Moderate variations of day/night temperatures affect flower induction and inflorescence development in *Phalaenopsis*

Roberta Paradiso*, Albino Maggio, Stefania De Pascale

Department of Agricultural Engineering and Agronomy, University of Naples Federico II, Via Università, 100, 80055 Portici, Naples, Italy

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ABSTRACT

We studied the effect of day/night thermal regimes on flower induction and development in *Phalaenopsis*. The experiment was carried out in Naples in heated glasshouse. Two day/night thermal treatments, 23/21 °C and 19/17 °C, were compared to the standard 21/19 °C recommended regime. The 60-day thermal regimes did not significantly modify the leaf number and final expansion. However, temperature affected the time for the appearance of the flower stem and the subsequent process of flowering. Under the standard regime, flower buds appeared 127 days after the beginning of the treatment and anthesis was completed in 70 days. At higher temperatures, flowering occurred earlier and flower development was faster. In contrast, these two parameters did not change under lower thermal regime. The two thermal treatments under assessment reduced stem and inflorescence length and number of flowers respect to the standard regime. However, lower temperatures promoted the flower stem branching and increased the percentage of plants with two flower stems.

1. Introduction

Commercial production of *Phalaenopsis* orchids has increased considerably in the last decade (Wang and Lee, 1994). *Phalaenopsis* originates from tropical and subtropical areas of the South Pacific Islands and Asia. In its native *habitat*, temperatures range throughout the year from 28 to 35 °C during the day and from 20 to 24 °C at night (Pridgeon, 2000). These temperatures differ from typical climatic conditions of Mediterranean areas where this species is nowadays largely cultivated (Lopez et al., 2007). In terms of light requirements, *Phalaenopsis* is considered a non-photoperiodic plant (Li et al., 2006) although some varieties or hybrids prefer short days (Sakanishi et al., 1980).

The juvenile phase is relatively long in this species and greatly varies among varieties and hybrids (between 12 and 24 months from transplanting of young micropropagated plants) (Goh et al., 1982; Lopez and Runkle, 2005). Consistent with this variability, the optimal growth stage to induce flowering in greenhouse cultivation also varies from 5 to 7 fully expanded leaves per plant (with a leaf length from 15 to 25 cm) (Blanchard et al., 2007).

Temperature is a critical environmental factor affecting plant phenology. Temperatures constantly higher than 26 °C promote the vegetative growth (i.e. juvenile phase) and inhibit flower induction; conversely, a lower thermal regime is required for flowering

(i.e. flower transition and subsequent inflorescence development) (Lopez et al., 2007). Therefore reference day/night (D/N) thermal levels for greenhouse cultivation in Italy are 28/26 °C (or higher) for the vegetative growth, for 12–24 months (depending on the hybrid); 21/19 °C for flower induction, for 30–60 days; 23/21 °C for inflorescence development, or finishing phase, for 100–150 days (with shorter time for potted plants, sold after the first flowers anthesis, and longer time for cut stems, sold at the complete anthesis of the inflorescence). Reduction of temperatures below 26 °C, especially during the day, can induce flowering in immature plants (Lopez et al., 2007). Chilling injuries have been reported below 10 °C and under large or rapid temperature fluctuations (Curry, 1975). However, it has been demonstrated that cooler night temperatures in the vegetative phase do not induce flowering, when the day temperature is sufficiently high (Blanchard and Runkle, 2006). Moreover, floral transition does not necessarily require day/night fluctuation in some hybrids (Blanchard and Runkle, 2006).

Due to the high thermal requirements, greenhouse heating is one of the main costs for *Phalaenopsis* production in Mediterranean areas (Pollet et al., 2011). Data on the effects of inductive temperatures on flowering earliness and characteristics are very limited (Sakanishi et al., 1980; Blanchard and Runkle, 2006). In some *old* selections, such as 'Brother Goldsmith' and 'Miva Smartissimo × Canberra', increasing temperatures from 14 to 25 °C anticipate flowering and increase the percentage of flowering plants, but they reduce the number of flowers per inflorescence (Blanchard and Runkle, 2006). However, for modern varieties and intra-/inter-species hybrids with very different genetic

* Corresponding author. Tel.: +39 081 2539135; fax: +39 081 2539152.
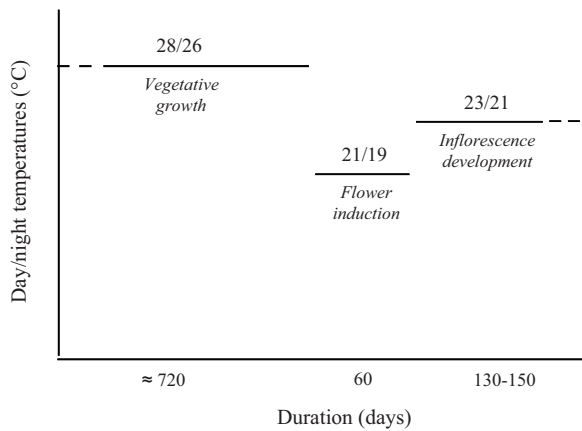*E-mail address:* roberta.paradiso@unina.it (R. Paradiso).

Fig. 1. Reference day/night temperatures and duration of the different phonological phases in greenhouse cultivation of *Phalaenopsis* 'Premium' in Italy.

	Set point	Actual values
RT	21/19	21.1/18.4
HT	23/21	23.1/21.1
LT	19/17	19.5/16.3
Flowering compartment	23/21	23.4/21.3

backgrounds (and presumably different environmental requirements for growth and flowering), the specific requirements are not known. A better understanding of flowering responses to temperatures is critical to optimize both production scheduling and heating strategies. In addition, information on the effects of temperature on the commercial plant quality may help growers to decide when "timing" is more important than "quality" to target specific market needs. In this experiment, we aimed at assessing whether moderate variations of temperature, a 2-degree increase or decrease, with respect to the standard cultivation regime, would affect flowering and production in pot-grown *Phalaenopsis* 'Premium', one of the most common hybrids in Europe for both cut flowering stems and potted plants production.

2. Materials and methods

2.1. Plant material, growth conditions and thermal treatments

The experiment was carried out in Naples (40°51′N, 14°22′E), in a commercial heated glasshouse, on *Phalaenopsis* hybrid 'Premium' (white flowers). Two-year plants were grown in 12 cm transparent plastic pots, on a mixture of bark (95%) and sphagnum (5%) on mobile benches, at a density of 48 plants/m².

Reference D/N thermal regimes adopted in the commercial practice for this hybrid are: 28/26 °C for vegetative growth (for approximately 24 months), 21/19 °C for flower induction (for 60 days), 23/21 °C for inflorescence development (for approximately 130 days and 150 days for flowering potted plants and cut flowering stems, respectively) (Fig. 1). Three thermal regimes, with slightly different day/night values, were compared during the 60-day phase of flower induction (from December 28 to February 28): 21/19 °C (RT), the thermal regime commonly adopted by growers taken as the reference temperature; 23/21 °C (moderately higher temperature, HT); 19/17 °C (moderately lower temperature, LT).

Thermal regimes were applied in greenhouse compartments, under natural day length, at the growth stage considered optimal for flowering (7 leaves/plant, corresponding to a leaf area of approximately 580 cm²/plant). At the end of the inductive treatments, all plants were moved to the flowering compartment (set points 23/21 °C), until the complete inflorescence development (commercial maturity for cut flower stems). All the compartments were heated via basal heating (hot water system). High temperature and low relative humidity were controlled during the spring and the summer by a cooling system (RH set point 70%) and by whitewashing the greenhouse roof (starting from April) to reduce the light intensity at the canopy level below the maximum level suggested for *Phalaenopsis* (200 μmol m⁻² s⁻¹).

Temperature and relative humidity in the greenhouse were recorded at hourly intervals with data loggers Tinytag Ultra 2 (Gemini Data Loggers Ltd., Chichester, West Sussex, UK). Actual and target values of the average air temperature for the inductive regimes and the flowering compartment are reported in Table 1. Light intensity in the greenhouse was recorded with a Delta OHM multifunction meter DO-9847 (Delta Ohm, Padova, Italy). The daily values measured during the experiment varied from 2.98 mol m⁻² d⁻¹, in cloudy days from January to March, to 46.17 mol m⁻² d⁻¹ in sunny days from the beginning of June to the end of July.

Plants were irrigated via a drip system (1 dripper per pot; 2 L/h), with reverse osmosis water (electrical conductivity, EC = 70 μS/cm at 25 °C), each pulse lasted 3 min and the number of pulses during the 7 months of experiment varied from 1 per week (from the end of December to the end of February) to 2 per week (from the beginning of March to the end of July). Fertigation was provided at 15-day intervals, pH and EC of the nutrient solution were kept at 6.5 and 1200 μS/cm, respectively; the N:P:K ratio was 1:0.5:1 as suggested by the technical literature (Anthura, 2007). Plants were supported with sticks and were cultivated according to common practice.

2.2. Measurements and data handling

At the beginning and at the end of the experiment, 5 plants per thermal regime were collected to measure the number of leaves, the leaf dimensions (length and width) and the mean single-leaf and total leaf area, with a LICOR 3000 Area-meter.

Flowering time was measured as days from the beginning of the inductive thermal treatment (DBT) to: (1) the emergence of the stem; (2) the appearance of the first visible flower bud; (3) the first flower anthesis (beginning of flowering, corresponding to the commercial maturity for potted plants); (4) the complete anthesis of the inflorescence (commercial maturity for cut stems) (Fig. 2).

Every 7 days, the stem elongation was measured on 10 plants per treatment. The logistic function of the Verhulst model (Verhulst, 1838; Yin et al., 2003) was chosen to fit the stem elongation data:

$$L = \frac{L_{max}}{1 + e^{-k(t-t_m)}}, \tag{1}$$

where L is the stem length (cm), t is the time, as days from the beginning of thermal treatment, t_m is the inflection point at which the growth rate reaches its maximum value, L_{max} is the maximum stem length and k is the growth rate that determines the curvature of the growth function. The values of the three parameters were calculated by an iterative programming procedure based on least-squares curve fitting and are reported in Table 2. The rate of stem elongation was calculated from the stem elongation data as first order derivative.

Flower stem characteristics (stem and inflorescence length, stem diameter, number of internodes, number and dimensions of flowers) were measured on 10 plants per treatment. Stem diameter and flower width and length were measured by using a digital