The main objectives of low-temperature storage of floral stems are to regulate market flow, reduce losses resulting from declining demand, enable transportation over long distances, break or maintain dormancy of some species, and regulate metabolism, including reducing ethylene synthesis (Sonego and Brackmann, 1995).

The cold storage room should have renewed and forced air circulation, but mild to uniformize the temperature and remove the internal ethylene. The relative humidity should be high to minimize water losses and prevent flower wilting (Sonego and Brackmann, 1995).

The exposure to inappropriate temperature for extended periods is the major cause of losses in floriculture. High temperature increases the respiration and transpiration processes, while excessively low temperatures also harm the conservation of flowers (Çelikel et al., 2002). Storing floral stems at appropriate temperatures can provide a vase life that adds value in the market due to the preservation of their morphological characteristics (Girardi et al., 2015; Dias et al., 2016).

Low storage temperatures reduce metabolic processes such as transpiration, ethylene production, and cellular respiration. Due to the reduction of these processes, reserve macromolecules such as sugars and proteins present in floral stems are preserved (Botini et al., 2023). Low storage temperatures and relative humidity above 80% are important factors to delay deterioration, as they also reduce the action of pathogens that cause injuries in floral stems (Lima and Ferraz, 2008).

The optimal temperature for storage of temperate-origin flowers is slightly above tissue freezing point, usually between 0 and 1 °C. For tropical species, however, storage is normally done at temperatures between 8 and 16 °C, as these species are more sensitive to cold injury (Sonego and Brackmann, 1995).

Conservative Solutions

One of the most established techniques for increasing the vase life of floral stems is the use of preservative solutions, and the results obtained indicate that the solutions meet this objective by increasing durability by 2 days (d = 2.350; minimum value = 1.502; maximum value = 3.199).

The vase life is important in determining the postharvest quality of the floral stem. Chemicals used in conservative solutions play a significant role in enhancing the commercial postharvest quality, and there is no need to change the solution daily (Almeida et al., 2009; Timalsina et al., 2023).

Several studies recommend the addition of preservatives to solutions to extend the vase life of floral stems (El-Attar and Sakr, 2022; Kumar et al., 2022). Preservative solutions act by promoting the transport of nutrients and water along the floral stem, maintaining cellular turgor and, consequently, preserving quality (Alam et al., 2023). Most preservatives used consist of carbohydrates, growth regulators, germicides, ethylene inhibitors, and some mineral compounds (Lima and Ferraz, 2008).

Carbohydrates

Several compounds and molecules are used in the solutions, with the most common being sucrose, which also shows an increase in the vase life of floral stems (Figure 8).

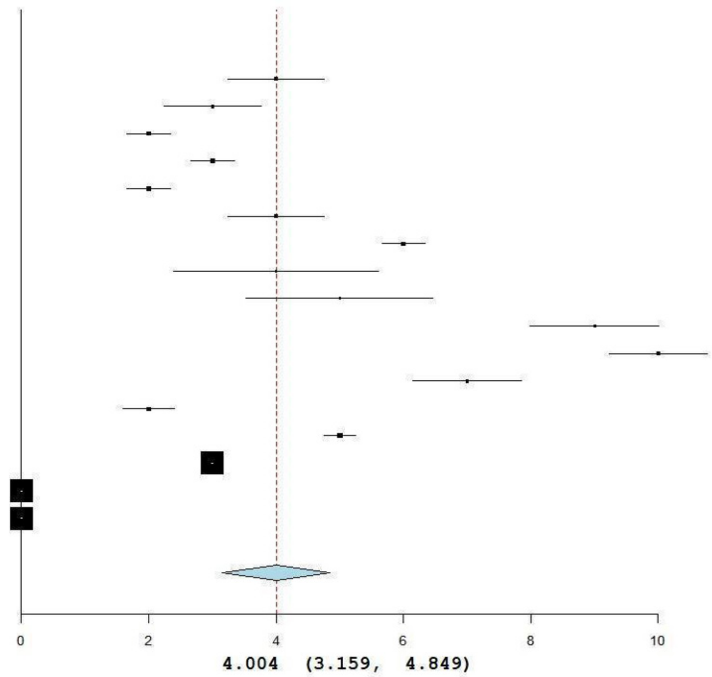

Figure 8. Effect size for the moderator sucrose, minimum and maximum values in parentheses at 5% significance level.

Post-harvest treatments with carbohydrate solutions (sucrose or glucose) have the potential to delay the senescence of cut flowers and promote the opening of flower buds (Chuang and Chang, 2013). As essential components in metabolism, carbohydrates provide nutritional support and sustained maintenance (Alam et al., 2023). Starch is crucial for floral opening, while sucrose is transported throughout the plant to promote its development. Polysaccharide reserves are gradually accumulated during petal development but are quickly depleted when anthesis begins, creating the potential for osmotic pressure that triggers cellular water influx and eventual bud opening (Costa et al., 2021). Additionally, flowers have high respiration rates and lack storage organs, which can lead to carbohydrate depletion during storage and trigger senescence events (Fatima et al., 2022). Respiratory control can be used as an excellent index to predict vase life longevity in a range of temperatures.

Sometimes solutions containing only sucrose can result in increased microbial growth, leading to reduced quality due to blockage of the conducting vessels and decreased water absorption (Fatima et al., 2022; Sales et al., 2021). Therefore, mixed compositions are more effective, as they generally include three components: carbohydrates, antimicrobial agent, and an acidifying agent (Seman and Rafdi, 2019). Carbohydrates provide structural support by supplementing carbon sources, aiding in cellular structure and osmotic adjustment. The antimicrobial agent inhibits the development of bacteria that clog the stem, while the acidifying agent, which can also act as an antimicrobial agent, slows down microbial growth and facilitates water absorption.

Sucrose acts not only as an energy source but also inhibits flower senescence and ethylene synthesis (Zeng et al., 2023) by functioning as an abscisic acid antagonist (Timalsina et al., 2023). Sucrose combined with acidifying agents decreases the pH, reducing ethylene production, bacterial and pathogen growth, and prolonging the vase life of cut flowers (Carlson et al., 2015).

The use of germicidal solutions on post-harvest flower stems is a common practice in floriculture that prevents the development of microorganisms that cause product deterioration (Menegaes et al., 2020). Although germicidal agents can be effective in reducing microorganisms, some compounds may be toxic to plants and cause negative effects, while others may leave residues that affect the quality of agricultural products and the environment (Eldeeb and Adam, 2021).

Conclusions

Meta-analysis is an innovative tool that can assist in decision-making for new studies in postharvest of tropical flowers. The development of new technologies to prolong the vase life of flower stems is important, as meta-analysis has positively indicated their use. In addition, the results also point to the need to deepen or improve postharvest research for some species such as *Etlingera elatior* and *Alstroemeria*, as the techniques to increase vase life were not significant. Among the postharvest technologies found, the use of coatings does not influence vase life and dry conditioning has a negative effect, reducing the vase life of flower stems.

Acknowledgements

The authors thank the research agencies Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES – Brazil), Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG – Brazil), and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq – Brazil).

Author contribution

ARCN: Data curation; formal analysis; investigation; methodology; writing - original draft. **PDOP:** Conceptualization; data curation; funding acquisition; project administration; writing - review & editing. **MMP:** Data curation; writing - original draft. **JVBC:** Data curation; writing - original draft. **SB:** Conceptualization; data curation; funding acquisition; project administration; writing - review & editing.

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