

ARTICLE

Planting date affects quantitative and qualitative traits of freesia flower stems

A data de plantio afeta as características quantitativas e qualitativas das hastes florais de freesia

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Abstract

The cut flower freesia (*Freesia x hybrida* Klatt) is highly demanded in the international market. Planting date determines the environmental conditions during crop development and can significantly influence flower stem quality. This study aimed to evaluate the effect of five planting dates on the quantitative and qualitative traits of flower stems in two freesia varieties, Blue Bayou and Yvonne, under high tunnel conditions. Plants were harvested at the opening of the first basal floret of the primary inflorescence. The longest flower stems were recorded in plants planted on the first and second dates. Inflorescence length was shortened with delay of planting date; the last date yielded inflorescences of 7.30 ± 0.25 cm in length. The number of inflorescences and the number of florets per inflorescence decreased with delay of planting date; on the last day, Yvonne exhibited 6.02 ± 0.19 florets per inflorescence. Fresh and dry weight of flower stems showed the same trend, decreasing with delay of planting date. Vase life of flower stems obtained from the first and last planting dates was 10.50 ± 0.13 and 8.04 ± 0.12 days, respectively. More than 50% of flower stems from Blue Bayou exhibited injuries under late planting. The best flower stem quality was obtained from the earliest planting dates. These results highlight the importance of planting date selection to synchronize reproductive development with favorable environmental conditions and maximize commercial stem quality.

Keywords: *Freesia x hybrida*, floriculture, geophytes, quality.

Resumo

A flor de corte freesia (*Freesia x hybrida* Klatt) é altamente demandada no mercado internacional. A data de plantio determina as condições ambientais durante o desenvolvimento da cultura e pode influenciar significativamente a qualidade das hastes florais. Este estudo teve como objetivo avaliar o efeito de cinco datas de plantio sobre as características quantitativas e qualitativas das hastes florais de duas variedades de freesia, Blue Bayou e Yvonne, sob condições de túnel alto. As plantas foram colhidas na abertura do primeiro flósculo basal da inflorescência principal. As hastes florais mais longas foram obtidas nas plantas plantadas nas duas primeiras datas. O comprimento da inflorescência foi reduzido com o atraso da data de plantio; a última data resultou em inflorescências com $7,30 \pm 0,25$ cm de comprimento. O número de inflorescências laterais e de flósculos por inflorescência também diminuiu com o atraso do plantio; na última data, Yvonne apresentou $6,02 \pm 0,19$ flósculos por inflorescência. O peso fresco e seco das hastes florais seguiu a mesma tendência decrescente. A longevidade pós-colheita das hastes foi de $10,50 \pm 0,13$ dias na primeira data e $8,04 \pm 0,12$ dias na última. Mais de 50% das hastes da variedade Blue Bayou apresentaram danos sob plantio tardio. A melhor qualidade das hastes florais foi obtida nas datas de plantio mais precoces. Esses resultados destacam a importância da escolha adequada da data de plantio para sincronizar o desenvolvimento reprodutivo com condições ambientais favoráveis e maximizar a qualidade comercial das hastes florais.

Palavras-chave: *Freesia x hybrida*, floricultura, geófitos, qualidade

Introduction

Freesia (*Freesia x hybrida* Klatt) is a commercially valued ornamental cut flower (Abdulazeez et al., 2020; Faust and Dole, 2021) originating from South Africa, belonging to the Iridaceae family (Mosa and Abdulrahman, 2022; Ahsan et al., 2024), the same as gladiolus (*Gladiolus x grandiflorus* Hort.) (Thompson et al., 2011). It has a cymose inflorescence with 10 to 12 sessile florets. Flower stems must meet certain quality criteria for the trade of cut flowers. Those criteria are used for flower classification and include quantitative (measurable) and qualitative (visual) variables (Schwab et al., 2018).

Corm planting date is a key factor in freesia production, since it determines the environmental conditions to which plants are exposed during growth and influences the development cycle (Santilli et al., 2023) and characteristics of flower stems (Adil et al., 2021). Among these environmental variables, air temperature has one of the strongest effects on flower stem development (Gilbertson-Ferris, 2018). The optimal temperature range during the development of the flower stem is 12 - 15 °C. This process is slowed down at 10 - 12 °C and is accelerated at temperatures above 16 °C. Temperature values above 16 °C typically reduce flower stem length, number of florets per inflorescence and number of lateral inflorescences (Gilbertson-Ferris, 2018; Adil et al., 2021).

Studies on other Iridaceae cut flowers have shown that planting date and genotype regulate the length of the development cycle (Schwab et al., 2018), harvest time (Adil et al., 2013; Schwab et al., 2018; Tomiozzo et al., 2018; Ali et al., 2023) and quantitative and qualitative characteristics of the flower stems (Adil et al., 2013; Schwab et al., 2015; Amjad et al., 2018; Nagar et al., 2018; Schwab et al., 2018; Tirkey et al., 2018; Tirkey et al., 2019; Ali et al., 2023). Regarding the qualitative characteristics, Schwab et al. (2018) demonstrated that in gladiolus, exposure to extreme air temperatures during the reproductive stage (above 35 °C or below -2 °C) may cause injuries such as sepal burns and reduced floret opening, compromising stem marketability.

In floriculture, understanding the plant's developmental response to environmental cues is essential for optimizing planting schedules, ensuring uniform flower quality, and aligning harvests with market demand peaks, which has a positive impact on sales price. (Amjad et al., 2018; Chandel et al., 2022; Paulus et al., 2022; Proietti et al., 2022).

However, while the effect of planting date has been widely studied in gladiolus, studies in freesia remain scarce, particularly regarding its impact on commercial flower stem quality.

Therefore, the objective of this study was to evaluate the effect of five planting dates on the quantitative and qualitative traits of flower stems in two *Freesia x hybrida* varieties, Blue Bayou and Yvonne, cultivated under high tunnel conditions.

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Materials and Methods

Vegetal material

Corms (2.0 to 2.2 cm in diameter) of *Freesia x hybrida* varieties Blue Bayou and Yvonne were used. The corms were originally acquired from a commercial supplier (FlorAr, Florencio Varela, Buenos Aires, Argentina) and propagated under local conditions prior to the experiment to obtain uniform planting material for all treatments. Corms were selected for uniformity and absence of visible damage or sprouting.

Planting was conducted in beds (0.70 m width, 0.20 m high, 4 m long). The substrate used was composed of previously solarized soil and agricultural perlite in 3:1 (v v⁻¹), 1.11 dS m⁻¹ electrical conductivity, pH 6.4, 2.5% – 3.5% organic matter, and 66.8% gravimetric water content at field capacity. The mixture was prepared and homogenized prior to filling the beds to ensure uniform conditions across treatments.

Management and experimental design

The trial was carried out in the year 2021, under high tunnel conditions. The tunnel measured 11 m in length, 5 m in width, and 4 m in height, and was covered with 100- μ m polyethylene film (long thermal duration). No active environmental control systems were used.

A 2 \times 5 factorial design (two varieties and five planting dates) was implemented in a completely randomized block design with four replicates. Each block contained all 10 treatments (BB-Feb15, Y-Feb15, BB-Mar19, Y-Mar19, BB-Apr16, Y-Apr16, BB-May21, Y-May21, BB-Jun21 and Y-Jun21) resulting from the combination of variety (Blue Bayou (BB), Yvonne (Y)) and planting date (February 15th, March 19th, April 16th, May 21st, June 21st), randomly distributed within the block. For each treatment, 18 corms were planted per bed, and 9 randomly selected plants were evaluated. A total of 36 flower stems were analyzed per treatment.

Throughout the experiment, pest control consisted of the application of a chemical insecticide (lambda-cyhalothrin at a rate of 400 cm³ ha⁻¹) and manual weeding. The crop was supported by two rows of mesh grids, each measuring 0.125 m by 0.125 m.

The experiment was carried out under non-limiting water conditions. Irrigation was applied periodically through a drip system, using the gravimetric value of the substrate at field capacity as the reference point.

Developmental phases

The phenological phases were recorded using the scale proposed by Santilli et al. (2021). The reproductive phase spanned from flag leaf emergence (code 500) to the harvesting of flower stems (code 600). Plants were considered to have reached a given phenological phase when 50% of them in each repetition were at that phase. Phase length was expressed in days.

Evaluation of quantitative and qualitative variables

Stems harvesting started when the first base floret of the primary inflorescence was open (code 600) (Santilli et al. 2021). Flower stems were harvested manually using pruning shears, placed in a container with water and transported to the laboratory for evaluation of the quantitative and qualitative variables.

Quantitative variables

- Flower stem length (cm): measured from the base of the stem (cut area) to the apical end of the first floret using a 1m graduated rule (1 mm accuracy).

- Primary inflorescence length (cm), measured from the insertion of the first floret to the distal end of the inflorescence with a 1 m graduated rule (1 mm accuracy).

- Number of florets in the primary inflorescence: the number of colored florets and buds present in the inflorescence was counted.

- Number of lateral inflorescences present in the flower stem.

- Fresh weight of the flower stem (g): measured with an electronic scale (Ohaus TA501, New Jersey, USA)

Stems were stored in a chamber with controlled conditions (25 \pm 1 °C, 85% - 90% relative humidity, and under cool white fluorescent lighting for 14 hours), where they were placed in a vase containing 250 mL of water. The water was changed daily.

- Vase life (days): was defined as the number of days from harvest until all florets of the inflorescence exhibited visible wilting (senescence).

Qualitative variable

- Percentage of flower stems with injuries (%): the flower stem was considered to exhibit injuries when one or more florets of the primary inflorescence had buds with burnt bracts (brown). Damage was assessed visually by the same trained evaluator and recorded as a binary variable (presence/absence).

Injury occurrence was associated with maximum air temperatures above 35 °C (Schwab et al., 2018), and to the frequency (number of days) and daily duration (hours) of those events during the reproductive phase. Low temperatures were not considered because the crop was not exposed to values below -2 °C.

Once all florets of the inflorescence reached the senescence state, they were taken to a heater (60 °C) with daily weighing until constant weight. Dry weight (g) was determined with an electronic scale (Ohaus TA501, New Jersey, USA).

Environmental data recording

A data logger (TPD8016, LogTag, New Zealand) was used to record the air temperature within the high tunnel 48 times daily. Maximum, mean and minimum daily and monthly temperatures were then calculated. These temperature data were then used to provide context for the occurrence, duration, and intensity of high-temperature events (>35 °C) associated with visual damage to flower stems during the reproductive phase.

Daily photoperiod was calculated using the Varast 1.0 spreadsheet (Fernández-Long et al., 2015). Although these data were not used in the statistical analysis, they were included to characterise the environmental conditions associated with each planting date.

Data analysis

Data was analyzed using Infostat (Di Rienzo et al., 2020). An analysis of variance was performed and the interaction between planting dates and varieties was evaluated. Means were compared with the DGC test (α = 0.05). The data analyzed met the normality assumptions, with zero expectation, and common and independent variance.

Results

Environmental conditions and reproductive phase

The environmental profile during the crop cycle under high tunnel conditions was previously described in detail by Santilli et al. (2023). The reproductive phase extended from July 1 to October 5, 2021, depending on the planting date. During this period, the highest daily air temperature recorded was 45.2 °C on October 2, and the lowest was 0.3 °C on July 10. Photoperiod progressively increased from 10.5 hours in early July to 12.8 hours in early October (Fig. 1).

The five planting dates resulted in different environmental conditions, meaning the reproductive phase occurred at different times under different combinations of thermal and photoperiodic conditions (Fig. 1). Similar environmental conditions were observed during the reproductive phase in treatments BB-Feb15, BB-Mar19, and BB-Apr16, as well as in Y-Feb15 and Y-Mar19 (Fig. 1).

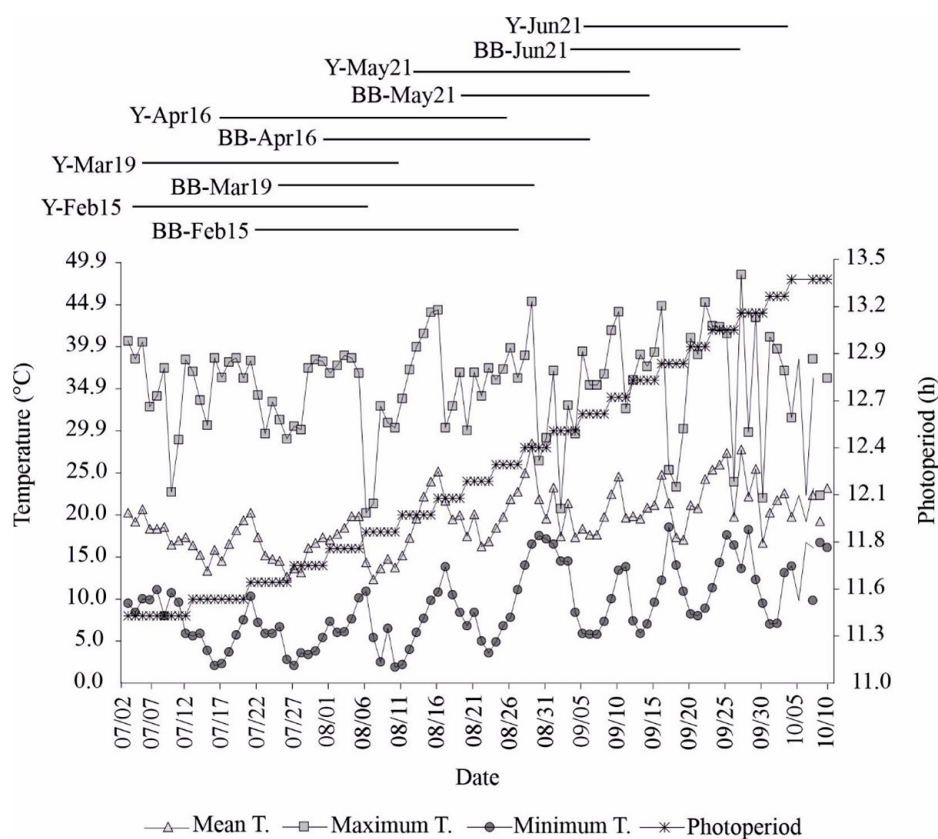


Fig. 1. Daily maximum, mean, and minimum air temperatures, and photoperiod, recorded under high tunnel conditions during the reproductive phase of *Freesia x hybrida* (July 1 to October 5, 2021). Horizontal lines show the start and duration (days) of the reproductive phase of treatments.

Influence of planting date on quantitative variables

There was no significant interaction between planting date and variety on flower stem length ($F = 1.72$; $df_{error} = 289$; $p = 0.1447$). The variety Blue Bayou produced significantly longer stems (50.22 ± 0.42 cm) than Yvonne (44.45 ± 0.44 cm) ($F = 66.56$; $df_{error} = 289$; $p < 0.0001$). The

analysis of the principal effect of planting date was also significant ($F = 113.61$; $df_{error} = 289$; $p < 0.0001$), February 15th and March 19th produced the longest flower stems, with values ranging from 54.21 ± 0.67 to 55.47 ± 0.72 cm. In contrast, May 21st and June 21st resulted in significantly shorter flower stems (Table 1).

Table 1. Mean values of quantitative traits of *Freesia x hybrida* flower stems as affected by variety and planting date.

	Flower stem length \pm S.E. (cm)	Number of lateral inflorescences \pm S.E.	Stem fresh weight (g)	Stem dry weight \pm S.E. (g)	Vase life (days)
Variety					
Blue Bayou	50.22 ± 0.42 a	5.16 ± 0.11 a	31.13 ± 0.62 a	3.43 ± 0.07 a	8.87 ± 0.08 b
Yvonne	44.45 ± 0.44 b	4.02 ± 0.12 a	25.06 ± 0.62 b	3.02 ± 0.07 b	9.63 ± 0.08 a
Planting Date					
February 15th	54.21 ± 0.67 a	7.93 ± 0.18 a	39.73 ± 0.95 a	4.72 ± 0.11 a	10.50 ± 0.13 a
March 19th	55.47 ± 0.72 a	7.32 ± 0.19 b	41.09 ± 1.03 a	4.72 ± 0.12 a	9.77 ± 0.14 b
April 16th	45.73 ± 0.67 b	4.79 ± 0.18 c	25.97 ± 0.94 b	3.02 ± 0.11 b	9.58 ± 0.13 b
May 21st	40.69 ± 0.69 c	2.95 ± 0.18 d	16.47 ± 0.97 c	1.87 ± 0.11 c	8.56 ± 0.13 c
June 21st	39.59 ± 0.63 c	2.46 ± 0.17 d	13.34 ± 0.91 d	1.61 ± 0.11 c	8.04 ± 0.13 d

Means with different letters in each column differ significantly according to the DGC test ($p < 0.05$).

Inflorescence length showed a significant interaction between planting date and variety ($F = 15.45$; $df = 289$; $p < 0.0001$). In both varieties, inflorescence length decreased with planting delay. The longest inflores-

cences were recorded in BB-Feb15, Y-Feb15, and Y-Mar19, and the shortest in Y-Jun21 (7.30 ± 0.25 cm) (Table 2).

Table 2. Mean values ± standard error (S.E.) of inflorescence length, number of florets, and percentage of injured flower stems in *Freesia x hybrida* as affected by variety and planting date.

Treatment	Inflorescence length ± S.E. (cm)	Florets per inflorescence ± S.E.	Injured stems (%) ± S.E.
BB-Feb15	10.24 ± 0.23 a	9.11 ± 0.17 a	0.0
Y-Feb15	10.30 ± 0.25 a	9.36 ± 0.19 a	0.0
BB-Mar19	9.51 ± 0.26 b	8.11 ± 0.19 b	0.0
Y-Mar19	10.68 ± 0.29 a	9.59 ± 0.22 a	0.0
BB-Apr16	9.17 ± 0.24 b	7.46 ± 0.19 c	8.75 ± 5.45 c
Y-Apr16	9.72 ± 0.26 b	8.74 ± 0.20 b	3.12 ± 5.45 c
BB-May21	8.95 ± 0.25 b	7.76 ± 0.19 c	52.0 ± 6.94 a
Y-May21	9.09 ± 0.25 b	8.42 ± 0.19 b	11.7 ± 6.94 c
BB-Jun21	8.70 ± 0.23 b	6.61 ± 0.17 d	58.6 ± 6.94 a
Y-Jun21	7.30 ± 0.25 c	6.02 ± 0.19 e	29.3 ± 6.94 b

Means followed by different letters in each column differ significantly according to the DGC test ($p < 0.05$).

The number of lateral inflorescences showed no significant interaction between the assessed factors ($F = 1.34$; $df_{error} = 289$; $p = 0.2533$). Likewise, the main effect of variety was not significant ($F = 0.64$; $df_{error} = 289$; $p = 0.4251$), whereas planting date had a significant impact ($F = 196.31$; $df_{error} = 289$; $p < 0.0001$). A gradual reduction in the number of inflorescences was observed as planting was delayed (Table 1)

A significant interaction was detected for the number of florets per primary inflorescence ($F = 19.86$; $df_{error} = 289$; $p < 0.0001$). In both varieties, this variable decreased significantly with delay of planting date. Treatments BB-Feb15, Y-Feb15 and Y-Mar19 showed the highest floret counts, while treatment Y-Jun21 recorded the lowest value (Table 2).

No significant interaction between factors was detected for flower stem fresh weight ($F = 0.54$; $df_{error} = 288$; $p = 0.7091$) or dry weight ($F = 2.46$; $df_{error} = 289$; $p = 0.0456$). The analysis of the effect of variety showed significant differences in fresh weight ($F = 15.61$; $df_{error} = 289$; $p = 0.0001$) and dry weight ($F = 4.38$; $df_{error} = 289$; $p = 0.0372$). Fresh and dry weight of stems of the variety Blue Bayou was 31.13 ± 0.62 g and 3.43 ± 0.07 g, respectively, with significant differences from the variety Yvonne, with stem fresh weight of 25.06 ± 0.62 g and dry weight of 3.02 ± 0.07 g. The effect of the factor planting date showed significant differences in fresh weight ($F = 181.37$; $df_{error} = 288$; $p < 0.0001$) and in dry

weight of stems ($F = 177.69$; $df_{error} = 289$; $p < 0.0001$). Both variables showed the same trend: they were significantly reduced with delay of planting date (Table 1).

The variable vase life did not show significant interaction between factors ($F = 2.22$; $df_{error} = 287$; $p = 0.0669$). A significant difference was observed in the analysis of the principal factor variety ($F = 42.02$; $df_{error} = 287$; $p < 0.0001$), with Yvonne lasting 9.63 ± 0.08 days and Blue Bayou lasting 8.87 ± 0.08 days (Table 1). Vase life decreased significantly with delayed planting ($F = 62.24$; $df_{error} = 287$; $p < 0.0001$), ranging from 10.50 ± 0.13 days on February 15th and 8.04 ± 0.13 days on June 21st (Table 1).

Influence of temperature on quality

Analysis of floret injury on the main stem indicated a statistically significant interaction between the evaluated factors ($F = 5.79$; $df_{error} = 30$; $p = 0.0014$). Treatments Y-Feb15 and Y-Mar19 did not exhibit injuries (Table 2). These treatments were subjected to maximum temperatures above 35°C for eight consecutive days; however, the extreme temperature did not last more than 4.5 h (Fig. 2). Treatments BB-Feb15 and BB-Mar19 did not show visual damage, although, unlike the previously mentioned treatments, extreme temperature events (above 35°C) lasted 7 h during four consecutive days (Fig. 2).

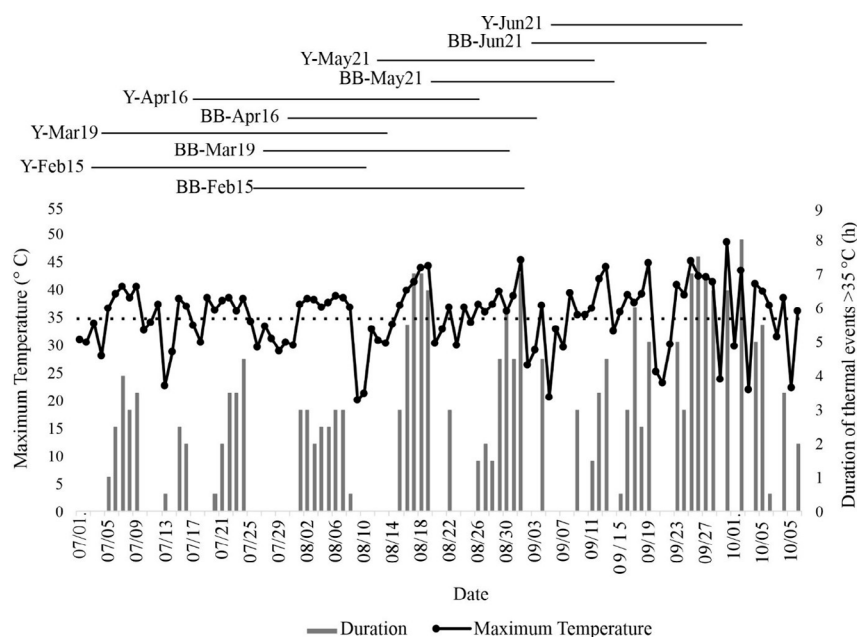


Fig. 2. Maximum temperatures recorded during the reproductive phase of treatments under the high tunnel. Vertical lines represent the duration of thermal events above 35°C (in hours), and horizontal lines indicate the onset and duration (in days) of the reproductive phase for each treatment.

In BB-Apr16, Y-Apr16 and Y-May21, 8.75%, 3.12% and 11.7% of stems exhibited injuries, respectively, with no statistical differences among them (Table 1). Treatments BB-Apr16, Y-Apr16 and Y-May21 were subjected to temperatures above 35 °C for 7 h, during a maximum of five consecutive days (frequency) (Fig. 2).

Treatments BB-May21 and BB-Jun21 differed significantly from the remaining treatments, with more than 50% of the harvested stems having visual signs of damage (Table 1). Both treatments were exposed to temperatures above 35 °C and the extreme temperature events were the most intense (45 °C), the most frequent (6 consecutive days) and the longest (8 h) of all the analyzed treatments (Fig. 2). In Y-Jun21, 29% of flower stems had injuries, with significant differences from the remaining treatments.

Discussion

Our findings demonstrate that both variety and the environmental conditions linked to the planting dates had a significant influence on the quantitative and qualitative traits of the *Freesia x hybrida* flower stem.

Our results indicate that variety and the environmental conditions associated with the five planting dates significantly affected the quantitative and qualitative characteristics of *Freesia x hybrida* flower stem. These findings are consistent with previous studies conducted in gladiolus, a crop from the same botanical family, where stem and inflorescence traits also varied with genotype and planting date (Schwab et al., 2015; Amjad et al., 2018).

In agreement with studies conducted in gladiolus (Schwab et al., 2015; Amjad et al., 2018; Nagar et al., 2018; Tirkey et al., 2018; Tirkey et al., 2019), in this work inflorescence length and flower stem length of freesia were influenced by planting date. Treatments BB-May21, Y-May21, BB-Jun21 and Y-Jun21, which were planted in late autumn and early winter, reached the reproductive phase under increasing temperatures and produced significantly shorter stems in both varieties compared to earlier planting dates.

Planting dates had a significant effect on the number of florets per inflorescence; this variable decreased with delay of planting date. However, Adil et al. (2021) did not find a relationship between number of florets per inflorescence and planting date.

Gilbertson-Ferriss (2018) reported that temperatures above 16 °C during the reproductive phase affects the characteristics of the flower stem. In the present study, temperatures above 16 °C were recorded in all the treatments. However, the flower stem reached commercial standards defined by the Dutch Flower Auctions Association VBN (Vereniging van Bloemveilingen in Nederland). For example, flowers stems from March 19th reached the 055 classification (55 cm length), whereas stems from June 21st were categorized as 039. Regarding the number of florets, the value was higher than the minimum required by the VBN (four florets) across all treatments.

Fresh weight decreased with planting delay, confirming patterns observed in gladiolus by Adil et al. (2013). In our study, flower stems on June 21st had a mean fresh weight of 13.34 ± 0.91 g, corresponding to the lowest VBN classification (013). This reinforces the negative impact of high ambient temperatures on dry matter accumulation during floral development.

Vase life was also affected by planting dates, with stems from early planting dates exhibiting significantly longer postharvest longevity. These findings are consistent with those of Amjad et al. (2018) and Nagar et al. (2018) in gladiolus. Furthermore, Yvonne exhibited longer vase life than Blue Bayou, highlighting a varietal difference in postharvest performance.

The occurrence of injuries (brown bract burns) in primary inflorescence was closely related to thermal stress. Treatments exposed to maximum temperatures above 35 °C for multiple days showed varying degrees of floral injury depending on the duration and frequency of heat events. Treatments BB-May21 and BB-Jun21 had more than 50% of stems affected and were exposed to the most extreme heat conditions: up to 35 °C, 6 consecutive days, and daily exposures lasting 8 hours. Blue Bayou showed a higher incidence of floral injuries than Yvonne across treatments. Although previous studies have explored the effects of high temperature on gladiolus (Schwab et al., 2018; Paulus et al., 2022), they did not consider the duration of thermal stress events. This study provides new evidence that not only the occurrence and frequency but also the duration of heat stress critically affects floral quality in freesia.

Altogether, these results contribute to the understanding of how planting date modulates the environmental conditions to which *Freesia x hybrida* is exposed during the reproductive phase, ultimately impacting commercial quality. The present study also highlights the importance of considering event duration as a key variable when assessing heat stress effects in ornamental crops.

Conclusions

The planting date had a significant effect on the quantitative and qualitative traits of the flower stems of *Freesia x hybrida*. The highest-quality stems, in terms of length, number of florets, fresh weight, and vase life, were obtained from corms planted in February and March.

In contrast, corms planted in May and June resulted in reduced fresh weight, lower biomass, shorter vase life and increased occurrence of floral injuries. These results highlight the importance of selecting appropriate planting dates to align crop development with favourable environmental conditions and maximize marketable flower stem quality.

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Author Contribution

MS: Conceptualization, Data Curation, Formal Analysis, Investigation, Project Administration, Resources, Software, Validation, Visualization, Writing – Original Draft. **SSBN:** Funding Acquisition, Investigation, Methodology, Software, Writing – Review & Editing. **NM:** Funding Acquisition, Supervision, Writing – Review & Editing.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

All the research data is contained in the manuscript.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that the use of AI and AI-assisted technologies was not applied in the writing process.

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