Scientia Horticulturae 130 (2011) 869–873

Contents lists available at SciVerse ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Deferring flowering of nobile dendrobium hybrids by holding plants under low temperature after vernalization

Min Lin[a], Terri W. Starman[a,*], Yin-Tung Wang[b], Genhua Niu[c], J. Tom Cothren[d]

[a] Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843-2133, USA
[b] Matsui Nursery, 1645 Old Stage Road, Salinas, CA 93908, USA
[c] Texas AgriLife Research at El Paso, Texas A&M University, El Paso, TX 79927, USA
[d] Department of Soil and Crop Science, Texas A&M University, College Station, TX 77843-2474, USA

ARTICLE INFO

Article history:
Received 6 April 2011
Received in revised form 25 July 2011
Accepted 22 August 2011

Keywords:
Orchid
Dendrobium nobile
Flowering control
Vernalization

ABSTRACT

Orchids are currently the most valuable potted crop in the United States. To date, no studies focused on making possible the year-round greenhouse production of flowering nobile dendrobium orchids. This experiment was aimed at developing a strategy to defer flowering of nobile dendrobium orchids by holding them under low temperature. Mature *Den.* Red Emperor 'Prince' and *Den.* Sea Mary 'Snow King' were held at 10 °C for various durations (0, 4, 8, 12 or 16 weeks) after vernalization (4 weeks at 10 °C). Plants were forced in a greenhouse after holding. Time to flower, flower differentiation (flowering node percentage, number of aerial shoot and aborted bud) and flower quality (total flower number, flower diameter, flower number per flowering node and flower longevity) were determined. Increase of low temperature holding duration from 0 to 16 weeks extended time to flower up to 3 months and did not affect parameters of flower except producing larger flowers and reducing flower number per flowering node for *Den.* Red Emperor 'Prince'. Notably, the flower longevity was not adversely affected. Defoliation was aggravated in *Den.* Red Emperor 'Prince' by longer duration of cooling and was considered a detrimental effect of low temperature holding.

1. Introduction

In 2009, the U.S. Department of Agriculture (USDA) reported that 19.5 million potted orchids, with a total wholesale value of $160 million, were sold and orchids have become the most valued flowering potted crop in the United States (USDA, 2010). In the same year, the pot number of sold *Phalaenopsis* was 100 million for Europe, 20 million for Japan, and 10 million for China (Yuan, 2011). Taiwan produced more than 70 million pots of *Phalaenopsis* annually and exported orchids valued at nearly $87 million in 2009 (Lai, 2010). An estimated 85–90% of the potted orchids sold in the United States are *Phalaenopsis* and related genera (Nash, 2003). Commercial growers are now looking for other orchids that have consumer appeal and can be grown and sold in mass markets.

The nobile dendrobium has been grown for many years in the history of orchid cultivation. Its commercial production around the world has much increased in recent years (Wang and Starman, 2008). The outstanding characteristic of this orchid is that the bright and lightly fragrant flowers are produced on each node of the pseudobulb and they nearly open simultaneously. The native *Dendrobium nobile* blooms after passing the winter drought and experiencing the low temperature in its natural habitat (SOC, 2009). *Dendrobium* Sea Mary 'Snow King' needs to be subjected to a specific amount of cooling for flowering (Yen et al., 2008). Lin et al. (2011) found that 2 weeks of 10 °C satisfied the vernalization requirement for *Den.* Sea Mary 'Snow King' and *Den.* Love Memory 'Fizz'; however, at least 4 weeks of 10 °C cooling was needed for *Den.* Red Emperor 'Prince' to flower best.

The ordinary prime blooming period of most nobile dendrobium hybrids is from February to March. However, plants to be sold for Mother's Day must start to bloom no earlier than late April for safe shipping (Wang, 1998). As a consequence, growers are looking for ways to produce quality, blooming nobile dendrobium from May through July for the Mother's Day and summer markets.

Several approaches have been used for delaying flowering in orchid species, but little information is available for nobile dendrobium. For species that require low temperatures for flower induction (vernalization), one way to defer flowering is to expose plants to high temperatures. Heating the greenhouse to ≥28 °C can keep *Phalaenopsis* from spiking (Sinoda, 1994). However, in temperate climates, this is an expensive cultural practice because of the large energy input. Since spiking induction of *Phalaenopsis* is light dependent, an inexpensive alternative for inhibiting spiking in *Phalaenopsis* is to alternate 5 d of heavy shading (darkness) with

* Corresponding author. Tel.: +1 979 862 2910; fax: +1 979 845 0627.
E-mail address: tstarman@tamu.edu (T.W. Starman).

0304-4238/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.scienta.2011.08.027

2 d of light (Wang, 1998; Wang et al., 2006) on weekly cycles. Different from *Phalaenopsis*, light does not affect flower induction of three dendrobium nobile hybrids (Lin et al., 2011), so darkness may not be an alternative to heating for flowering control of the nobile dendrobium.

Another strategy to defer flowering of vernalization requiring plants in temperate climates is to hold plants under low temperature to slow the growth and development process. Tulip (*Tulipa gesneriaana*) growers in the Netherlands schedule planting that is followed by freezing and subsequent thawing of tulip bulbs to extend the forcing period and lead to year-round tulip production (Roh, 1990). Easter lilies (*Lilium longiflorum*) at the "puffy white" bud stage can be kept in dark coolers at 1–4 °C for up to 1 week to delay flower development without adverse effects (Kessler, 2001). Increasing vernalization duration (up to 8 weeks) deferred flowering of three nobile dendrobium hybrids (Lin et al., 2011; Yen et al., 2008).

However, adverse impacts on plant quality could occur with long periods of cooling. More than 1 week of cooling during the "puffy white" bud stage increased foliar chlorosis and decreased postharvest flower longevity of Easter lilies (Prince et al., 1987; Staby and Erwin, 1977). After flower initiation of Asiatic hybrid lilies, the number of blasted primary and aborted secondary and tertiary buds increased as the bulb freezing duration increased (Roh, 1990). Low day temperatures caused leaf yellowing, defoliation and reduction of growth rate on *Den*. Snowflake 'Red Star' (Sinoda et al., 1984, 1985).

The objective of this experiment was to develop a strategy to defer flowering of nobile dendrobium by holding them under low temperature after vernalization and to determine whether long duration of holding at low temperature would negatively impact flower quality.

2. Materials and methods

2.1. Plant materials and growing conditions

Mature plants of two cultivars (the diploid *Den*. Sea Mary 'Snow King' and tetraploid *Den*. Red Emperor 'Prince') with an average of 14 and 11 total nodes, respectively, and potted in standard green plastic pots (10.2 cm top diameter, 414 mL vol.), were shipped from Matsui Nursery in Salinas, CA. Plants arrived at Texas A&M University, College Station on 12 September 2008 and were immediately placed in a greenhouse having glass walls and a polycarbonate roof. The root substrate consisted of nine parts of bark mix (95% pine bark and 5% ground sphagnum moss, Bas Van Buuren B.V., De Lier, The Netherlands) to one part long fiber peat (Pindstrup Mosebrug A/S, Ryomgaard, Denmark).

Plants were irrigated with reverse osmosis (RO) water and spaced in every other hole in 30.8 × 51.4-cm molded polypropylene carrying trays [4.00 Transport Tray (15); Landmark Plastic Corporation, Akron, OH] on the greenhouse bench with leaves orienting east and west to best capture the sunlight. To maintain a single pseudobulb per pot, all undesirable secondary shoots were removed when emerged.

Greenhouse irradiance and air temperature at plant canopy level were recorded every 30 min with a Quantum Light 3 Sensor Bar (Spectrum Technologies, Plainfield, IL) and a WatchDog Data Logger Model 450 (Spectrum Technologies). Plants were grown in a warm greenhouse (Fig. 1) with mean daily temperature ranging from 20 to 25 °C and a mean photosynthetic daily light integral (DLI) of 9.5 mol m^{-2} d^{-1} (Fig. 1). The automatic thermal screen system was set to be pulled as needed to control the light level and prevent severe temperature increase in the greenhouse. Pots were irrigated every fourth watering with a nutrient solution

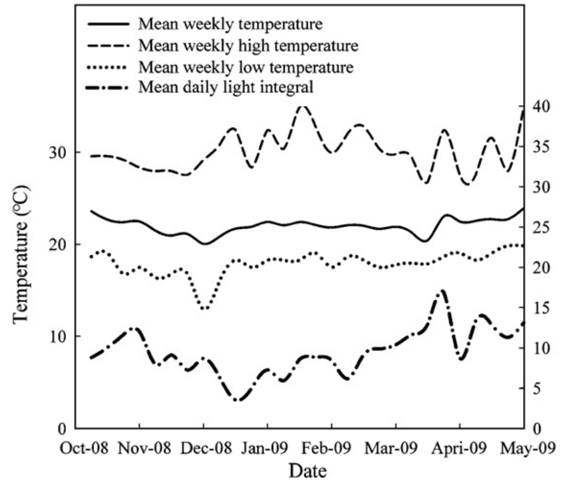

Fig. 1. Mean weekly air temperature and photosynthetic daily light integral (DLI) in the greenhouse throughout the experimental period (from October, 2008 to May, 2009) in College Station, TX, USA.

made with RO water and a 15N–2.2P–12.5 K (Peters Excel 15-5-15 Cal-Mag; Scotts, Marysville, OH) water-soluble fertilizer at 0.33 g/L. Pesticides azoxystrobin (Heritage, Syngenta Crop Protection, Greensboro, NC) and chlorfenapyr (Pylon, OHP, Mainland, PA) were applied when necessary to control fungus and spider mites, respectively.

On 15 September 2008, vernalization commenced by placing plants in a growth chamber with mean air temperature of 10.0 ± 0.2 °C and mean relative humidity of 75% for 4 weeks. The growth chamber had a 12-h photoperiod of 300–350 μmol m^{-2} s^{-1} *PPF* (13–15 mol m^{-2} d^{-1} of photosynthetic photons) provided by both fluorescent and incandescent lamps. Following vernalization, cooling with five durations (0, 4, 8, 12 or 16 weeks) was conducted in the same growth chamber. Plants were moved back to the greenhouse after the completion of each cooling treatment. A completely randomized design with 10 single plant replicates for each treatment was used.

2.2. Data collection

Time to flower (when the first flower bud opened); flowering node percentage (flowering node number/total nodes); number of aerial shoots, aborted buds, and total flowers; flower diameter (mean diameter of the three largest flowers); flower number per flowering node; time to full flower (duration from the first flower bud opened until all flowers on the pseudobulb opened); flower longevity (duration from the first flower bud opened until this flower wilted); and remaining leaf percentage were recorded. Time to flower was presented from the beginning and the end of the low temperature treatment after vernalization.

2.3. Statistical analysis

All data were first tested on additivity and normal distribution, and then subjected to analysis by GLM and Duncan's multiple range tests for comparing the treatment means, all at $P \leq 0.05$. Statistical analysis was performed by SAS 9.2 statistical software (SAS Institute, Cary, NC). The correlation between time to flower and low temperature holding duration, and the correlation between remaining leaf percentage and low temperature holding duration were investigated by linear regression. Differences of two lines were analyzed using GLM procedure by comparing the slopes and intercepts.