Colegio de Postgraduados

Time to flowering of ornamental orchids

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ABSTRACT
Objective: To analyze features of time to flowering of orchids and some strategies for its control in cultivation for ornamental purposes.
Design/methodology/approach: Information from various authors and our own data is shown, in relation to the management of flowering time of ornamental orchids, based on treatments of environmental effects, plant growth regulators (PGRs) and nutrition.
Findings/conclusions: It is possible to reduce the flowering time of orchids by environmental modifications, mainly temperature and photoperiod. This can also be achieved by nutritional management, mainly macro-nutritional, and through organic nutrition and PGRs. However, much more information is needed, especially for native orchid species with ornamental potential.

Keywords: Management of environmental factors, nutrition, orchid cultivation, ornamental orchids, plant growth regulators.

INTRODUCTION

Orchids as potted and cut flowers represent a large segment of the floriculture industry, due to their spectacular blooms. The value of world flower production is estimated at US$ 55 billion [Rabobank Food & Agribusiness Research and Advisory y Royal FloraHolland (Consulta: enero, 2022)]. Thus, the cultivation of orchids on a large scale as cut flowers and in pots continues to be a trend, and they head the highest prices in the world market (Hew y Yong, 2004; Rabobank, 2016; 2022). Southeast Asian countries are the major players in the global orchid trade, among which Thailand is the largest producer, with USD $60 million in 2014 (Thammasiri, 2016). The European Union (EU) and the United States are the most important countries or areas for the commercialization of orchid products, but new orchid markets are increasing every year (Yuan *et al.*, 2021).

While the COVID 19 pandemic affected the floriculture production sector (Anacleto *et al.*, 2020), there was an increase in the consumption preference of horticultural products, as during the pandemic quarantine, people encouraged the cultivation of ornamental plants at home (Pérez-Urrestarazu *et al.*, 2021). Likewise, the orchid trade has increased through digitalization or electronic commerce (E-commerce), coexisting with traditional flower shops

Image by Alejandro Sánchez

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and supermarkets (Yuan *et al.*, 2021), and consumer preference for continuing to purchase orchids has increased in some countries, such as Indonesia (Nadzifah *et al.*, 2022). *Phalaenopsis* is the world's most commercialized orchid with tremendous technological advances in breeding and micropropagation in several countries, such as the Netherlands, Taiwan, and Thailand, among others, for its ease of controlled flower induction for scheduled and year-round production (Yuan *et al.*, 2021). In the future, greater production and demand for orchid products are expected to arise from non-conventional technologies, such as efficient biotechnological breeding, (Yuan *et al.*, 2021), or from the introduction of wild species as new ornamental products, among which many species have been successful (Darras, 2020), and of which orchids should represent a fundamental group.

From a commercial point of view, one of the problems with orchids is that they have long juvenile periods before reaching the reproductive stage. Some important commercial orchids can take 2 to 3 years, such as *Phalaenopsis* (Wang *et al.*, 2017), but others take extreme periods, such as Aranda, which can require up to 13 years (Hew and Yong, 2004; Huang *et al.*, 2021). Likewise, some species have irregular or long flowering cycles throughout the year, so that alterations in the weather, for example, make it difficult to make materials available at times of high market demand (Hew and Young, 2004.). Thus, the long wait for flowering is a disadvantage for their success in the market, so the regulation of flowering time is the key to studies on the floral development of orchids (Ahmad *et al.*, 2022).

Scientists are therefore increasingly interested in better understanding the mechanisms and factors that influence the vegetative to reproductive transition in orchids to reduce their time to flowering, shorten production cycles, and thus reduce their time in the greenhouse and their use of agrochemicals and energy. Based on genetic, physiological and technological studies, various techniques are available to control the time to flowering, hastening or retarding the growth of the plant and its rate of development to adapt flowering to market demand (Proietti *et al.*, 2022). In this paper we reviewed current information on flowering time in orchids, as well as some approaches to its control for the cultivation of ornamental orchids. In addition, data derived from our research are incorporated.

Flowering of orchids

Orchid flower structure is uniquely diversified among flowering plants, and most orchid species have defined seasons favourable for flower induction and development, but there are many unknown features beyond our understanding of the orchid flower transition phenomenon (Wang *et al.*, 2017). A better understanding through different biotechnological, genetic and molecular techniques facilitates the modification of desirable flowering characteristics to promote ornamental breeding programs (Li *et al.*, 2021; Liyama *et al.*, 2024). There is some information in the literature on how to manipulate flower induction in orchid species, nevertheless, the lack of scientific information on the control of flowering of most orchids limits greenhouse growers and hobbyists to flower their plants outside their natural flowering period (López y Runkle, 2005).

Time to flowering of orchids

Each plant species, herbaceous or woody, has its characteristic juvenile cycles, during which, even when plants are provided with favourable conditions for flowering or treated with horticultural methods, it is difficult to induce the beginning of flowering (Tsai y Chang, 2022). Orchids present the greatest problems in this regard because of their long juvenile cycles that can range from 3 to 13 years before reaching the reproductive stage (Hew and Yong, 2004). For example, the duration of the juvenile phase in some Vanda hybrids can range from 3 to 8 years; similarly, some *Aranda* hybrids can range from 4 to 13 years. For *Laeliocattleya* Cheah Chuan Keat 6.7 years of juvenile period duration is reported (Hew y Yong, 2004).

Therefore, manipulation of flowering time and frequency of flowering is essential to increase the ornamental value of orchids (Ahmad *et al.*, 2021). Time to flowering is one of the most important horticultural characteristics of orchid cultivars, and a stable flowering time is the main objective of breeding programmes to induce horticultural novelties in commercial crops (Ahmad *et al.*, 2022).

According to Hew and Yong (2004) the flowering routes of orchids are divided into 7 groups : i) Year-round free flowering (*Arundina graminifolia*) (Ahmad *et al.*, 2021); *Prosthechea cochleata**; ii) long flowering season with short to medium non-flowering intervals (*Laelia anceps**); iii) seasonal, flowering mainly during the dry season (*Vanilla planifolia**; *Oncidium sphacelatum**); iv) seasonal, flowering mainly during the rainy season (*Stanhopea* sp.); v) regular in flowering; vi) sporadic at flowering; vii) spontaneous flowering (*personal observations of some species). Induction and seasonality of flowering are significant factors that determine the price and marketability of a popular orchid cut flower. Therefore, a precise recording of the flowering months is essential in a commercial crop. (Hew and Yong, 2004). *Phalaenopsis*, the most traded genus worldwide, usually reach maturity after three to five leaves have developed, which can take a few years (Wang *et al.*, 2019).

In a study of the time-phenological phase of *L. anceps* subsp. *anceps*, Tejeda-Sartorius *et al.* (2017) reported that the period to reach anthesis of the first raceme flower, measured from the visible inflorescence (VINF), 10 cm in length above the pseudobulb apex, is around 130 days on average. Subsequent observations show that to this period must be added another 20 days, on average, which is the time it takes for the flower stalk to reach the indicated length of 10 cm from the time it is just visible. In addition, to this period must be included the time from flower induction in the apical meristem of the stem (pseudobulb), with the signs of flower differentiation, which has not been determined. Thus, considering the periods of visible inflorescence onset, a 150-day cycle mean is established for *L. anceps* subsp. *anceps* (Figure 1), which may vary depending on climatic conditions or management. Based on this characterisation, *Laelia anceps* subsp. *anceps* is in the classification "long flowering season with short to medium non-flowering intervals".

Flowering time management

Time to flowering is controlled by endogenous genetic cues, influenced by plant age, hormones and circadian rhythm, as well as by environmental conditions such as day length, temperature and different types of stresses (drought, salinity, pathogens, water

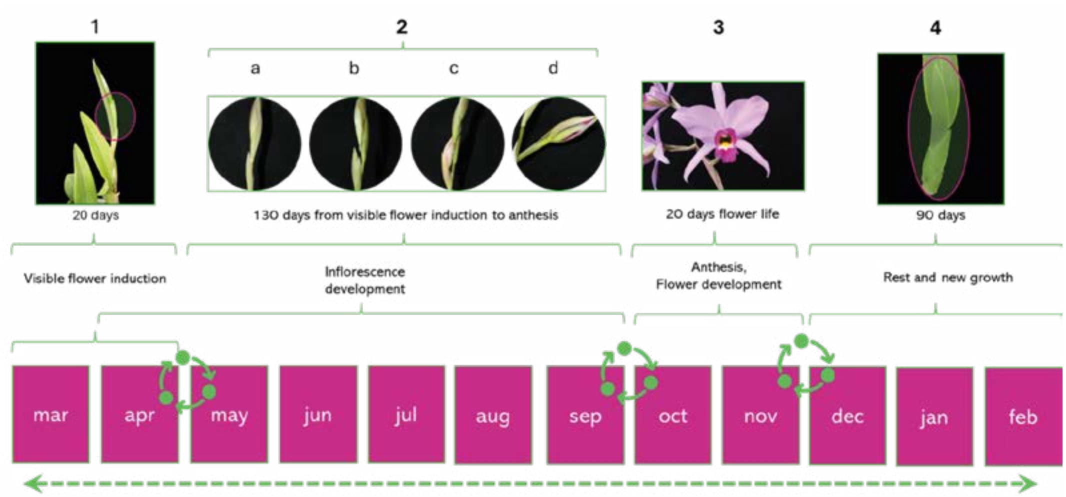

Figure 1. Flowering cycle of *Laelia anceps* in cultivation: 1: 20 days to visible flower induction when the inflorescence has reached 10 cm in length above the pseudobulb apex (pink circle). 2 a-d: 130 days includes elongation of the flower stalk and advancement of flower bud filling until the flower bud opens, and the labellum becomes visible. 3: 20 days flower life is the average derived from several flowers in different flowering cycles, without applications of plant growth regulators or any other bloom inducing substance or treatment. 4: 90 days of vegetative rest (mainly December and January) and in February the formation of new vegetative shoots begins (pink circle), which will give rise to the next flowering. Arrows in circles indicate possible temporal alterations in the different stages of the flowering phenology caused, for instance, by alterations in environmental conditions or management. Dotted arrow indicates repetition of the annual vegetative-reproductive growth cycle.

availability, etc.) (Amasino and Michaels, 2010; Cho *et al.*, 2017). In addition, flowering time is influenced by nutrient availability and exogenously applied chemicals (Cho *et al.*, 2017). Flowering of orchids responds in a similar pattern to that of other angiosperms.

Role of environmental factors in the orchid flowering

Light effect. Kim *et al.* (2015) reported that a night interruption (NI) period with high light intensity (120 μmol m^{-2} s^{-1}) reduced the time to visible buds and flowering of different *Doritaenopsis* cultivars more than NI with low light intensity (3 to 7 μmol m^{-2} s^{-1}). And they suggested high light intensity strategies in *Doritaenopsis* cultivation to obtain early flowering with high quality plants, using the IN treatment during their reproductive stage. Lee *et al.* (2019) found that during forced conditions for flowering of *Phalaenopsis* Queen Beer Mantefon, irrespective of the applied photoperiod [(8/16, 16/8 or '8+8' light/dark)] the highest applied light intensity (300 μmol m^{-2} s^{-1}) decreased the time to visible inflorescence by approximately 20 days compared to 75 μmol m^{-2} s^{-1}.

Efecto de temperatura. Lin *et al.* (2011) found that at least four weeks of chilling at 10 °C with light is needed for full flowering initiation time of *Dendrobium* Red Emperor 'Prince; while Den. Sea Mary 'Snow King' and Den. Love Memory 'Fizz' only needed two weeks of chilling at 10 °C, regardless of light. In other work, Han *et al.* (2020) investigated different temperatures and photoperiods in the regulation of flowering time of *Anoectochilus roxburghii* (Orchidaceae) and found that flowering time can be early under long day conditions of 16/8 h (day/night) and 25/20 °C (day/night). But it is delayed under short day conditions, 8/16 h at 20/15 °C.

In some work with *Laelia anceps*, comparisons were made between i) environment 1, with light combining high-pressure discharge (HID) lamps: metal additive (MA)+high-pressure sodium (HPS)+fluorescent lamps (F), with an intensity of 80 μmol m^{-2} s^{-1}; ii) environment 2, with light emitting diode (LEDs), red/blue (90/10%), 64 μmol m^{-2} s^{-1}. Both environments with day/night temperature 25/13 and 25/17 °C, and photoperiods 9/15 and 12/12 h. We found that environment 1 reduced the time to anthesis by 35 to 75 days (38 and 54%) at 25/17 °C, compared to 25/13 °C, regardless of photoperiod or type of light environment (Figure 2). It is observed that a higher night temperature (17 °C) is necessary to decrease the time to anthesis, or it may be the effect of a lower day/night temperature difference of 8 °C compared to the day/night difference of 12 °C of the other temperature tested (25/13 °C) (Figure 2), (unpublished data).

Furthermore, when comparing greenhouse and controlled conditions of light and temperature in flowering of *L. anceps*, it was found that the time to visible flower induction (VFI) decreased by up to 43 days in the controlled conditions (Sánchez-Vidaña *et al.*, 2018). Once VFI was present, flower development was promoted in the greenhouse and greater uniformity of flowering was observed. Thus, temperature and photoperiod in controlled environment can help not only to reduce the time to anthesis, but also to uniform floral development.

Chemical control of orchid flowering time

Plant growth regulators

A further alternative to plant breeding methods is the chemical engineering of flowering time by external application of flowering-inducing chemical compounds (Ionescu *et al.*, 2017). Among these, phytohormones and their synthetic compounds have long been used in the horticultural industry (Lee *et al.*, 2021), and have important application in the regulation of orchid flowering. Of these, cytokinins (CKs) and gibberellins (GAs) are of the most important, with possible effects, depending on the species, on flower induction and flower stalk elongation, as well as on time to flowering (Ahmad *et al.*, 2022; Yin *et al.*, 2022). Blanchard and Runkle (2008) reported shortening the time to visible flower

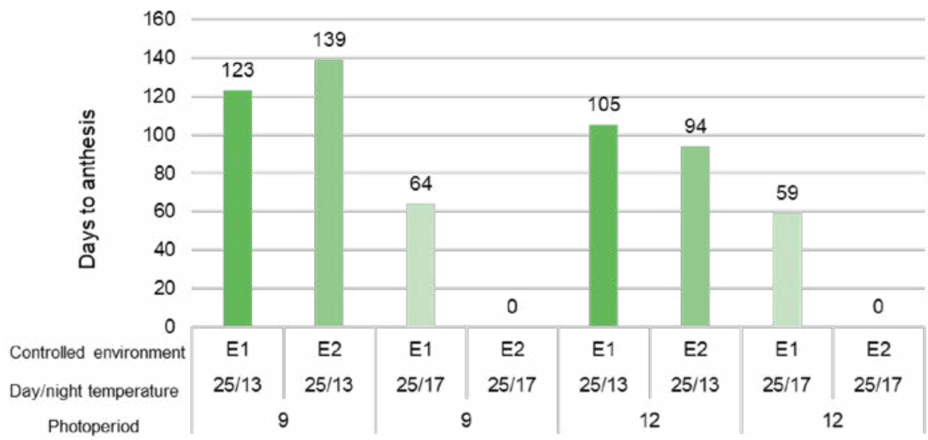

Figure 2. Days to anthesis of *Laelia anceps* under the influence of two controlled environments (E) of light and temperature: E1) fluorescent + metal additive + high pressure sodium; E2) light emitting diode (LED), red/blue.

induction from 2 to 6 days in *Phalaenopsis*, using GA_3 and BA. Similarly, Nambiar *et al.* (2012) found that BAP promoted earlier flowering in *Dendrobium* hybrid (Dendrobium Angel White). In a study to evaluate exogenous application of gibberellic acid (GA_3) and 6-benzylaminopurine (BAP) in *Phalaenopsis*, cytokinins were associated with rupture of axillary vegetative meristems and inflorescence, but exogenous GA_3 spraying did not improve inflorescence initiation (Lee *et al.*, 2021). Yin *et al.* (2022) found that exogenous application of gibberellin (GA_3) promoted flowering of *Paphiopedilum callosum* by inducing early bud break. At different doses of BA and GA_3 we have found that the higher the concentration of BA, the fewer days to visible inflorescence. On the contrary, both days to visible inflorescence and days to anthesis increase with higher GA_3 concentration (Figure 3).

Likewise, in a study of three flowering cycles, Tejeda-Sartorius *et al.* (2021) reported that different doses of GA_3 and BA reduced days to visible flower induction and days to anthesis of *L. anceps*. The reduction of the complete flowering cycle was between 3 to 4 months, which is a very considerable time given the long flowering cycle of the species. Positive correlations have been observed between flower spike length and time to anthesis, as well as higher flower spike strength, among other characteristics of flower development (higher number of flower spikes and flowers), compared to the control (Figura 4).

Other regulators are also being tested, such as paclobutrazol (PBZ), a plant growth regulator with gibberellin inhibitor function (Desta and Amare, 2021), which is showing that when PBZ is sprayed on different sized stalks, the smallest ones (between 5 and 15 cm) accelerate their flowering, being very similar to that of stalks larger than 30 cm. This means that flowering is advanced, with reduction in the length of the flowering stalk (unpublished data).

Nutrition management in time to flowering

Inorganic nutrition. The nutritional management of orchids is more complicated than any other agri/horticultural crop, especially in epiphytic orchids, because of the nutrient and water scarcity conditions to which they are often exposed (Biswas *et al.*, 2021). To face

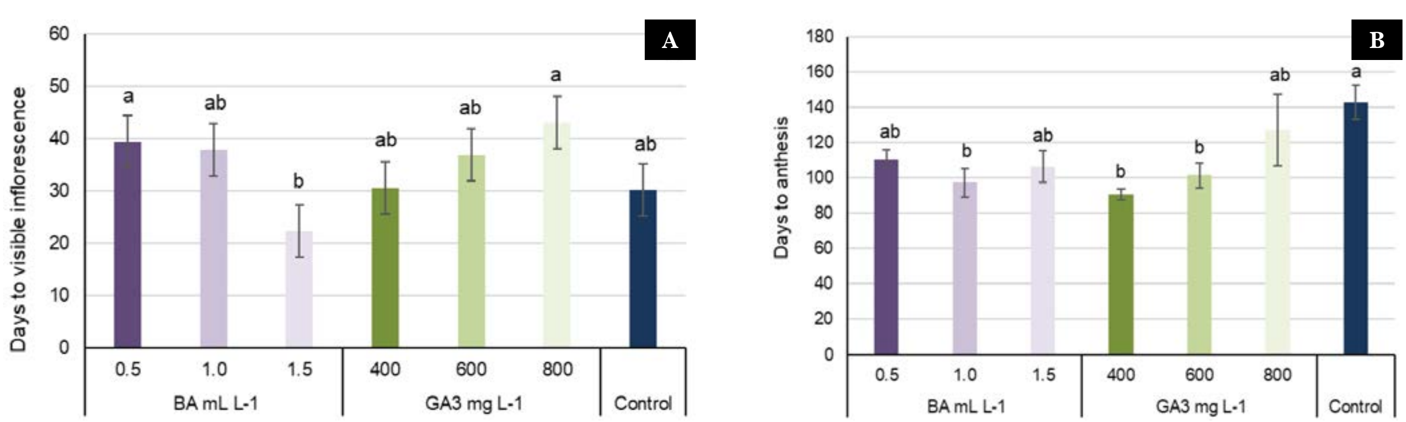

Figure 3. Days to visible inflorescence (A) and anthesis (B) of *Laelia anceps* with different concentrations of benzyladenine (BA) and gibberellic acid (AG_3). Means $\pm$ SD with different letters indicate statistical differences between treatments (Tukey, $P \leq 0.05$). Control without plant growth regulators.

Figure 4. Flowering of *Laelia anceps* treated with next doses of plant growth regulators (PGRs) (mg L^{-1}): A) 19 BA; B) 600 AG_3; C) 2.37 BA + 100 AG_3; D) Control plants were sprayed with distilled water and without spraying PGRs. The dose BA + GA_3 (C) showed the greatest reduction in the time to anthesis, *i.e.*, 44 days earlier than the control (D). However, the other treatments also reduced the time (21 days mean) *vs*. the control. Furthermore, both the number of flowering spikes and the number of flowers in A, B and C are noteworthy in relation to the control (D) Source: Data from Tejeda-Sartorius *et al.* (2021).

adverse environmental conditions, orchids have developed highly specialized mechanisms, such as the root velamen, which can absorb water and nutrients quickly and retain them to reduce losses (Zots & Winkler *et al.*, 2013). Research related to mineral fertilisation in orchids is scarce, but orchids are considered to have nutritional requirements like other species (Ichinose *et al.*, 2018; Biswas *et al.*, 2021). Thus, nitrogen nutrition is an essential practice for orchid cultivation (Mantovani *et al.*, 2018) and can help growers to produce orchids more efficiently (Zong-min *et al.*, 2012). But growers generally use mineral nutrition based on other agricultural crops, without considering the specific nutritional needs of each species (Costa *et al.*, 2024). Mineral fertilization, together with substrate mixtures, are very important for vegetative growth to have quality blooms. For *L. anceps*, we obtained early inflorescence emergence in substrates with pine bark (PB) and 200 mg L^{-1} N, or when PB was combined with other substrates. Likewise, there is considerable decrease in the time to inflorescence when lower proportions of PB are present in the mixture (50%) in relation to peat moss (PM) or coconut fibre (CF) (Cuadro 1).

Wang (2007) showed that *Phalaenopsis* Taisuco Kochdian plants treated with 200 mg L^{-1} of N and P, but with low doses of K (50 and 100 mg L^{-1}) in substrate with only pine bark, advanced their flowering, approximately by 15 days, compared to plants grown with moss. Themselves, Zong-min *et al.* (2012) reported that *Paphiopedilum armeniacum* with a high dose of N (420 mg L^{-1}) decreased the time to flowering by five days compared to the lower dose (105 mg L^{-1}), and 8 days when no N was applied. Satari *et al.* (2022) observed no difference in time to first flower opening of *Phalaenopsis*, with application of various NPK formulations (19-6-20, 12-12-36, 20-20-20), where the range of days to anthesis was 278 to 282 days. Ruamrungsri *et al.* (2021) found a positive correlation between K concentration and days to flower opening of Vanda 'Manuvadee'. Tsai and Chang (2022) found no positive linear correlation between C/N ratio and days to inflorescence, or days to first visible bud or first anthesis. For *Laelia anceps* we have found a decrease in time to

Table 1. Interaction of study factors on days to visible flower induction of *Laelia anceps*, by effect of different substrate blends, proportion of pine bark in the substrate and nitrogen levels.

Substrate	**N Fertilisation ($mg\ L^{-1}$)**	**Days to visible flower induction**
PB+P	100	101.3 a
PB+P	200	65.9 b
PB+PM	100	77.8 b
PB+PM	200	77.9 b
PB+CF	100	39.1 c
PB+CF	200	26.9 c
Proportion of CP in substrate (%)		
75	100	142.8 a
75	200	105.3 ab
50	100	25.6 c
50	200	22.8 c
25	100	49.8 bc
25	200	42.7 bc

Means with different letters in the column are statistically different (Tukey, 0.05). PB: pine bark; PM: peat moss; CF: coconut fibre.

flowering (up to 50 days) or earlier flowering (in June-July) or outside the normal flowering season (October-November) with an NPK fertilisation programme: high N application in vegetative phase, with a change to high P and K application in flowering inductive stages.

Organic nutrition. There are specific organic orchid fertilisers on the market, some of which greatly stimulate rooting and vegetative growth (Rodrigues *et al.*, 2010), but there is little research on the use of organic fertilizers or biofertilizers for orchid growth and flowering (Tejeda-Sartorius *et al.*, 2013). Some authors have tested these products, with better results when combining mineral and organic fertilization (Rodrigues *et al.*, 2010; Tejeda-Sartorius *et al.*, 2018; Biswas *et al.*, 2021) or when applied separately (Tejeda-Sartorius *et al.*, 2013). Significant effects on physiological parameters during the vegetative growth phase of some orchids have been found (Tejeda-Sartorius *et al.*, 2018; Hoshino *et al.*, 2021), and the positive effects could be observed later in the flowering time and reproductive stage of these species.

There are reports of other products considered as biostimulants, explicitly defined as "substances or micro-organisms applied on plants in order to improve nutritional efficiency, abiotic stress, regardless of their nutrient content" (du Jardin, 2015). These include humic and fulvic acids, seaweed extracts, beneficial fungi and bacteria, composts and humus-derived substances, etc. (du Jardin, 2015; Bose y Pal, 2023), of which positive effects on orchid growth and flowering have been reported (Biswas *et al.*, 2021). Some biofertilisations based on different concentrations of vermicompost leachates were tested, and we found that the lowest concentration can decrease the time to anthesis of *L. anceps* (according to some of our studies), (Figure 5).

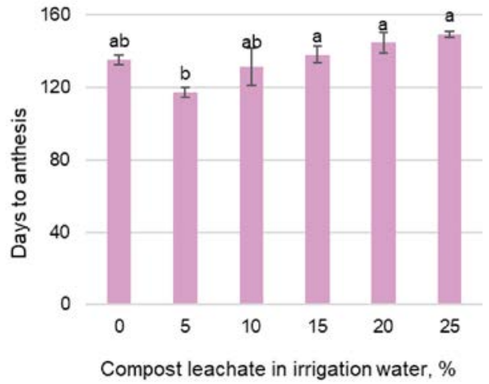

Figure 5. Days to first flower anthesis of *Laelia anceps* with different concentrations of vermicompost leachates. Means ± SD with different letters indicate statistical differences (LSD at 5%).

Several countries are working on their native orchid-flora for ornamental purposes, from the characterization of their plants and blooms to the management of commercial crops and the generation of hybrids, which requires several years of observation and waiting for results but ensuring the intellectual property of their orchid-derived floricultural products. It is also necessary that these products meet the demands of sustainability in production, established by the commercial chain and society (carbon footprint, specialty crops, etc.) Therefore, research on environmental management and inputs will continue to be essential, both for the control of time to flowering and other morpho-floral traits, since flowering behavior is species-dependent. Thus, research for the appropriate use of environmentally friendly inputs, such as biofertilizers, biostimulants, plant growth regulators, environmental management combined with clean energies, among others, must increase to effectively and sustainably complement traditional production systems.

CONCLUSIONS

The long juvenile periods of orchids will continue to be a challenge for both researcher and grower. The data presented in this review show that it is feasible to reduce the time to flowering of ornamental orchids by using different types of environmental controls and inputs, among which nutrition and plant growth regulators are of particular importance. A major challenge is attempting a better understanding of how these factors interact. Although molecular advances aimed at improving commercial flowering traits to overcome the adverse effect of time to flowering, only a few orchid genera and species have been able to achieve this goal. However, further exploration of native species is also essential to increase the diversity of floricultural products in countries with less access to biotechnological advances.

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