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Original article

Effects of Ethephon, Ethylene, and Acetylene Applications at Different Dosages and Temperature Conditions on Flower Induction in Selected *Bromeliaceae* Species

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Abstract

Understanding the physiological basis of ethylene-mediated reproductive development in ornamental *Bromeliaceae* species is essential for developing reliable cultivation protocols in climatically variable regions. This study comparatively evaluated the dose- and temperature-dependent efficacy of ethephon, ethylene, and acetylene as floral induction agents in two commercially important taxa, *Guzmania* 'Ostara' and *Tillandsia cyanea*, under controlled environmental conditions. The experiment was designed as a randomized complete block design with two temperature regimes (22°C and 35°C) and seven hormone application combinations. Flowering success, developmental synchronization, flowering time, and morphological parameters were analyzed using ANOVA, Tukey HSD multiple comparison test, and chi-square independence analysis ($p < 0.05$). At 22°C, ethephon applications at all tested concentrations (60, 80, and 150 mL/100 L) induced consistent, uniform flowering. The highest flowering success in T. cyanea was recorded at 80 mL/100 L (91.0 ± 2.65%; 44 ± 1.0 days to flowering). In contrast, aqueous ethylene and acetylene solutions produced irregular flowering responses in *T. cyanea*, while inducing greater plant height in *Guzmania* 'Ostara' compared with ethephon treatments (55.0-56.5 cm versus 36.0-45.0 cm; ANOVA: $F = 453.12$, $p < 0.001$). Under elevated temperature stress (35°C), ethephon retained considerable efficacy in T. cyanea (76.0 ± 3.00%; 49 ± 1.0 days to flowering), whereas *Guzmania* 'Ostara' showed severe reproductive suppression, with only limited and irregular flowering. Applications of ethylene and acetylene failed to elicit consistent flowering responses under high-temperature conditions. These findings indicate that flowering induction in *Bromeliaceae* is strongly influenced by hormone source, dose, temperature, and species-specific physiological responsiveness. Ethephon was identified as the most reliable floral induction agent under variable production conditions, while acetylene may serve as a practical alternative to ethylene under favorable temperatures. Overall, the results provide valuable guidance for improving flowering synchronization and developing species-specific, climate-adapted cultivation strategies in commercial bromeliad production.

Keywords: *Bromeliaceae*, Ethephon, Ethylene, Flowering Induction, Temperature, *Guzmania, Tillandsia*

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INTRODUCTION

The *Bromeliaceae* family occupies a significant position in the global ornamental plant sector due to its approximately 3,000 species, wide variety of epiphytic and terrestrial growth forms, and long-lasting flower structures. Genera such as *Guzmania, Tillandsia, Vriesea*, and *Aechmea* are particularly prominent in commercial production due to their aesthetic value and suitability for controlled cultivation. *Bromeliaceae* species are widely cultivated in European ornamental plant markets, with annual production volumes estimated at over 25 million units, primarily centered in the Netherlands, Germany, and Scandinavia. In Turkey, commercial-scale *Bromeliaceae* production has been successfully established in recent years, reaching an annual production volume of approximately 300,000 units. However, the lack of standardized hormone application protocols optimized for local climatic conditions - particularly temperature variability - remains a significant challenge for producers seeking consistent flowering and marketable product quality (Benzing, 2000; Luther & Sieff, 1994).

In most *Bromeliaceae* species, flowering in the natural environment occurs as a result of the interaction between environmental stresses and hormone signals. However, since these natural triggers are absent in controlled production greenhouses, external hormone applications have become an indispensable component of modern bromeliad production in directing flowering. In this context, it has long been known that ethylene and ethylene-releasing compounds play an active role in flowering induction (De Greef et al., 1989; Benzing, 2000; Dukovski, 2006).

The *Guzmania* 'Ostara' and *Tillandsia cyanea* used in this study represent two commercially important taxa of the *Bromeliaceae* family. Guzmania species are characterized by rosette structures composed of broad, glossy leaves and long-lived, colorful bracts that develop on a peduncle rising from the center during flowering (Benzing, 2000). *Tillandsia cyanea*, on the other hand, has a more compact rosette structure, narrow and stiff leaf morphology, and flattened pink flower bracts. As an epiphytic species, *T. cyanea* attaches to tree surfaces in its natural habitat and efficiently absorbs water from atmospheric moisture through dense trichome structures on its leaves (Benzing, 2000; Luther & Sieff, 1994).

In both species, flowering represents the single (monocarpic) generative phase of the life cycle; the parent plant propagates by forming side shoots after flowering. Therefore, the timing and homogeneity of flower induction are crucial not only for aesthetic quality but also for production continuity and commercial efficiency.

Ethylene is considered one of the key signaling molecules that trigger flowering in the *Bromeliaceae* family. Ethephon, an ethylene-releasing compound, is widely used as a reliable flowering induction agent in bromeliads because it breaks down within plant tissue, releasing ethylene in a controlled manner (De Greef et al., 1989; Dukovski, 2006). The effectiveness of ethephon is closely related to the transformation process within plant tissue, which is influenced by environmental factors such as temperature and pH (Abeles et al., 1992). Although ethylene in gaseous form produces a rapid physiological response, its application difficulties and practical limitations have resulted in more restricted use in commercial production. Although acetylene is known to exhibit ethylene-like biological effects, its effectiveness in bromeliad species has been reported to vary depending on environmental conditions and application methods (Dukovski, 2006).

Environmental factors, particularly temperature, directly affect ethylene biosynthesis and signal transduction processes, determining the intensity and success of the hormone response. Under high temperature conditions, ethylene perception and signal activity can be suppressed, which can reduce the reliability of flowering induction (Abeles et al., 1992). In commercial bromeliad production, several factors limit flowering success and product quality. Temperature fluctuations, inadequate light and humidity management, and operational errors such as incorrect hormone dosing or application timing can result in irregular or incomplete flowering, reduced flower quality, and shortened flower longevity. These issues directly reduce the proportion of marketable plants, increase production costs per unit, and complicate inventory and logistics planning. Therefore, identifying reliable and optimized hormone application protocols under varying temperature conditions is of critical practical importance for commercial producers. Although there are studies addressing the effects of temperature on flowering in *Bromeliaceae*, studies systematically comparing different ethylene sources such as ethephon, ethylene, and acetylene under varying temperature conditions are limited. Furthermore, comprehensive data on the effects of hormone applications on flowering homogeneity, plant height, and marketable quality are still insufficient for commercial production.

This study comparatively evaluates the effects of ethephon, ethylene, and acetylene applications on flowering induction at two different temperature levels (22°C and 35°C) in *Guzmania* 'Ostara' and *Tillandsia cyanea* species, which are widely cultivated in the ornamental plant sector. The main objective of the study is to reveal the effects of hormone–temperature interaction on commercially critical parameters such as flowering success, flower homogeneity, and plant height. The findings are expected to fill gaps in the literature on ethylene-mediated flowering induction in bromeliads and contribute to the development of applicable hormone protocols.

MATERIALS AND METHODS

Plant Material

This research was conducted under controlled greenhouse conditions (Figure 1). The plant material used in the study consisted of *Guzmania* 'Ostara' and *Tillandsia cyanea* species belonging to the *Bromeliaceae* family.

The plants used in the experiment were selected based on two criteria: commercial relevance and physiological readiness for flowering induction. *Guzmania* 'Ostara' and *Tillandsia cyanea* were chosen because they represent the most widely cultivated and commercially dominant cultivars within their respective genera in the global ornamental plant trade. Only healthy and homogeneous individuals that had completed their vegetative development and reached flowering maturity were included in the study. Flowering maturity was assessed according to the standard commercial production criteria established by Royal FloraHolland, the leading international floriculture auction and knowledge center, which defines maturity thresholds for ornamental bromeliad species based on rosette development, leaf count, and plant age. Standard commercial substrate mixtures were used as the growing medium, and plant feeding and watering procedures were carried out according to the company's standard production program.

Figure 1. General view of the commercial greenhouse facility (Gardenkoala Ltd., Tarsus/Mersin, Türkiye) where the experimental trials were conducted under controlled temperature and humidity conditions.

Experimental Design

The research was designed according to the randomized block design. The experiment was conducted under two different temperature conditions (22°C and 35°C). A total of 21 plants were used per species per temperature condition, with three plants assigned to each of the seven hormone treatment combinations. A separate control group (no hormone application) was not included in the experimental design, as ethylene-mediated flowering induction is an established requirement in commercial bromeliad production. Without hormone application, flowering in both *Guzmania* and *Tillandsia* species typically requires 18-24 months under standard greenhouse conditions, compared to 9-12 months with ethylene-based treatments, making an untreated control group neither practically relevant nor commercially applicable (De Greef et al., 1989; Dukovski, 2006). During the experimental period, plants were grown on production benches under homogeneous environmental conditions, and hormone applications were carried out in these areas (Figure 2). Ethephon was evaluated at three doses, while ethylene and acetylene were evaluated with two different gas application replicates (1 and 3 replicates). In all applications, the solution and gas treatment environment were maintained at a pH of 5.0. The selection of pH 5.0 was based on the known relationship between solution acidity and ethephon hydrolysis efficiency. At pH 5.0, ethephon undergoes more controlled decomposition within plant tissue, enhancing ethylene release. Furthermore, acidic conditions facilitate the solubility and uptake of gaseous hormones by the rosette tissue of bromeliad species (Abeles et al., 1992). The experiment was structured as a cycle of hormone application, temperature conditioning, monitoring, and measurement, and the continuity of environmental parameters was ensured throughout the process.

Figure 2. Experimental greenhouse area showing successful flowering of both species during the study period. A) *Guzmania* 'Ostara' displaying homogeneous red inflorescence development following ethephon application at 22°C. B) *Tillandsia cyanea* displaying successful pink spike inflorescence development following ethephon application.

Hormone Applications

Ethephon Applications: Derim Extra (720 g L^{-1} 0 used as the commercial product. Ethephon was prepared in three different doses and applied to the rosette part of the plants in a single application:

- 60 mL / 100 L water (432 ppm)
- 80 mL / 100 L water (576 ppm)
- 150 mL / 100 L water (1080 ppm)

These doses were selected based on prior production experience at the commercial greenhouse facility, where preliminary observations indicated effective flowering induction within this concentration range. The prepared solutions were mixed to ensure a homogeneous mixture prior to application and applied to all plants using the same volume and technique.

Ethylene and Acetylene Gas Applications (Aqueous Solution): Ethylene and acetylene applications were performed using a standard method based on dissolving the gaseous hormones in water. Both gases were dissolved in water by being pumped into a 1-ton water tank for 15 minutes to obtain a saturated solution. The gas saturation method was applied under standardized conditions (15 minutes, constant temperature, 22°C water temperature) to ensure consistent hormone concentration across all applications. Although exact dissolved gas concentrations were not independently measured, the standardized preparation protocol was maintained throughout the experiment to minimize variability. This solution was applied directly to the rosette cavity of the plants.

Two different application frequencies were tested in the gas applications: a single application (1 application) and three applications repeated with 48-hour intervals between each application (3 applications). This method aimed to increase the effectiveness of the plant's perception of the ethylene-like flowering signal by directing the gaseous hormones to the natural water storage area of the *Bromeliaceae* rosette structure.

Temperature Conditions

The study was conducted under two different temperature regimes to reveal the influence of environmental temperature on the success of hormone applications: 22°C, representing the optimal growing conditions for *Bromeliaceae*, and 35°C, modeling heat stress. These two temperature levels were selected to represent contrasting production environments. At 22°C, gas solubility in water is higher, facilitating effective uptake of ethylene and acetylene by plant tissues. At 35°C, reduced gas solubility and increased ethylene volatilization limit hormone availability within the rosette cavity, contributing to the observed reduction in flowering success under heat stress conditions (Abeles et al., 1992). Temperature changes were applied using a gradual transition protocol to prevent sudden thermal shocks from affecting physiological responses, and plants were grown in both temperature chambers under 85% relative humidity, 200 μmol m^{-2} s^{-1} photosynthetic radiation, and a 12-hour photoperiod. The consistency of environmental parameters under both temperature conditions was ensured by a sensor-based automation system, thus creating a consistent experimental environment that isolated the effects of hormone-temperature interactions on the flowering response.

Evaluated Parameters

The effects of hormone and temperature treatments on plants were evaluated based on four key parameters: Flowering rate (%) was calculated as the mean individual flowering performance percentage of three plants within each treatment. Each plant was evaluated according to the degree of flowering initiation, inflorescence development, flowering completeness, and marketable visual quality. Therefore, flowering rate values represent the average flowering performance of individual plants rather than the proportion of plants that produced flowers. The flowering response was classified into three categories based on phenological regularity: "regular flowering," "irregular flowering," and "no flowering observed during the study period." Plant height in *Guzmania* 'Ostara' individuals was determined by measuring stem length at the end of the flowering period. Flowering homogeneity was evaluated by recording the temporal distribution of flowering within each treatment group. All parameters were recorded using standard measurement criteria throughout the same observation period.

Statistical Analysis

Continuous data such as plant height and proportional data such as flowering rate were analyzed using analysis of variance (ANOVA). For proportional data, arcsine square root angle transformation was applied prior to analysis to ensure statistical assumptions. If the differences between factors were found to be statistically significant ($p<0.05$) as a result of ANOVA, Tukey's Honestly Significant Difference (HSD) test was used to group the differences between means and compare them reliably. Results determined categorically, such as flowering homogeneity, were analyzed using the Chi-square Independence Test to test the dependence of the relationship between hormone applications and homogeneity status.

RESULTS

In this study, the effects of ethephon, water-soluble ethylene, and acetylene applications on flowering induction in *Guzmania* 'Ostara' and *Tillandsia cyanea* were examined under two different temperature regimes. The results showed that flowering responses differed according to plant species, hormone source form, and temperature conditions. All flowering responses are summarized in Table 1.

At 22°C, both species exhibited flowering responses following hormone applications, and hormone treatments had statistically significant effects on flowering rates ($p < 0.05$). In *Guzmania* 'Ostara,' flowering was observed at all ethephon application rates, with corresponding plant height values of 45 cm, 42 cm, and 36 cm, respectively. Plant height measured under water-soluble ethylene applications was 55 cm and 56.5 cm in the single and triple application groups, respectively, while acetylene applications resulted in plant heights of 55 cm and 55.5 cm.

In *Tillandsia cyanea* at 22°C, ethephon applications resulted in regular and successful flowering responses. The highest flowering success was recorded at 80 mL/100 L (91.0 ± 2.65%, mean 44 days), followed by 150 mL/100 L (86.0 ± 3.00%, mean 41 days) and 60 mL/100 L (82.0 ± 3.00%, mean 48 days). Ethylene and acetylene applications resulted in irregular flowering at 22°C in *Tillandsia cyanea*. Analyses of flowering homogeneity revealed a statistically significant relationship between hormone type and flowering regularity ($p < 0.05$).

Table 1. Flowering responses to different hormone applications at 22°C and 35°C (*Guzmania* 'Ostara' and *Tillandsia cyanea*). Values for *Tillandsia cyanea* represent mean flowering success rates and mean days to flowering (n=3).

Temperature (°C)	Hormone	Dose / Preparation	Number of Applications	*Guzmania* 'Ostara' Response	*Tillandsia cyanea* Response
22°C	Ethephon	60 mL/100 L	1	45 cm	82% flowering success, 48 days
22°C	Ethephon	80 mL/100 L	1	42 cm	91% flowering success, 44 days
22°C	Ethephon	150 mL/100 L	1	36 cm	86% flowering success, 41 days
22°C	Ethylene	Dissolved in water for 15 min	1	55 cm	Irregular flowering
22°C	Ethylene	Dissolved in water for 15 min	3	56.5 cm	Irregular flowering
22°C	Acetylene	Dissolved in water for 15 min	1	55 cm	Irregular flowering
22°C	Acetylene	Dissolved in water for 15 min	3	55.5 cm	Irregular flowering
35°C	Ethephon	60 mL/100 L	1	Flowering not observed	68% flowering success, 53 days
35°C	Ethephon	80 mL/100 L	1	Flowering not observed	76% flowering success, 49 days
35°C	Ethephon	150 mL/100 L	1	Irregular flowering	71% flowering success, 46 days
35°C	Ethylene	Dissolved in water for 15 min	1	Flowering not observed	Flowering not observed
35°C	Ethylene	Dissolved in water for 15 min	3	Irregular flowering	Flowering not observed
35°C	Acetylene	Dissolved in water for 15 min	1	Flowering not observed	Flowering not observed
35°C	Acetylene	Dissolved in water for 15 min	3	Irregular flowering	Flowering not observed

Responses to hormone applications at 35°C differed between species. In *Guzmania* 'Ostara,' flowering was not observed under low ethephon doses (60 mL and 80 mL/100 L) or any gas applications. Only at the highest ethephon dose (150 mL/100 L) was limited and irregular flowering recorded. As flower stalk formation did not occur at this temperature, plant height measurements were not performed for *Guzmania* individuals. In *Tillandsia cyanea*, flowering at 35°C was observed only in ethephon-treated plants, whereas ethylene and acetylene applications were ineffective regardless of application frequency. The highest flowering success at 35°C was recorded at 80 mL/100 L (76.0 ± 3.00%, mean 49 days), followed by 150 mL/100 L (71.0 ± 3.00%, mean 46 days) and 60 mL/100 L (68.0 ± 3.00%, mean 53 days).

Overall flowering rates at 35°C were low, and differences among hormone treatments did not reach statistical significance ($p > 0.05$). This lack of statistical significance does not imply that hormone treatments were equally effective but rather reflects the overriding suppressive effect of high temperature on flowering induction. Under severe heat stress conditions, the physiological capacity of both species to respond to hormonal signals was markedly reduced, rendering differences among hormone treatments statistically undetectable (Abeles et al., 1992). The morphological differences associated with hormone applications are presented in Figure 3.

Figure 3. Morphological differences in *Guzmania* 'Ostara' individuals caused by different hormone applications at 22°C. From left to right: Ethephon 432 ppm (60 mL/100 L) - shorter plant height (45 cm), fully developed red inflorescence; Ethephon 1080 ppm (150 mL/100 L) - most compact growth (36 cm), intense red coloration; Ethylene dissolved in water for 15 min - tallest growth (55 cm), lighter coloration; Acetylene dissolved in water for 15 min - similar tall growth (55 cm), comparable morphology to ethylene treatment.

Statistical Analysis

Plant height values of *Guzmania* 'Ostara' recorded at 22°C differed significantly among hormone treatments (ANOVA: $F = 453.12$, $p < 0.001$). Tukey's HSD post-hoc test revealed three distinct groups: ethephon at 150 mL/100 L produced the shortest plants (36.0 ± 0.53 cm, group c), followed by ethephon at 80 mL/100 L (42.0 ± 0.61 cm, group b) and 60 mL/100 L (45.0 ± 0.75 cm, group a). Ethylene and acetylene applications produced significantly taller plants (55.0–56.5 cm) with no statistically significant differences among them (group d). These results are summarized in Table 2. Under this temperature regime, flowering was observed in all hormone-treated *Guzmania* individuals.

Table 2. Plant height of *Guzmania* 'Ostara' under different hormone applications at 22°C (mean ± SD, n=3).

Hormone	Dose/Preparation	Mean Plant Height (cm)	Tukey Group
Ethephon	60 mL/100 L	45.0 ± 0.75	a
Ethephon	80 mL/100 L	42.0 ± 0.61	b
Ethephon	150 mL/100 L	36.0 ± 0.53	c
Ethylene	Dissolved in water for 15 min (1x)	55.0 ± 0.79	d
Ethylene	Dissolved in water for 15 min (3x)	56.5 ± 0.62	d
Acetylene	Dissolved in water for 15 min (1x)	55.0 ± 0.75	d
Acetylene	Dissolved in water for 15 min (3x)	55.5 ± 0.56	d

Different letters indicate statistically significant differences according to Tukey's HSD test ($p < 0.05$). ANOVA: $F = 453.12$, $p < 0.001$.

In *Tillandsia cyanea* at 22°C, ethephon applications resulted in regular and successful flowering responses. The highest flowering success was recorded at 80 mL/100 L (91.0 ± 2.65%, mean 44 days, group a), followed by 150 mL/100 L (86.0 ± 3.00%, mean 41 days, group ab) and 60 mL/100 L (82.0 ± 3.00%, mean 48 days, group ab). At 35°C, *Tillandsia cyanea* maintained successful flowering responses to ethephon; however, both flowering rates and timing were significantly affected by the elevated temperature. The highest success at 35°C was recorded at 80 mL/100 L (76.0 ± 3.00%, mean 49 days, group bc), followed by 150 mL/100 L (71.0 ± 3.00%, mean 46 days, group c) and 60 mL/100 L (68.0 ± 3.00%, mean 53 days, group c). These results are summarized in Table 3. Analyses of flowering homogeneity revealed a statistically significant relationship between hormone type and flowering regularity ($p < 0.05$).

Table 3. Flowering success rate and days to flowering of *Tillandsia cyanea* under ethephon applications at 22°C and 35°C (mean ± SD, n=3).

Temperature	Dose	Flowering Rate (%)	Tukey Group	Days to Flowering	Tukey Group
22°C	60 mL/100 L	82.0 ± 3.00	ab	48.0 ± 1.00	bc
22°C	80 mL/100 L	91.0 ± 2.65	a	44.0 ± 1.00	d
22°C	150 mL/100 L	86.0 ± 3.00	ab	41.0 ± 1.00	e
35°C	60 mL/100 L	68.0 ± 3.00	c	53.0 ± 1.00	a
35°C	80 mL/100 L	76.0 ± 3.00	bc	49.0 ± 1.00	b
35°C	150 mL/100 L	71.0 ± 3.00	c	46.0 ± 1.00	cd

Different letters indicate statistically significant differences according to Tukey's HSD test ($p < 0.05$). Flowering rate ANOVA: $F = 27.42$, $p < 0.001$. Days to flowering ANOVA: $F = 52.10$, $p < 0.001$.

DISCUSSION

The findings obtained in this study demonstrate that the flowering responses of both *Guzmania* 'Ostara' and *Tillandsia cyanea* are strongly influenced by the interaction between hormone source and environmental temperature conditions. In particular, the flowering response observed to hormone treatments under 22°C conditions are consistent with previous studies reporting that ethylene plays a central role in flowering induction in bromeliads (De Greef et al., 1989; Benzing, 2000; Dukovski, 2006).

These results obtained under moderate temperature conditions are also consistent with physiological explanations that reveal the sensitivity of ethylene perception and signal transmission processes to environmental factors. The biological activity of ethylene depends on the hormone being present in plant tissue for a sufficient period of time and being detectable by target tissues. This explains the effectiveness of compounds such as ethephon, which enable the controlled release of ethylene within plant tissue, inducing flowering (Abeles et al., 1992).

The fact that only ethephon applications resulted in flowering in *Tillandsia cyanea* at 35°C highlights the decisive role of the application method on hormone efficacy. In contrast, the near-complete suppression of flowering in *Guzmania* 'Ostara' at 35°C - with only limited irregular flowering observed at the highest ethephon dose (150 mL/100 L) and under repeated gas applications - suggests that this species' ethylene-mediated flowering response is highly sensitive to elevated temperature. These differences based on application method are consistent with previous studies reporting that the success of ethylene-induced flowering in bromeliads is closely related to environmental conditions (Dukovski, 2006; Schiappacasse et al., 2016). The contrasting temperature responses observed between the two species may be explained by their differing ecological origins. *Tillandsia cyanea*, as an epiphytic species naturally inhabiting exposed tree branches in tropical environments, has likely developed greater tolerance to temperature fluctuations and heat stress. In contrast, *Guzmania* 'Ostara', which typically grows in shaded understory conditions with more stable and moderate temperatures, appears to be more sensitive to elevated temperatures, resulting in near-complete suppression of ethylene-mediated flowering at 35°C. This ecological divergence is reflected in their hormone-temperature response profiles and has direct implications for commercial production: while *Tillandsia cyanea* can be reliably induced to flower across a broader temperature range, *Guzmania* 'Ostara' requires more precise temperature management for consistent flowering induction (Benzing, 2000; Poór et al., 2022).

In *Guzmania* 'Ostara' at 22°C, plant height showed a clear inverse relationship with ethephon dose: 45 cm at 60 mL/100 L, 42 cm at 80 mL/100 L, and 36 cm at 150 mL/100 L. In contrast, ethylene and acetylene applications produced significantly taller plants (55-56.5 cm). This 10-13 cm difference has direct commercial implications: for markets preferring taller flowering plants, ethylene or acetylene applications may be advantageous despite their lower flowering homogeneity. Furthermore, increasing ethephon dose beyond 60 mL/100 L provided no additional benefit in flowering success, suggesting that 60 mL/100 L represents the optimal dose for *Guzmania* 'Ostara' under optimal temperature conditions. Additionally, acetylene and ethylene applications produced comparable flowering outcomes in both species at 22°C. Given that acetylene is generally more cost-effective than ethylene, it may represent a practical and economical alternative for producers where ethylene gas is less accessible or more expensive.

Findings obtained at the molecular level indicate that ethylene activates specific developmental and genetic pathways when triggering flowering in bromeliads. The initiation of the flowering process in *Aechmea fasciata* through ethylene application revealed that the hormone functions not only as an environmental trigger but also as a developmental regulator (Ding et al., 2020; Lei et al., 2016). In this context, it is likely that the flowering responses observed in *Tillandsia cyanea* are also related to similar hormone-mediated mechanisms.

CONCLUSION

This study demonstrated that flowering induction in *Guzmania* 'Ostara' and *Tillandsia cyanea* is strongly regulated by the interaction between hormone source and temperature. Ethephon was the most reliable and consistent flowering agent across both temperature conditions, providing higher and more homogeneous flowering rates compared to ethylene and acetylene gas applications. At 22°C, all hormone sources induced flowering; however, ethephon produced superior homogeneity. At 35°C, only ethephon maintained effective flowering induction, particularly in *Tillandsia cyanea*, while *Guzmania* 'Ostara' showed near-complete suppression except at the highest ethephon dose. Hormone selection should be guided by temperature conditions, target market requirements for plant height, and cost-effectiveness. Year-round cultivation of *Guzmania* 'Ostara' in warm climates exceeding 30°C is not recommended without cooling infrastructure.

These findings highlight the importance of planning hormone strategies in a species-specific and climate-sensitive manner. For markets preferring taller flowering plants, ethylene or acetylene applications offer a practical advantage over ethephon despite their lower homogeneity. Furthermore, acetylene represents a cost-effective alternative to ethylene gas, producing comparable flowering outcomes. Future studies should investigate intermediate temperature thresholds and additional bromeliad species to further refine hormone application protocols for diverse production environments.

Additional Declaration

Author Contributions

In this study, the authors contributed equally to all stages of this study. The research ideas and experimental design were developed jointly by all authors. Data collection, data analysis, and interpretation were carried out collaboratively. The manuscript was written, reviewed, and approved by all authors, who also take collective responsibility for the final version of the paper.

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Responsible Artificial Intelligence Statement

In this study, no artificial intelligence support was received in any part of this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to the publication of this study.

Conference Presentation

This study was presented at the III. International Biological and Life Sciences Congress (BIOLIC 2025), held in Antalya, Turkey, on November 16-19, 2025.

Ethics Approval

In all processes of this study, the principles of Pen Academic Publishing Research Ethics Policy were followed.

This study does not require ethics committee approval as it does not involve any direct application on human or animal subjects.

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