Innovative Production Systems for Ornamental Potted Plants: a Case Study for *Phalaenopsis* Orchids

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Abstract

Flowering *Phalaenopsis* orchids and related genera are one of the most valuable potted floriculture crops produced throughout the world. Successful production of high quality finish plants requires young plants that are consistently uniform, reliably available, and free of pathogens including viruses. To facilitate the entry of roots into the growing media, young plants are transplanted into translucent plastic pots that contain a well-drained media consisting of bark, coconut chunks, or sphagnum peat. *Phalaenopsis* are grown at a temperature ≥ 28°C to inhibit flowering and promote rapid leaf development. Once plants are mature and have attained a desirable size for their container, plants are transferred to a separate growing environment with a temperature between 18 and 25°C to induce flowering. During both production stages, the maximum light intensity available to plants is controlled to ≈ 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$. To reliably provide an inductive temperature, some growers located in tropical and subtropical climates transport plants to cooler locations (e.g., a greenhouse at a higher elevation) while more modern operations provide air conditioning inside the greenhouse. Sophisticated commercial orchid producers rely on automation to quantify the size and then sort young plants, to transport plants to different growing environments and staging areas, and to provide fertigation. In addition, light intensity and temperature are controlled by environmental computers that control multiple layers of retractable curtains, supplemental lighting, and staged venting and heating systems. However, there are two production processes that have not yet been fully automated: the transplanting of young plants and the staking of inflorescences. Growers in the Netherlands have the most sophisticated production facilities with the lowest labor inputs; it is estimated that each plant is cumulatively handled less than one minute from the time plants are removed from flasks as tissue-cultured propagules until they are flowering and are placed on carts for transport to market.

INTRODUCTION

Phalaenopsis, *Doritaenopsis*, and their related species and hybrids (subsequently referred to only as phalaenopsis orchids) are among the most valuable potted flowering plants produced throughout the world. Phalaenopsis have numerous desirable consumer attributes including long-lasting flowers (>8 weeks is common), an exotic and stylish plant architecture, and a variety of flower colors and patterns (Runkle et al., 2005). From a production standpoint, a long period of time (22 to 28 months) is required to propagate and produce a marketable flowering plant (Blanchard et al., 2005). To minimize production expenses, plants are increasingly being produced in greenhouse factories, during which plants are provided with precisely controlled environmental conditions for rapid plant development and high quality attributes.

The production of phalaenopsis can be divided into four phases: the propagation phase, two vegetative phases, and the flowering phase. During the propagation phase, plants are most commonly produced as clones from meristems (mericlones) using tissue culture, although some companies continue to raise seedlings. The mericlone process typically takes 10 to 12 months and is performed by breeding companies throughout the world, but especially in Germany, the Netherlands, Taiwan, and Thailand. The first vegetative phase begins at the end of the tissue culture process. Young plants are usually transplanted into community trays or plug trays and are grown at warm temperatures (>28°C) to promote leaf development and inhibit flowering. During the second vegetative phase, plants are transplanted into their finish containers, usually between 10 and 13 cm in diameter. To obtain a larger, higher quality finish plant, plants may be transplanted from 8 or 10 cm pots to a 15-cm pot, and thus some growers have three vegetative phases. Once plants reach a desirable size, they are usually transported to a separate growing environment for the final production phase for flower initiation and development.

This paper describes the overall commercial production process of phalaenopsis orchids beginning from the first vegetative phase until flowers open, with an emphasis on managing the aerial environment. In addition, personal experiences at phalaenopsis production facilities in North America, Europe, and Asia have been incorporated. Implementation of research-based information combined with grower experiences have made the production of phalaenopsis orchids one of the most technically advanced and profitable crops in floriculture. Many of the innovative production techniques used to produce potted phalaenopsis orchids can conceptually be applied to other floriculture crops produced in mass.

VEGETATIVE PHASE I

The vegetative phase begins when young plants are removed from their tissue culture flasks and are transplanted into community trays or plug trays. In the Netherlands, many growers transplant 40 to 50 plants from flasks into 1300 to 1500 cm^2 square or slightly rectangular community trays. In Taiwan, many growers transplant young plants into every other cell of a 128-cell plug tray (1300 cm^2). Plants are manually removed from their flasks and are transplanted; this is one of the few production processes that has not yet been automated. Plants are grown in various media depending on the characteristics of the tray, environmental conditions, costs, and grower preference. In tropical and subtropical climates, sphagnum moss is the most common media used in plug trays during the first vegetative phase. In contrast, growers in temperate regions such as the Netherlands use a well-drained bark-based media in their community trays.

Phalaenopsis orchids remain vegetative when grown at 27ºC or higher (Sakanishi et al., 1980). In particular, a 12-h day temperature above 29ºC inhibits flowering even when the night temperature is as low as 17ºC (Blanchard and Runkle, 2006). However, because the rate of plant development decreases as the average daily temperature decreases, commercial growers use a high temperature during the day and the night to promote rapid leaf development. The photosynthetic photon flux (PPF) is usually controlled to a maximum of 300 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$ to avoid leaf scorch. Plants grown under higher light intensities have smaller leaves and can have a purplish appearance (Blanchard and Runkle, 2005). During the first 4 to 8 weeks after transplant, the recommended maximum light intensity is 75 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$ to acclimate plants to the greenhouse environment (van der Knaap et al., 2005).

Light is controlled using a variety of shading systems depending on their location and structure. In tropical climates and in regions with little or no snow, some producers have installed automated external shade curtain systems. A curtain system outside of the greenhouse structure is desirable because it reflects solar energy before it enters the greenhouse and thus can create a cooler interior environment than curtain systems located inside the greenhouse (Heins and Runkle, 2004). Many large-scale commercial phalaenopsis growers also utilize one or several interior curtain systems that usually contain aluminized strips to reflect the solar energy. Phalaenopsis growers using less sophisticated structures rely on whitewash that is applied to the exterior side of the glazing. The primary disadvantage of whitewash is that the PPF may be undesirably low during cloudy periods.

In temperate regions, growers are increasingly using thermal blankets, which are automatically deployed in the evening and retracted in the morning. Thermal blankets provide an additional layer of insulation, which reduces structural heat loss, and provide a warmer "sky" temperature so that plants lose less heat to the otherwise cold glazing. Consequently, energy consumption for heating is reduced and plant temperature is warmer during cold nights (Bartok, 2001). When heating systems are used, some growers use a misting system to increase the relative humidity to approximately 50% to 60%.

Supplemental photosynthetic lighting is used by some phalaenopsis producers located in temperate climates, particularly in northern Europe. During the winter, the PPF may be too low to produce a high quality young plant. The addition of 50 to 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of light from high-pressure sodium lamps can increase leaf thickness, decrease leaf size, increase plant temperature, and promote greater root growth of phalaenopsis (Konow and Wang, 2001). In addition, media dries faster when plants are provided with supplemental light, which helps avoid excessively moist media that is conducive to root rot and pathogen invasion. Lamps are typically operated for a maximum of 16 hours per day so that an adequate period of darkness is provided for crassulacean acid metabolism photosynthesis (van der Knaap et al., 2005). In addition, some growers enrich the environment with carbon dioxide at 600 to 800 $\mu mol \cdot mol^{-1}$ when ventilation is minimal.

VEGETATIVE PHASE II

After approximately 18 to 24 weeks of growth in plug or community trays, plants are most commonly transplanted into 10 to 13 cm translucent plastic pots (Table 1). Plants grown in translucent pots have fewer roots outside of the container compared to opaque pots because phalaenopsis roots avoid darkness (Blanchard and Runkle, in press). The transplant process is partially automated in some greenhouse operations particularly in northern Europe. Growers place empty pots into round slots of a rotating disc. Plants are manually removed from community trays and are held at the desired level inside the pot. Media is delivered by a conveyer belt and falls into the pots while a person compresses the media around the roots. The media is compressed just to the point that the plant can be picked up by its leaves while remaining intact in the pot. Plants are then placed on a conveyor belt and are automatically placed on greenhouse benches.

The environmental conditions provided during the second vegetative stage are similar to that described during the first stage. Plants are usually grown pot-to-pot, at least initially. Some growers will provide wider plant spacing once the leaves of adjacent plants begin to touch. Plant spacing is sometimes performed manually but is increasingly done using automated equipment, especially in Europe. Plants continue to grow until they attain their desirable size, which depends on the container size, hybrid, grower, and desired finish quality. More mature plants typically produce a larger or more branched inflorescence, more inflorescences, or both. A population of plants that is not uniform in size and contains excessively small plants will not flower uniformly and will be of poor quality, and thus the market value of the crop is lower.

The most sophisticated phalaenopsis growers use an automated camera system to quantify each plant's leaf span to determine when each plant is of desirable size for the flowering phase. Plants are transported automatically on moving benches from the greenhouse to the grading area. Robotic arms pick up the plants, several at a time, and place them on a conveyor belt. The conveyor belt transports plants to a camera that measures leaf span of each plant. Based on the leaf span and the computer inputs, plants are automatically sorted and placed back onto benches. Benches that contain plants deemed large enough for flowering are transported to a separate greenhouse for the onset of the next production phase, whereas smaller plants are returned to the warm growing environment for additional vegetative growth. This grading system improves the uniformity of the finish crop and also ensures virtually 100% of plants flower because they are of adequate size.

FLOWERING PHASE

Once plants grow a desired number of leaves and have a desirable leaf span, plants are exposed to temperatures of 25°C or lower for flower induction (Lee and Lin, 1984).

Approximately three or four weeks at this low temperature are required for uniform flower induction of a population of plants. Warmer temperatures, particularly during the day, can delay or completely prevent flower initiation (Blanchard and Runkle, 2006). A common induction temperature in tropical and subtropical climates is 25/20°C day/night, whereas many growers in more temperate climates provide a temperature of 18 to 21°C, at least during the first 4 or 5 weeks of the flowering phase. Inflorescence and flower bud number was greater when phalaenopsis was induced at 14 or 17°C compared to warmer temperatures (Blanchard and Runkle, 2006).

Delivering a temperature <25°C can be challenging during the day in tropical and subtropical climates, and during the summer in temperate climates. Some growers at low elevations transport plants to greenhouses located at higher elevations, where the temperature is lower, to induce flowering. However, this practice requires a substantial amount of labor and greenhouse expenses for the additional growing space. More recently, growers have installed air conditioning systems to sections of their greenhouse that are used specifically to induce flowering. Plants may be moved to a separate greenhouse without air conditioning once inflorescences are visible, or may remain in the air conditioned greenhouses until plants are shipped. After the inflorescence has appeared, prolonged periods at 28ºC or higher can abort flower buds or the inflorescence may terminate and form a vegetative plant on the inflorescence (Wang, 1995).

A significant amount of shading is used to help reduce the temperature rise in greenhouses used to induce flowering. However, if the light intensity is excessively low, flowering can be inhibited; flowering of phalaenopsis was progressively delayed when plants were exposed to increasing durations of darkness or 8 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of light (Wang, 1995). During the vegetative phase, a few growers use blackout for 5 or 6 days a week to prevent or delay flowering during periods of cool weather rather than heat the greenhouse to >26°C. Some growers provide a slightly higher irradiance (maximum of 350 $\mu mol \cdot m^{-2} \cdot s^{-1}$) during the flower initiation phase in an attempt to increase the flowering response (van der Knaap et al., 2005).

Once inflorescences are visible, time to open flower is dependent on the average daily temperature and varies by hybrid. The estimated base temperature, or the temperature at which development ceases, is approximately 11°C for phalaenopsis (Robinson, 2002). Therefore, the rate of flower development decreases as the temperature decreases and essentially ceases development at 11°C. In general, commercial growers provide temperatures between 18 and 23°C from the time plants are induced to flower until they are marketed. Inflorescences may have more flowers when they develop slowly at the lower end of this temperature range, but time to the first open flower is delayed (Blanchard and Runkle, 2006). For example, time from the appearance of an inflorescence to first open flower of 'Taisuco Sugar' was 17 weeks at 17°C and 9 weeks at 23°C (Robinson, 2002).

Once flower buds are about 0.5 cm in diameter, the inflorescences are usually staked upright. Staking is performed to position the inflorescence in a desirable manner and to also protect the fragile inflorescence. The staking process is performed manually, although some companies use conveyor belts to bring plants to the people to more efficiently perform this task. Once the inflorescence is attached to the bamboo, wood, wire, or plastic stake, it is returned to the flowering environment until at least one flower is open. Plants are sometimes graded based on inflorescence or flower bud number prior to being marketed.

To make a more showy floral appearance, some producers transplant or combine plants into a larger decorative container before being marketed. Inflorescences can be arranged using wire to create a cascading form, and decorative materials such as moss or colored sand are sometimes used to cover the roots and media (Blanchard et al., 2005). The effects of shaping the inflorescences can be quite dramatic, and although a significant amount of labor is required to create a premium quality plant for sale, the plants command a justifiable market price.

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Tables

Table 1. A simplified schedule for commercial production of potted flowering phalaenopsis orchids in 10 to 13 cm finish containers. The propagation phase is performed in laboratories and most growers begin greenhouse production with plants at the end of the propagation or vegetative I phase.

	Production phases			
	Propagation	Vegetative I	Vegetative II	Flowering
Duration (weeks)	42 – 52	18 – 24	25 – 40	14 – 18
Temperature (°C)	26 – 28	28 – 30	28 – 30	18 – 24
Container	Flasks	Community or plug tray	10 – 13 cm pot	10 – 13 cm pot