PRODUCTION TECHNIQUES FOR THREE NOVEL POTTED FLOWERING PLANTS

By

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Bachelor of Science

Louis Pasteur University

Strasbourg, France

1995

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2000

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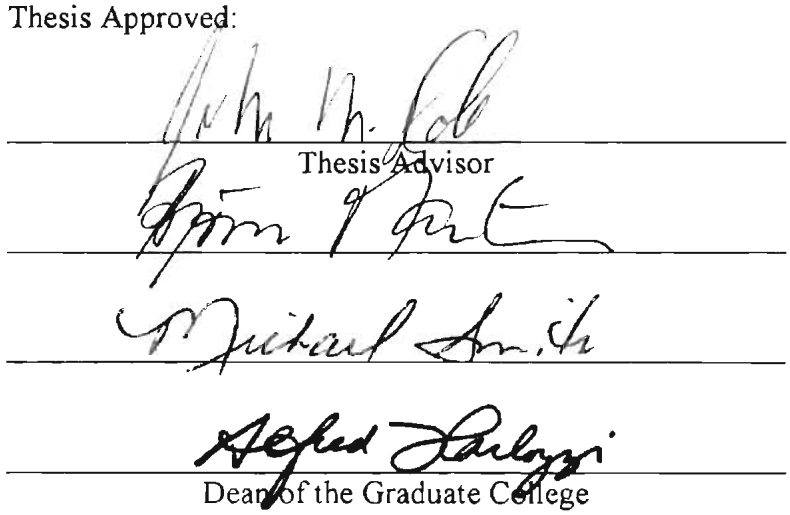
PLANTS

Thesis Approved:



Thesis Advisor

Dean of the Graduate College

ACKNOWLEDGEMENTS

The purpose of this study was to find suitable production techniques for novel potted flowering plants, as well as to find ways to improve postproduction life of these plants, especially in the home environment.

This study involved three plant species with high potential for the potted production. Partial funding was provided by Alex R. Masson, Inc., Linwood, KS. I would like to thank them for their help and support and for donating good quality plants. Thanks to them, I've been able to work with my favorite crop (orchids)! I certainly hope, I was of some help to them in return.

I would like to thank my academic advisor, Dr. John M. Dole, for his irreplaceable help, his countless advice, and for all the support and reassurance he gave me. John, I would not have wanted anybody but you as my advisor! Thank you for everything!

I would also like to thank Dr. Michael W. Smith and Dr. Bjorn Martin for serving on my committee. Dr. Smith, I would never have been able to get the statistics right without your help! Thanks for all the time you spent working with me on my programs. Dr. Martin, thank you for being your happy and positive self! I knew I could always count on you to show me the bright side (if there is a bright side!). Thanks to you and Louise, I finally know what real Chinese food is!!!

Thank you to Leah Aufill, and Tim Hooper, for assisting me with the technical aspect of my research (now I know how to build a wooden frame, and install a misting system!), and for taking good care of my plants! It would not have been the same without you!

Thank you to Theresa Bosma for always being there when I needed help or support. I'm glad we got to share the same office, because it gave me a chance to know you better! I learned a lot from you!

Thanks to Margaret Struble, Donna Dollins and Rhiannon Battles for their warmth and endless support! Nobody could have endured my whining like you did! Thanks for your understanding, and all the stress relieving breaks you provided me with!

A very special thank you to Dr. Brett F. Carver, for his constant encouragement and support... his patience and understanding! Dr. Carver, I know I took a lot of your time, but your warm reassurance is what really helped me get through.

A heartfelt thank you to Joy Martin! You are the best friend one could ever dream of, and you made those last semesters a whole lot easier for me! You were my companion of suffering (when even the Stairmaster was not enough to let go of all the steam!), thank you for your attentive ear, your understanding and your empathy! I owe you big time!

To my "Mom", Gerry: you are and always will be my true inspiration! Thank you for the moral and physical help (nobody cleans greenhouse benches like you!)! Thank you for all the tender loving care you provided me with! Bless your heart for all these countless hours you spent listening to me (and you know more than anybody else how much I can talk!), and for letting me pour my heart out to you! If I did not go insane in

the last months, I owe it to you! Katy, Maggy, William and Steve, thank you for letting me spend so much time with your mother or wife! You are the best! I love you all!

To my family back home: thank you for the endless moral and financial support. I don't think I could have made it without you! Most of all, thanks to my Dad for being the greatest ever. You made me what I am today, and I hope I will always make you proud!

I, finally, dedicate this work to Angel and Cleo, my two cats, whose unconditional love, lively personalities and relaxing purring was an appreciated comfort, and stress reliever all along!

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CHAPTER I

INTRODUCTION

As we enter the 21st century, the annual sales of flowering potted plants keep setting new records. The introduction of new plant species, flower colors, plant forms and interior uses is increasing the popularity of flowering potted plants among consumers.

To maintain consumer demand, growers must produce high quality plants that perform well in interior environments. Longevity and interior performance of potted flowering plants have become a primary concern for commercial producers, floral buyers and consumers (Nell and Hoyer, 1995). Plant quality and maximum postproduction longevity are determined during production and crop quality must be at the highest level when the plant leaves the production facility (Nell et al., 1997).

The effect of different production techniques, ethylene and environmental conditions on the longevity of a few new potted crops has been researched (Nell and Barrett, 1989). However, little work has been accomplished on three plant species that show potential as potted flowering plants: *Gynura aurantiaca, Helianthus annuus* and *Phalaenopsis* hybrids.

PRODUCTION STUDY OF *GYNURA AURANTIACA*

Gynura plants have attractive green and purple foliage, which offers a dramatic effect when grown in hanging baskets or pots. The purple velvet plant, *Gynura*

aurantiaca, which has become popular with indoor gardeners in North America and Europe, has such colorful foliage that flowers are unnecessary. Unfortunately, the yellow to orange flowers, that appear from midwinter to early spring, are malodorous and detrimental to sales.

Ethylene. Foliar application of ethylene releasing compounds (ethephon) delayed flowering on chrysanthemums (*Dendranthema x grandiflorum* Kitam.), *Begonia x cheimantha* Everett and *Camellia japonica* L. (Cockshull et al., 1979; Moe and Smith-Eriksen, 1986; Woolf et al., 1992) or induced abscission of flower buds with minimal abscission of other plant organs, due to the greater sensitivity of floral buds to ethylene (Edgerton and Greenhalgh, 1969; Sanderson et al., 1988; Woolf et al., 1992).

Photoperiod. Photoperiods may decrease time to anthesis or prevent flowering. Beattie et al. (1989) showed that to maintain vegetative meristems, stock plants of *Physostegia virginiana* L. had to be held under short days. Cavins (1999) also found that short days prevented flowering of young *Campanula medium* L plants. On the other hand, poinsettias (*Euphorbia pulcherrima* Willd. ex Klotzsch.) must be placed under long days to remain vegetative (Kofranek and Hackett, 1965). Stefanis and Langhans (1983) showed that night interruption with light from incandescent lamps (long days) was the recommended method for keeping chrysanthemums vegetative.

Light Intensity. Light intensity may influence flowering. Insufficient light intensity can prevent flowering in *Saintpaulia ionantha* Wendl. (Stinson and Laurie, 1954). Hanchey (1955) showed that no flowers occurred in the *Saintpaulia* plants grown at 20 $\mu mol.m^{-2}.s^{-1}$ for 6 h, and that only 40% flowering occurred at 20 $\mu mol.m^{-2}.s^{-1}$ for 12

and 18 h. The percentage of *Saintpaulia* plants flowering increased with increasing light intensity and duration (Conover and Poole, 1981).

PRODUCTION AND POSTPRODUCTION OF *HELIANTHUS ANNUUS*

Helianthus annuus is an important cut flower and garden ornamental, and has great potential as a potted flowering plant due to short crop time, ease of propagation and large flowers.

Cultivars. Cultivar study is required to select plants most adapted to container production (Shafer, 1986). The most important potted sunflower cultivars are 'Big Smile', 'Elf', 'Pacino', 'Sundance Kid', 'Sunspot', and 'Teddy Bear' (Dasoju et al., 1998). All cultivars are single flowered, except for 'Teddy Bear', which is double flowered. 'Big Smile' flowers have yellow petals surrounding a black center. 'Pacino' and 'Elf' has yellow flower petals and centers and are abundant pollen producers. They have a single dominant flower that reaches anthesis first, followed by 4 to 6 secondary flowers that usually open 4 to 6 days later. 'Sundance Kid' produces a mixture of bronze to pure yellow flowers. 'Sunspot' produces a single large flower with yellow petals and a slightly darker center (Whipker et al., 1998).

Plant number per pot. One or more plants per pot may be more desirable for production and marketing. However, competition for nutrients may induce premature leaf senescence in the potted sunflowers and a relationship could exist between the amount of media available and senescence of older leaves.

Pot size. Selection of an adequate pot size in relation to the height of the plant is required. Whipker et al. (1998) produced marketable-sized plants in 1.2 L pots.

Plant growth regulators.

Chemical growth retardant. Many floricultural crops are too large for standard container culture, and chemical growth retardants are required to manipulate plant size. The choice of a growth regulator is usually based on ease of application, concentration, timing, consistency, effects on vegetative and reproductive development, effects on postproduction quality and performance, and economics of application (Davis and Andersen, 1989). Whipker et al. (1998) produced marketable-sized sunflower plants in 1.2 L pots with paclobutrazol concentrations from 2 to 4 $mg.L^{-1}$ or with daminozide concentrations from 4,000 to 8,000 $mg.L^{-1}$.

Delay in senescence. Cytokinins and gibberellins have been shown to decrease leaf senescence (Jordi, 1995; Leopold and Kawase, 1964). Promalin, which is a mix of cytokinin (benzyladenine, BA) and gibberellin (GA_{4+7}) reduced leaf senescence of potted *Lilium* L. (Funnell and Heins, 1998). Han (1997) showed that concentrations even as low as 25 $mg.L^{-1}$ were effective in reducing leaf yellowing in Easter lily (*Lilium longiflorum* Thunb.). 'Stargazer' hybrid lily (*Lilium* sp. 'Stargazer') and Easter lily flower longevity increased when Promalin was foliar applied at 100 $mg.L^{-1}$ (Ranwala and Miller, 1998; Ranwala et al., 2000).

Photoperiod. Photoperiod is the period of darkness that regulates certain responses in some plants such as flower initiation and development and growth habit (Dole and Wilkins, 1999). Control of plant height and flowering can also be attained with photoperiod, as Armitage et al. (1981) showed in *Zinnia elegans* Jacq., where days to anthesis and plant height and weight were reduced under a 9-h photoperiod. Poinsettia

plants can be kept short by reducing the number of days from propagation or pinching to the beginning of short day photoperiods for flower initiation (Ecke et al., 1990).

Temperature. Postproduction longevity of many plants has been extended by holding or shipping at low temperatures (Shanks et al., 1970; Halevy and Kofranek, 1976; Staby et al., 1978; Poole and Conover, 1983). Storage of plants at low temperature (1 to 5°C) decreases respiration and ethylene effects and increases postproduction life on potted flowering plants (Nell and Noordegraaf, 1991). Duration of storage may also affect plant quality (Gibbs et al., 1989). Some plants can tolerate low temperatures for a short time, but prolonged exposure to the same temperature can cause chilling injury (Marousky and Harbaugh, 1980). *Hibiscus rosa-sinensis* L. 'Brilliant Red' plants stored at 10°C had higher visual quality immediately after storage than plants stored at 20 or 30°C (Thaxton et al., 1988). Gibbs et al. (1989) showed that pot-grown 'Angie Physic' hibiscus stored at 10.0 or 15.5°C had delayed flowering, larger or more flowers, less flower bud and leaf abscission and a higher plant quality than when stored at higher temperatures.

ESTABLISHMENT OF PRE-FINISHED BARE-ROOT *PHALAENOPSIS* PLANTS

The flowers of the *Phalaenopsis* plants are long lasting and plants can flower for 2 to 4 months under favorable interior conditions, which makes them valuable potted flowering plants. The major problem with using prefinished plants has been poor plant establishment after the bare root plants are planted (R. Wolf and A. Blair, personal communications). New root development is delayed or does not occur, resulting in leaf

yellowing and occasional plant death. Plants may produce low quality flower stalks even when not well-rooted.

Media. The choice of medium influences establishment of *Phalaenopsis* orchid plants. Wang (1995a) tested different media and fertilization frequencies on *Phalaenopsis* 'Taisuco Kochdian', and two media (3 perlite: 3 Metro Mix 250: 1 charcoal and 1 perlite: 1 rockwool) resulted in root systems inferior to that in other media. Live moss (species non-specified) has also been considered as a good media for *Phalaenopsis* plants because it provides high humidity, excellent aeration of the roots and also nutrition; live moss nourishes blue green algae, which in turn fixes atmospheric nitrogen into amines, a natural source of fertilizer of orchids in nature (Fowlie, 1987).

Light Intensity. Orchids are usually epiphytes and grow under the canopy of trees. Light is an important factor in the establishment and growth of *Phalaenopsis* orchids. Shading plants would reduce stress caused by high light intensity and high temperature. Wang (1995b) noted that a minimum of 60 $\mu mol.m^{-2}.s^{-1}$ PPF was necessary to keep healthy leaves, induce spiking and reach anthesis in about 167 days from potting.

Humidity levels. Orchids are tropical plants and might require high humidity levels for rapid establishment. *Phalaenopsis* plants grow best under 50-60% humidity (Gordon, 1990).

OBJECTIVES

The research had three objectives:

1) to determine appropriate production techniques for *Gynura aurantiaca* and prevent flowering by examining photoperiod, light intensity and ethephon treatments.

2) to determine appropriate production techniques for potted *Helianthus annuus* plants by examining plant number per pot, pot size, photoperiod, and growth regulators; and to improve postproduction life through Promalin and 5°C storage.

3) to determine optimum production techniques for rapid and successful establishment of prefinished *Phalaenopsis* plants by examining media, light intensity and humidity.

The information gained from this research will provide growers with production and postproduction methods for three novel potted flowering plants.

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CHAPTER II

MAINTAINING VEGETATIVE POTTED PURPLE VELVET PLANTS

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Additional index words: *Gynura aurantiaca*, ethephon, photoperiod, shade.

Abstract. The purple velvet plant (*Gynura aurantiaca* Bl.) has potential as a potted plant due to its attractive purple foliage, if the malodorous flowers can be avoided. Ethephon was not commercially useful in producing marketable plants, or maintaining stock plants. Although foliar application of ethephon at 1200 to 4800 $\mu L.L^{-1}$ completely inhibited flowering of the purple velvet plants, plants were stunted and cutting harvest was impossible. At lower application rates (150 to 300 $\mu L.L^{-1}$), flowering was promoted. An 8-h photoperiod increased plant quality, with the largest number of vegetative shoots and the brightest purple color, compared to 12 or 16-h photoperiods. All of the shoots were reproductive under the 16-h photoperiod. Increasing the shade level from 0 to 60% (790 $\mu mol.m^{-2}.s^{-1}$ to 230 $\mu mol.m^{-2}.s^{-1}$) increased the number of vegetative shoots. Plants under 60% shade and natural short days had over 80% vegetative shoots. Growing plants under 60% shade and 8-h photoperiod is recommended to maintain stock plants and obtain high quality marketable plants.

Chemical names used: (2-chloroethyl) phosphonic acid (ethephon).

Introduction

Gynura is a genus with about one hundred species of herbs and small shrubs native to tropical regions of Africa and Asia. Cultivated species have attractive green and purple foliage and are grown as hanging basket and potted plants (McConnel, 1981). The purple color is caused by numerous small deep purple trichomes that cover the leaves and stems (Kalmbacher, 1975). The purple velvet plant has colorful foliage resulting in its popularity with indoor gardeners in North America and Europe. Unfortunately, the yellow to orange flowers, that appear from midwinter to early spring, are malodorous and detrimental to sales.

Gynura aurantiaca plants must remain vegetative for successful production and marketing. Bud abscission and flower senescence in miniature roses (*Rosa* sp. L.) was accelerated by foliar application of ethephon (Serek and Andersen, 1995). Ethephon has also been used for selective removal of flower buds in apple (*Malus* sp.) (Edgerton and Greenhalgh, 1969), and a single spray of 200 $\mu L.L^{-1}$ ethephon applied to rooted chrysanthemum (*Dendranthema x grandiflorum* Kitam.) cuttings three days after planting delayed flower bud formation (Cockshull et al., 1979). More recently, a 2,000 $\mu L.L^{-1}$ ethephon spray almost completely inhibited flower bud opening in *Begonia X cheimantha* Everett when applied in the early stages of flower bud formation (Moe and Smith-Eriksen, 1986) and 1500 $\mu L.L^{-1}$ ethephon sprays removed *Camellia japonica* L. flower buds with minimal abscission of leaves and vegetative buds (Woolf et al., 1992). Ethephon has been used to induce axillary shoot development and abscission of unwanted

flower buds in azaleas (*Rhododendron* sp.) (Sanderson et al., 1988). To date, no published information is available on ethephon application to *Gynura.*

Photoperiod has been used to regulate flowering of certain plant species. Beattie et al. (1989) showed that to ensure maintenance of vegetative meristems, stock plants of *Physostegia virginiana* L. had to be held under short days. Cavins (1999) also found that short days would prevent flowering on young *Campanula medium* L. plants. On the other hand, poinsettias (*Euphorbia pulcherrima* Willd. ex Klotzsch.) must be placed under long days to remain vegetative (Kofranek and Hackett, 1965). Stefanis and Langhans (1983) showed that night interruption with light from incandescent lamps (long days) was the recommended method for keeping chrysanthemums vegetative.

Shade (light intensity) may also influence flowering. Insufficient light intensity is thought to be the primary cause of failure to flower in *Saintpaulia ionantha* Wendl., and inhibition of floral initiation is observed at 20 or 60 $\mu mol.m^{-2}.s^{-1}$ (Stinson and Laurie, 1954). Hanchey (1955) showed that no flowers occurred in the *Saintpaulia* plants grown at 20 $\mu mol.m^{-2}.s^{-1}$ for 6 h, and that only 40 percent flowering occurred at 20 $\mu mol.m^{-2}.s^{-1}$ for 12 or 18 h. The percentage of *Saintpaulia* plants flowering increased with increasing light intensity and duration (Conover and Poole, 1981). A combination of shade and photoperiod could reduce flowering of both stock plants and marketed plants.

The objective of our studies was to prevent flowering of *Gynura aurantiaca* by ethephon foliar sprays, photoperiod or reduced light intensity.

Materials and Methods

Plants were propagated directly into 10-cm (0.4-L) pots from tip cuttings, using a commercial soilless medium (Universal Mix, Strong/Lite Horticultural Products, Pine Bluff, AK). The plants were grown in a corrugated polycarbonate-covered greenhouse set at 25/15° C day/night temperatures. Plants were fertigated with 250 $mg.L^{-1}$ N from a premixed commercial 20-4.4-16.6 fertilizer (Peter's Professional, Scott's Company, Marysville, Ohio). Data were subjected to analysis of variance using the general linear model (GLM) procedure (SAS Institute, Cary, NC).

Ethephon (Expt. 1). Plants were propagated on 27 Mar. 1999, and sprayed on 19 May 1999 with 0, 150, 300, 600, 1200, 2400 or 4800 $\mu L.L^{-1}$ ethephon (Florel, Lawn & Garden Products, Inc., Fresno, CA). Data collected once a week for four weeks included date of transplanting into final pot, first visible flower bud, number of open flower buds and foliage chlorosis ratings. Chlorosis ratings ranged from 1 to 5: 5 = plants with > 25% chlorotic leaves, 4 = plants with >10% and < 25% chlorotic leaves, 3 = plants with >5% and <10% chlorotic leaves, 2 = plants with <5% chlorotic leaves and 1 = plants without chlorotic leaves. Plants were arranged in a completely randomized design on greenhouse benches with ten single plant replications per treatment.

Photoperiod (Expt. 2). Cuttings were propagated on 9 Sept. 1999, pinched on 8 Oct. 1999 and placed under 8-, 12-, or 16-h photoperiods on 1 Nov. 1999. The 8-h photoperiod received 8 h of natural daylight concurrent with 8 h of incandescent light. The 12-h photoperiod received 8 h of natural daylight along with 4 h of concurrent incandescent light and 4 h of day extension incandescent light. The 16-h photoperiod received 8 h of natural daylight and an additional 8 h of day extension provided by

incandescent lights. Thus, each treatment had 8 h of natural daylight and 8 h of incandescent light. Data collected included pinching date and number of vegetative and reproductive shoots recorded every four weeks for three months after placement of plants in the photoperiods. Twenty single plant samples were used per treatment.

Light intensity (Expt. 3). Cuttings were propagated on 4 Nov. 1999 and placed on 26 Nov. 1999 under three shade levels: 0, 30 or 60%, resulting in an average of 790, 375 or 230 $\mu mol.m^{-2}.s^{-1}$, respectively. Data collected were similar to Expt. 2. Twenty single plant samples were used per treatment.

8-h photoperiod and 0 or 60% shade (Expt. 4). Cuttings were propagated on 11 Feb. 2000 under 60% shade in the 8-h photoperiod. Once fully rooted, on 25 Mar. 2000, plants were split in two equal groups of twenty plants with each group placed under 60 or 0% shade; all plants remained under 8-h photoperiod. Data collected were similar to Expt. 2, except that data were collected only twice, 74 (24 Apr. 2000) and 102 (22 May 2000) days after placement in final shade treatment. Twenty single plant samples were used per treatment.

8- or 16-h photoperiod and 0 or 60% shade (Expt. 5). Plants that had been grown under 60% shade were split in four equal groups of five plants on 10 Mar. 2000, and placed in the 8- and 16-h photoperiods, with or without 60% shade. Data collected were similar to Expt. 4. Five single plant samples were used per treatment.

Results

Ethephon. Ethephon foliar application had no effect on flowering one week after treatment (Table 2.1). Two weeks after treatment flower number per plant was inversely

related to ethephon rate. A curvilinear relationship existed between ethephon rate and flower number at 3 and 4 weeks after treatment. Ethephon increased flower number up to 300 $\mu L.L^{-1}$, then reduced flowering. Flowering inhibition was complete at $\geq$ 1200 $\mu L.L^{-1}$ during 3 or 4 weeks after treatment. Ethephon was not detrimental to the foliage, but high levels of ethephon stunted plants (data not shown).

Photoperiod. The percentage of vegetative shoots decreased with increasing photoperiod for all three data collection dates (Table 2.2). Effect of the 8-h photoperiod decreased with time as the percentage of vegetative shoots decreased from 42 to 68 days after treatment. The 16-h photoperiod produced only reproductive shoots at all three data collection dates.

Light intensity. The percentage of vegetative shoots increased with increasing shade (Table 2.3). Plants under 60% shade had the highest percentage of vegetative shoots at 74 days after beginning of the treatment then decreased at 108 days.

8-h photoperiod and 0 or 60% shade. At 74 days, plants were more than 80% vegetative, with no difference between the light intensities tested (Table 2.4). At 102 days, plants under no shade were less vegetative (65%) than plants under 60% shade (99%). The difference between dates, within light levels, was significant (data not presented); percent of vegetative shoots decreased from 74 days (84%) to 102 days (65%) when the plants were grown with no shade, but increase from 88% to 99%, respectively, when the plants were grown under 60% shade (Table 2.4).

8- or 16-h photoperiod and 0 or 60% shade. At 74 days plants grown under 8-h photoperiod had more vegetative shoots than those grown under 16-h photoperiod, regardless of the light intensity (Table 2.5). At 102 days, plants grown under 8-h

photoperiod and 60% shade had more vegetative shoots than any other combination. The plants grown under 8-h photoperiod and 60% shade were more vegetative after 102 days (94%) than after 74 days (63%) (statistics not presented).

Discussion

Ethephon. Ethylene in ornamentals is used to promote flower formation in bromeliads and certain bulbous plants (Halevy, 1995). Low ethephon concentrations (150 to 300 $\mu L.L^{-1}$) induced flowering in the *Gynura* (Table 2.1), which is similar to results for *Gladiolus* (Abd El-Rahman and Abd El-Hamied, 1985). The differentiation and development of lobes, flower primordia and the extension of the *Gladiolus* flower spike were advanced as the concentration of ethephon decreased from 100 $\mu L.L^{-1}$ to 1 $\mu L.L^{-1}$, one month after planting. Also, 200 $\mu L.L^{-1}$ ethephon on lychee (*Litchi chinensis* Sonn.) shoots induced flowering 7 to 10 days earlier than those of the controls, but relatively few flower buds were formed (Chen and Ku, 1988). The mode of action of ethylene in promoting flowering is not known (Halevy, 1990). One hypothesis would be that ethylene enhances carbohydrate mobilization from the reserve parts to the meristem (bulbous plants). However, analysis of sugar concentration in *Triteleia laxa* corms (Han et al., 1989) did not reveal any difference between ethylene treated and control bulbs. Examination of the apical meristem of the ethylene-treated plants of *T. laxa* revealed that their apices grew at twice the rate of untreated plants (Han et al., 1989). The increase in size of the apical dome was not due to increase in cell size, but to promotion of cell division. The primary effect of ethylene on flowering of *T. laxa*, and perhaps also in

other geophytes, may be the stimulation of cell division in the apical meristem, which seems to be correlated with apex size and its ability to produce flowers (Halevy, 1990).

In many plants, exogenous ethylene, applied either as the gas or by the use of ethylene-releasing agents such as ethephon, inhibits or delays flower formation (Arteca, 1996). High levels of ethephon (1200 to 4800 $\mu L.L^{-1}$) completely inhibited *Gynura* flowering (Table 2.1). Similar results were found on mango (*Mangifera indica* L.) but only with ethephon levels up to 800 $\mu L.L^{-1}$ (Sauco et al.,1991). However, the *Gynura* plants were stunted, preventing cutting harvest. Also, high concentrations of ethephon decreased the purple coloration of the foliage (loss of the foliar hairs) (personal observation). Ethephon did not produce acceptable results to be commercially useful in maintaining vegetative *Gynura*.

Photoperiod. All of the shoots were reproductive under the 16-h photoperiod (Table 2.2). The highest percentage of vegetative shoots was under 8-h photoperiod, which would make *Gynura* a facultative long day plant with a critical daylength less than 8 h. Photoperiod also influenced the quality of the cuttings, with the 8-h photoperiod producing the darkest purple color (personal observation).

Shade. Increasing the shade level significantly increased the percentage of vegetative shoots in *Gynura* and could be used commercially for stock plants production (Table 2.3). The highest percentage of vegetative shoots was at 74 days after beginning of the treatment and decreased thereafter, indicating that plant maturity might play a role in the flowering of *Gynura*. Lyons and Booze-Daniels (1986) indicated that a specific node number may affect floral induction in California poppy (*Eschscholzia californica*

Cham.). In addition, Lyons and Neale (1983) identified a negative linear relationship between number of unfolded California poppy leaves and days to anthesis.

Photoperiod and shade. Plants grown under 8-h photoperiod and 60% shade had the most vegetative shoots (94% to 99% after 102 days of treatment) (Tables 2.4 and 2.5). Armitage (1995) showed similar results in *Hamelia patens* Jacq.; flowering was delayed under low light intensity, and flower development was completely arrested under 8-h photoperiod. Adams et al. (1998) also showed that flowering of *Petunia X hybrida* was significantly delayed when photosynthetic photon flux (PPF) decreased from 13 to 6.5 $mol.m^{-2}.d^{-1}$, and photoperiods were less than 14 h. Corr and Widmer (1990) observed that decreased irradiance lowered the number of flowers per plant of *Zantedeschia elliottiana* and *Z. rhemannii*.

Conclusion. *Gynura* plants should be grown under 8-h photoperiod and 60% shade (230 $\mu mol.m^{-2}.s^{-1}$) to maintain vegetative growth and prevent flowering. Both 8-h photoperiod and 60% shade were required for vegetative growth as shade did not prevent flowering under 16-h photoperiod and 8-h photoperiod did not prevent flowering under high light intensity. Long days of 12-h or greater photoperiods should be avoided. Ethylene sprays were not commercially useful.

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Table 2.1. Effect of ethephon (Florel) on *Gynura* flower development. Data are means of 10 plants per treatment. Expt. 1.

Ethephon ($\mu L.L^{-1}$)	Weeks after treatment (flower number / plant)			
	1	2	3	4
0	0.0	0.1	1.3	4.7
150	0.7	2.4	3.7	6.5
300	0.5	1.1	2.8	4.8
600	0.2	0.3	0.3	0.9
1200	0.0	0.0	0.0	0.0
2400	0.0	0.0	0.0	0.0
4800	0.0	0.0	0.0	0.0
Significance:				
Linear	NS	0.0231[z]	0.0032	0.0001
Quadratic	NS	NS	0.0308	0.0013
Cubic	NS	NS	NS	NS
Residual	NS	NS	NS	NS

[NS] Nonsignificant.

[z] P>F.

Table 2.2. Effect of photoperiod on *Gynura* flower development. Data are means of 20 plants per treatment. Expt. 2.

Photoperiod (h)	Days in photoperiod (% vegetative shoots / plant)		
	42	68	96
8	82	44	46
12	35	39	26
16	0	0	0
Significance:			
Linear (L)	0.0001[z]	0.0001	0.0001
Quadratic (Q)	0.0270	0.0039	NS
Photoperiod $(P)_L$ x Time $(T)_L$	0.0001		
P_Q x T_L	0.0001		
P_L x T_Q	0.0076		
P_Q x T_Q	0.0003		

[NS] Nonsignificant.

[z] P>F.

Table 2.3. Effect of 0, 30 or 60% shade on *Gynura* flower development. Data are means of 20 plants per treatment. Expt. 3.

	Days exposed to treatment (% vegetative shoots / plant)		
Shade level (%)	46	74	108
0	54	57	13
30	58	80	32
60	74	93	82
Significance:			
Linear (L)	0.0100[z]	0.0001	0.0001
Quadratic (Q)	NS	NS	0.0500
Shade $(S)_L$ x Time $(T)_L$	0.0004		
S_Q x T_L	NS		
S_L x T_Q	NS		
S_Q x T_Q	NS		

[NS] Nonsignificant.

[z] P>F.

Table 2.4. Effect of 8-h photoperiod and 0 or 60% shade on *Gynura* flower development.

Data are means of 20 plants per treatment. Expt. 4.

	Days exposed to treatment (% vegetative shoots / plant)	
Shade level (%)	74	102
0	84	65
60	88	99
Significance within date		
Shade	NS	0.0001[z]

[NS] Nonsignificant.

[z] P>F.

Table 2.5. Effect of 8- or 16-h photoperiods and 0 or 60% shade on *Gynura* flower development. Data are means of 5 plants per treatment. Expt. 5.

Shade level (%)	Photoperiod (h)	Days exposed to treatment (% vegetative shoots / plant) 74	102
0	8	47	79
	16	17	9
60	8	63	94
	16	27	27
Significance within date			
Shade (S)		NS	0.0001[z]
Photoperiod (P)		0.0091	0.0078
S*P		NS	NS

[NS] Nonsignificant.

[z] P>F.

CHAPTER III

POTTED SUNFLOWERS: PRODUCTION AND POSTPRODUCTION STUDY

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Additional index words. Daminozide, paclobutrazol, Promalin, photoperiod, container size, plants per pot, *Helianthus annuus*.

Abstract. Days from sowing to anthesis were significantly different among six sunflower (*Helianthus annuus* L.) cultivars and ranged from 52 days for 'Teddy Bear' to 87 days for 'Pacino.' Height ranged from 13.5 cm for 'Big Smile' to 37.3 cm for 'Pacino', postproduction life from 10 days for 'Pacino' and 'Elf' to 15 days for 'Big Smile', and postproduction chlorosis ratings (1 to 5, with 1 the least) ranged from 1 to 2.1 after 5 days and 1.8 to 4.7 after 10 days. Foliar chlorosis ratings after 15 days were not significantly different among cultivars, because few plants were marketable at 15 days. Plant number per pot was negatively related to number of days to anthesis and postproduction life.

Increasing pot sizes from 10- to 15-cm diameter decreased postproduction life and plants in 13-cm pots were tallest. Most cultivars were facultative short day plants, except for 'Sundance Kid' which was day neutral. Storing potted sunflowers at 5°C for a week did not reduce postproduction life; however, two weeks of cold storage resulted in foliar damage. Promalin (Ga_{4+7} and BA) at 62.5 to 500.0 mg.L^{-1} was not commercially useful in extending postproduction life. Three cultivars were found to be most suitable for pot production, 'Elf', 'Pacino' and 'Teddy Bear', with one or three plants per 15 cm-pot and sprayed with daminozide at 8,000 mg.L^{-1}, or drenched with paclobutrazol at 2 mg.L^{-1}. Chemical names used: gibberellins A4A7 (GA_{4+7}); N-(phenylmethyl)-1*H*-purine 6-amine (benzyladenine, BA); 2,2- dimethylhydrazide (daminozide, B-Nine); (2R, 3R+ 2S, 3S)-1-(4-chlorophenyl)-4,4-dimethyl-2(1,2,4-triazol-1-yl) pentan-3-ol (paclobutrazol, Bonzi).

Introduction

The cultivated sunflower ranks with soybean [*Glycine max* (L.) Merrill], rapeseed (*Brassica napus* L.) and peanut (*Arachis hypogaea* L.) as one of the four most important annual edible oil crops in the world (Connor and Hall, 1997). Sunflowers are also an important cut flower and garden ornamental, and could make an ideal potted flowering plant due to short crop time, ease of propagation and large flowers.

A challenge when growing potted sunflowers is that they can become disproportionately large relative to their container size, especially when grown in a greenhouse, and can be difficult to keep well-watered during marketing (Whipker and Dasoju, 1998). The most important potted sunflower cultivars are 'Big Smile', 'Elf', 'Pacino', 'Sundance Kid', 'Sunspot', and 'Teddy Bear' (Dasoju et al., 1998). 'Big Smile', 'Pacino' and 'Elf' are dwarf cultivars, which are easy to grow in pots, but require the application of growth regulators to produce properly proportioned plants. Davis and Andersen (1989) documented the use of growth retardants as aids in adapting new floricultural crops to pot culture. Whipker et al. (1998) produced marketable-sized plants in 1.2 L pots with paclobutrazol concentrations from 2 to 4 $mg.L^{-1}$ or with daminozide concentrations from 4,000 to 8,000 $mg.L^{-1}$.

Control of plant height and flowering can also be attained with photoperiod, as Armitage et al. (1981) showed in *Zinnia elegans* Jacq., where flowering time, plant height and weight were reduced under a 9-h photoperiod. Poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch.) plants can be kept short by reducing the number of days from propagation or pinching to the beginning of short day photoperiods for flower initiation (Ecke et al., 1990).

Research has also been conducted on postproduction factors for potted sunflowers. Whipker and Dasoju (1997) found that a rate of 150 $mg.L^{-1}$ nitrogen was recommended for maximum shelf life, with fertilization discontinued 7 to 10 days before flower. A preliminary experiment on potted sunflowers (data not published) showed that flowers remain acceptable for up to 2 weeks, but the lower foliage began to yellow and senesce immediately after anthesis. The senescence of older leaves must be delayed to improve the longevity and quality of the crop.

Gibberellins can delay senescence of *Alstroemeria pelegrina* L. leaves (Jordi, 1995) and benzyladenine can increase vegetative growth in bean (*Phaseolus vulgaris* L.) leaves (Leopold and Kawase, 1964). Treatments with Promalin (Abbott Laboratories, North Chicago, Ill.), a mixture of gibberellins (GA_{4+7}) and cytokinin (BA), at 250 $mg.L^{-1}$ reduced leaf senescence of potted *Lilium* hybrid L. (Funnell and Heins, 1998). Han (1997) even showed that concentrations as low as 25 $mg.L^{-1}$ were effective in reducing leaf yellowing in Easter lilies (*Lilium longiflorum* Thunb.). Flower longevity increased when 'Stargazer' hybrid lily (*Lilium* sp. 'Stargazer') and Easter lily were sprayed with Promalin at 100 $mg.L^{-1}$ (Ranwala and Miller, 1998; Ranwala et al., 2000).

Competition for nutrients could also induce premature leaf senescence in potted sunflowers, and a relationship could exist between the amount of media available and senescence of older leaves. No information is available concerning the influence of the number of plants per pot or pot size on the senescence of older sunflower leaves.

Postproduction longevity of many plants has been extended by holding or shipping at lower temperatures (Shanks et al., 1970; Halevy and Kofranek, 1976; Staby et al., 1978; Poole and Conover, 1983). Storage of plants at low temperature (1 to 5°C)

decreases deleterious effects of respiration and ethylene, and increases postproduction life on potted flowering plants (Nell and Noordegraaf, 1991). Duration of storage may also affect plant quality (Gibbs et al., 1989). Some plants tolerate low temperatures for a short time, but prolonged exposure to the same temperature can cause chilling injury (Marousky and Harbaugh, 1980). *Hibiscus rosa-sinensis* L. 'Brilliant Red' plants stored at 10°C had higher visual quality immediately after storage than plants stored at 20 or 30°C (Thaxton et al., 1988). Gibbs et al. (1989) showed that pot-grown 'Angie Physic' hibiscus stored at 10.0 or 15.5°C had delayed flowering, larger or more flowers, less flower bud and leaf abscission and a higher plant quality than when stored at higher temperatures.

The objectives of our studies were to determine optimum production techniques by examining plant number, pot size, growth regulator and photoperiod and improve the postproduction life of potted *Helianthus annuus* plants through Promalin sprays and cold storage.

Materials and Methods

Experiments 1 to 4, Oklahoma. Four experiments were conducted using six dwarf *Helianthus* cultivars: 'Big Smile', 'Elf' (Expts. 3 and 4 only), 'Pacino', 'Sundance Kid', 'Sunspot' and 'Teddy Bear'. Seeds were sown on 12 Nov.1998 (Expt. 1-3) or 6 Dec. 1999 (Expt. 4) into 1206 cell-packs (50 cm^3/cell) filled with a peat-based commercial root substrate (Redi Earth, Scotts-Sierra Horticultural Products Company, Marysville, Ohio) and transplanted on 30 Nov. 1999 (Expt. 1 to 3) or 26 Dec. 1999 (Expt. 4) into the

final pot using a soilless commercial medium (BM1, Berger Peat Moss, Saint-Modeste, Que.).

The plants were grown in a corrugated polycarbonate-covered greenhouse set at 22/15°C day/night temperatures. Plants were fertigated at each irrigation with 250 $mg.L^{-1}$ N from a premixed commercial 20.0-4.4-16.6 fertilizer (Peter's Professional, Scott's Company, Marysville, Ohio).

Anthesis date and plant height from substrate to top of plant (at anthesis) were recorded. Plants were moved to postproduction area when they reached anthesis and foliar chlorosis ratings were taken after 5, 10 and 15 days, and termination date (date of unacceptable appearance) was recorded. Foliar chlorosis ratings ranged from 1 to 5: 5 = plants with > 25% chlorotic leaves, 4 = plants with >10% and < 25% chlorotic leaves, 3 = plants with >5% and < 10% chlorotic leaves, 2 = plants with <5% chlorotic leaves and 1 = plants without chlorotic leaves. For Expt. 4, the number of nodes was also recorded at flowering and foliar chlorosis was not rated.

Ten-single plant replications were used in each experiment. Plants were arranged in a completely randomized design on greenhouse benches and in the postproduction area. Data were subjected to analysis of variance using the general linear models (GLM) procedure (SAS Institute, Cary, NC).

Plants per pot (Expt. 1). 'Big Smile', 'Pacino', 'Sundance Kid', 'Sunspot' and 'Teddy Bear' plants were transplanted into 15-cm (0.9 L) pots with 1, 3 or 5 plants/pot, resulting in a 5 x 3 factorial arrangement of five cultivars and three different numbers of plants per pot.

Promalin rates (Expt. 2). 'Big Smile', 'Pacino', 'Sundance Kid', 'Sunspot' and 'Teddy Bear' plants were transplanted into 15-cm (0.9 L) pots with 1 plant/pot and sprayed with 0, 62.5, 125, 250 or 500 mg.L^{-1} Promalin at anthesis, resulting in a 5 x 5 factorial arrangement of five cultivars and five Promalin concentrations.

Pot size (Expt. 3). 'Big Smile', 'Elf', 'Pacino', 'Sundance Kid', 'Sunspot' and 'Teddy Bear' plants were transplanted into 10-, 13-, or 15-cm (0.4, 0.5 or 0.9 L / pot, respectively) pots with 1 plant/pot, resulting in a 5 x 3 factorial arrangement of five cultivars and three pot sizes.

Photoperiod (Expt. 4). 'Big Smile', 'Elf', 'Pacino', 'Sundance Kid', 'Sunspot' and 'Teddy Bear' plants were transplanted into 15-cm (0.9 L) pots with 1 plant/pot, and placed under 8-, 12-, or 16-h photoperiods, resulting in a 6 x 3 factorial arrangement of six cultivars and three photoperiods. The 8-h photoperiod received 8 h of natural daylight concurrent with 8 h of incandescent light. The 12-h photoperiod received 8 h of natural daylight along with 4 h of concurrent incandescent light and 4 h of day extension incandescent light. The 16-h photoperiod received 8 h of natural daylight and an additional 8 h of day extension provided by incandescent lights. Thus, each treatment had 8 h of natural daylight and 8 h of incandescent light. Ten single plant replications were used and plants were arranged in a completely randomized design in each photoperiod. Data were subjected to analysis of variance using the general linear models (GLM) procedure (SAS Institute, Cary, NC).

Cold storage (Expt. 5). Seeds of 'Pacino' and 'Teddy Bear' were sown on 25 Mar. 1999 into 1206 cell-packs (50 cm^3 / cell). On 15 Apr. 1999, seedlings were transplanted into 15-cm (1.2 L) round plastic pots using a soilless commercial medium

(BM1, Berger Peat Moss, Saint-Modeste, Que.). Plants were fertigated at each irrigation with 250 $mg.L^{-1}$ N from a premixed commercial 20.0-4.4-16.6 fertilizer (Peter's Professional, Scott's Company, Marysville, Ohio). Greenhouse day/night set points were 22/15° C. The plants were grown under natural daylength. One-half of the plants of each cultivar received a daminozide (B-Nine, Uniroyal Chemical, Middlebury, Connecticut) foliar spray at 8,000 $mg.L^{-1}$, 14 days after potting. As plants within growth retardant treatment reached anthesis, five sets of three plants each were removed from the greenhouse. One plant was immediately placed in the postproduction area (control); two plants were placed in a cooler at 5°C, one for 1 week and the other for 2 weeks. Plants were then transferred to the postproduction area where the termination date was recorded. Five single plant replications were used and plants were arranged in a completely randomized design in the postproduction area. Data were subjected to analysis of variance using the general linear models (GLM) procedure (SAS Institute, Cary, NC).

Promalin / daminozide combination (Expt. 6) and plant growth retardant / number of plants per pot combination (Expt. 7), Oklahoma and North Carolina. Seeds of 'Pacino' and 'Teddy Bear' were sown on 25 Mar. 1999 (Expt. 6) and on 21 Dec. 1999 (Expt. 7) into 1206 cell-packs (50 cm^3 / cell). On 15 Apr. 1999 (Expt. 6) and on 20 Jan. 2000 (Expt. 7), seedlings were transplanted into 15-cm (1.2 L) round plastic pots, using a soilless commercial medium (BM1, Berger Peat Moss, Saint-Modeste, Que.). Plants were fertigated at each irrigation with 250 $mg.L^{-1}$ N from a premixed commercial 20.0-4.4-16.6 fertilizer (Peter's Professional, Scott's Company, Marysville, Ohio). Greenhouse day/night set points were 22/15° C. The plants were grown under natural daylength. Promalin (Abbott Laboratories, North Chicago, Ill.) at 125 $mg.L^{-1}$ plus

surfactant (0.25% Tween 20) were applied to each cultivar at one of three stages of growth: visible bud, one week after visible bud and first flower color. Half of the plants of each cultivar received a daminozide (B-Nine, Uniroyal Chemical, Middlebury, Connecticut) foliar spray at 8,000 $mg.L^{-1}$, 14 days after potting and the other half a water-only spray.

Expt. 6 was duplicated in North Carolina in the same manner as in Oklahoma, except seeds were sown into cell packs (180 cm^3/cell), root substrate was a soilless commercial medium (Fafard 4P, Anderson, SC), and 150 $mg.L^{-1}$ N fertilizer was used. Plants were grown in a double-polyethylene covered greenhouse with day/night set points of 24/18° C.

Data collected were visible bud date, anthesis date, plant height from substrate to top of plants, foliar chlorosis ratings were taken after 5, 10 and 15 days, and termination date was recorded. Foliar chlorosis ratings ranged from 1 to 5: 5 = plants with > 25% chlorotic leaves, 4 = plants with >10% and < 25% chlorotic leaves, 3 = plants with >5% and < 10% chlorotic leaves, 2 = plants with <5% chlorotic leaves and 1 = plants without chlorotic leaves. Expt.6 was a completely randomized design with a factorial of two locations, two levels of daminozide and three application dates of Promalin. Each treatment contained ten replicates, with each replication being an individual plant in a separate pot. Data were subjected to analysis of variance using the general linear models (GLM) procedure (SAS Institute, Cary, NC). Control treatments of water or water plus surfactant (0.25% Tween 20) were also applied to 10 additional plants at visible bud in Oklahoma but not North Carolina due to insufficient plant numbers.

In Expt. 7, 'Pacino' and 'Teddy Bear' seedlings were transplanted into 15-cm (0.9 L) pots with 1 or 3 plants/pot, and sprayed with water or 8,000 $mg.L^{-1}$ daminozide or drenched with 2 $mg.L^{-1}$ paclobutrazol, both in Oklahoma and North Carolina, resulting in a 2 x 2 x 3 x 2 factorial arrangement of two cultivars, two different plant numbers per pot, three plant growth regulators and two locations. Data collected were visible bud date, anthesis date, plant height from substrate to top of plant, number of nodes and termination date. Ten single plant replications were used and arranged in a completely randomized design, at each site, on the greenhouse benches. Data were subjected to analysis of variance using the general linear models (GLM) procedure (SAS Institute, Cary, NC).

Results

Days from sowing to anthesis. In all experiments, 'Pacino' and 'Elf' had the greatest number of days to flower, while 'Big Smile' had the least (Tables 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7 and 3.16). Three plants per pot reduced days to anthesis compared to one or five plants per pot (Tables 3.1 and 3.15). Pot size had no effect on days to anthesis (Table 3.3). All sunflower cultivars under 16-h photoperiod flowered later than under 8- or 12-h photoperiods, except for 'Sundance Kid' for which photoperiod had no effect (Table 3.4).

In Expt. 6, 'Teddy Bear' plants grown in North Carolina required fewer days to anthesis than in Oklahoma (Table 3.6). In Oklahoma, daminozide application at visible bud significantly reduced days to anthesis for 'Pacino', but increased days to anthesis when Promalin was sprayed at first flower color. In North Carolina, application of daminozide increased days to anthesis for 'Teddy Bear' and 'Pacino' only when Promalin

was applied at first flower color. For 'Teddy Bear', Promalin at visible bud or visible bud plus one week reduced days to anthesis for plants sprayed with daminozide. The control containing the surfactant decreased time to flowering significantly compared to plain water (Table 3.14).

In Expt. 7, plants grown in North Carolina required fewer days to flowering than plants in Oklahoma (Table 3.16). The use of plant growth retardant increased time to anthesis compared to the control (Table 3.15).

Height. In all experiments, 'Pacino' and 'Elf' were the tallest cultivars (34.7 to 55.9 cm) and 'Big Smile' was the shortest (16.6 to 27.9 cm) (Tables 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, and 3.15). Number of plants per pot did not influence plant height (Table 3.1). When applied at anthesis, increasing Promalin concentration increased height (Table 3.2). A quadratic relationship existed between pot size and plant height such that plants were tallest when grown in 13-cm pots (Table 3.3). Plant height increased with increasing daylength for all cultivars except for 'Sundance Kid' for which photoperiod had no effect (Table 3.4).

Growth retardant treatments prevented excessive stem elongation, at both locations for all cultivars (Tables 3.7 and 3.19). Plants were shorter in Oklahoma than North Carolina. In both locations, Promalin applied at visible bud or visible bud plus one week produced taller 'Teddy Bear' plants than when applied at first flower color (Table 3.8). Plants were shorter with 3 plants/pot than with 1 plant/pot, except for 'Teddy Bear' plants in Oklahoma, which were similar in height (Table 3.20). Height of control plants sprayed with water or water plus surfactant was similar to that of plants sprayed with Promalin at anthesis (Table 3.14).

Number of nodes. Node number increased with increasing daylength for 'Big Smile', 'Elf', and 'Pacino' (Table 3.4). Node number was least for the 12-h photoperiod and greatest with the 16-h photoperiod for 'Sunspot' and 'Teddy Bear.' Photoperiod had no effect on node number for 'Sundance Kid.'

Flower diameter. Plants in Oklahoma had smaller flowers than the ones in North Carolina (Tables 3.17 and 3.18). The use of plant growth retardant decreased flower diameter compared to the untreated controls in Oklahoma (Table 3.17). In North Carolina, 3 plants/pot decreased flower diameter compared to 1 plant/pot (Table 3.18).

Postproduction. Increasing plant number per pot, Promalin concentration and pot size decreased postproduction life (Tables 3.1, 3.2 and 3.3). In Expt. 1-3, postproduction life varied from 10 to 15 days, with 'Pacino' and 'Elf' generally having the shortest life (Tables 3.1, 3.2, and 3.3). Cold storage for one to two weeks increased total postproduction life for 'Pacino' and 'Teddy Bear' but had no influence on the post-cooler life (Table 3.5).

In both locations (Expt. 6), 'Pacino' had a longer postproduction life than 'Teddy Bear' (Tables 3.10 and 3.14). Plants grown in Oklahoma had a longer postproduction life (13 days) than in North Carolina (11 days) (data not presented). When plants were sprayed with daminozide, a Promalin spray at first flower color decreased postproduction life (Table 3.9).

Foliar chlorosis rating after 5 days. 'Sundance Kid' and 'Teddy Bear' had the least chlorosis after 5 days (1 to 1.2) (Tables 3.1, 3.2 and 3.3). Number of plants/pot, Promalin applied at anthesis, and pot size had no effect on foliar chlorosis after 5 days. In Expt. 6, 'Pacino' had less foliar chlorosis than 'Teddy Bear' in both locations (Table

3.8). A daminozide spray decreased foliar chlorosis rating by 1.5 to 1.3 (data not presented). Within the controls, water plus surfactant or Promalin increased foliar chlorosis in 'Teddy Bear' (Table 3.14).

Foliar chlorosis rating after 10 days. 'Teddy Bear' had the least foliar chlorosis after 10 days in Expt. 1-3 (1.8 to 2.3) and 'Sunspot' had the most (2.9 to 3.3) (Tables 3.1, 3.2 and 3.3). Number of plants/pot and pot size had no effect on foliar chlorosis after 10 days (Tables 3.1 and 3.3). In Expt. 2, plants treated with 0 or 500 $mg.L^{-1}$ Promalin had the greatest foliar chlorosis (Table 3.2). In Expt. 6, foliar chlorosis ratings after 10 days was higher in Oklahoma than in North Carolina (Tables 3.12 and 3.13). With 'Teddy Bear' and both locations, Promalin applied at visible bud or first flower color had higher foliar chlorosis ratings then when applied one week after visible bud; however, time of Promalin application had no effect on 'Pacino' foliar chlorosis after 10 days (Tables 3.11 and 3.13). Application of water plus surfactant on 'Teddy Bear' increased foliar chlorosis compared to water only. (Table 3.14).

Foliar chlorosis rating after 15 days. Most plants were not marketable at 15 days after anthesis (Tables 3.1, 3.2, 3.3, 3.6 and 3.15).

Discussion

Cultivar. Only three of the six cultivars were acceptable: 'Elf', 'Pacino' and 'Teddy Bear' (Tables 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.10, 3.11, 3.12, 3.14, 3.16, 3.19, and 3.20) which was in agreement with results by Whipker et al. (1998). All three cultivars had an acceptable height, proper balance between foliage and flower, and a postproduction time of 10 days or more. Use of a plant growth regulator is recommended, whether it is a foliar spray of daminozide at 8,000 $mg.L^{-1}$ or paclobutrazol

drenches at 2 or 4 mg.L^{-1} (Tables 3.5, 3.6, 3.7, 3.9, 3.14, 3.15, 3.17, and 3.19), with drenches providing a greater degree of control (Whipker et al., 1998). 'Big Smile' plants were too short with very small flowers (Tables 3.1, 3.2, 3.3, and 3.4). 'Sundance Kid', on the other hand, was too tall, with long stems and few leaves and produced unattractive pots. The flowers of 'Sunspot' were often malformed, and petals did not expand. 'Elf' gave similar results to 'Pacino' and could be interchangeable.

Plant number per pot. Three plants per pot reduced time to anthesis compared with one plant/pot (Tables 3.1 and 3.15), possibly due to a slight stress caused by competition for nutrients, water and light (Bernier et al.,1981). However, increasing number of plants per pot to five increased plant height (Tables 3.1 and 3.20) and shortened postproduction life (Table 3.1) which may have been due to too much interplant competition. Pots with three or five plants per pot wilted readily which reduced postproduction time significantly, but surprisingly had no significant influence on plant foliar chlorosis.

Pot size. Pot size slightly influenced height and postproduction life (Table 3.3). The 10-cm diameter pots dried quickly each day, which could increase irrigation expenses.

Photoperiod. Most cultivars were facultative short day plants, with a critical daylength of approximately 12 h (Table 3.4). 'Sundance Kid' was a day neutral cultivar. Sunflowers have always been considered to be day neutral, but Robinson et al. (1967) and Schuster (1985) found that some sunflower cultivars were short day plants and some were day neutral.

Cold storage. Storage of the sunflower plants at 5°C for a week extended their postproduction life (Table 3.5). Thaxton et al. (1988) had shown similar results with *Hibiscus rosa-sinensis* in which plants stored at 10°C were of higher visual quality after storage than plants stored at 20 or 30°C. Also, potted carnations longevity was higher when stored at 7°C (24 days) than when stored at 13 or 18°C (22 and 18 days, respectively) (Leonard et al., 1995). Although cold storage for 2 weeks increased the overall postproduction life of the sunflowers and did not decrease the post-treatment life, foliage was cold damaged, thus 2 weeks cold storage was not commercially useful. Leonard et al. (1995) showed that potted carnations longevity was reduced from 11 to 4 days when stored for 6 or more days at 13 or 18°C.

Location / Promalin / Daminozide. Plants in North Carolina had fewer days to anthesis, but were taller and had a slightly shorter postproduction life than the plants in Oklahoma (Tables 3.6, 3.7, 3.8, and 3.9). The day/night set points were 24/18°C in North Carolina and 22/15°C in Oklahoma. Higher temperatures in North Carolina accelerated plant development relative to Oklahoma. Although daily temperatures were not recorded in North Carolina, average daily temperature may have been higher than in Oklahoma and North Carolina plants may have been subjected to a greater DIF. Berghage et al. (1990) showed that increasing the difference between day temperature (DT) and night temperature (NT) (DIF= DT-NT) increases plant height. Daminozide sprays were very effective in controlling plant height (Table 3.7) and decreased days to anthesis for both cultivars in both locations (Table 3.6). Promalin sprays reversed the effect of daminozide on 'Teddy Bear' when applied at early stages (visible bud and visible bud plus one week). Ranwala and Miller (1999) had showed stimulation of stem elongation induced

by early sprays of Promalin on Easter lilies (*Lilium longiflorum* Thunb.). Promalin did not produce sufficient results to be commercially useful in extending postproduction life or reduce foliar chlorosis of sunflowers.

Location / PGR / Plant number per pot. Daminozide and paclobutrazol treatments, following the rates recommended by Whipker and Dasoju (1998), were both effective in reducing plant height, regardless of cultivar or location (Table 3.19). Three plants per pot reduced days to anthesis and plant height, and gave a fuller look to the pot, which may make it more attractive for the consumer (Tables 3.15 and 3.20).

Conclusion. 'Elf', 'Pacino' and 'Teddy Bear' were determined to be the best cultivars for the production of potted sunflowers. One plant per 15-cm diameter pot gave excellent results, but three plants per pot might be more appealing to the consumers (J.Young, personal communication). A spray of daminozide at 8,000 $mg.L^{-1}$ or a paclobutrazol drench of 2 $mg.L^{-1}$ were very effective in controlling plant height and making plants suitable for pot production. A photoperiod of 12 hours is suggested to obtain a profitable high quality crop. Since plants required frequent irrigation, automated irrigation would be best. Promalin is not commercially useful. Cold storage for a week could extend postproduction life of the potted sunflowers. Sunflowers have potential as a potted crop, even if the postproduction life is still too short.

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Table 3.1. Effect of cultivar and number of plants per pot on sunflower production and postproduction life. Data are means of 30 to 40 plants per treatment. Expt. 1.

Treatment	Sowing to anthesis [z] (days)	Height (cm)	Post-production (days)	CL5[y]	CL10[y]	CL15[y]
			Cultivar main effect			
Big Smile	54	14.7	15	1.7	2.4	3.4
Pacino	86	36.1	10	1.5	2.5	3.0
Sundance Kid	70	35.3	13	1.2	2.4	3.0
Sunspot	65	19.3	11	1.7	3.3	4.7
Teddy Bear	70	22.9	13	1.2	2.3	3.2
Significance:						
$LSD_{0.05}$	1	0.8	3	0.2	0.3	-[x]
			Treatment main effect			
1	70	25.4	13	1.4	2.6	3.5
3	67	25.7	13	1.4	2.5	3.8
5	70	29. 5	12	1.5	2.6	3.5
Linear (L)	NS	NS	0.0070[w]	NS	NS	-[x]
Quadratic (Q)	0.0092	NS	NS	NS	NS	-[x]

[NS] Nonsignificant.

[z] Seeds were sown on 12 Nov. 1998.

[y] Foliar chlorosis rating 1-5, with 1 the least, determined at five (CL5), ten (CL10) and fifteen (CL15) days after placement in postproduction area.

[x] Insufficient plants were marketable at 15 days after placement in postproduction area for statistical analysis.

[w] P>F.

Table 3.2. Effect of cultivar and Promalin sprays on sunflower production and postproduction life. Data are means of 50 plants per treatment. Expt. 2.

Treatment	Sowing to anthesis [z] (days)	Height (cm)	Post-production (days)	CL5[y]	CL10[y]	CL15[y]
		Cultivar main effect				
Big Smile	54	13.5	12	1.7	2.6	3.0
Pacino	87	37.3	10	1.3	2.3	3.0
Sundance Kid	69	36.6	14	1.2	2.2	3.7
Sunspot	66	21.1	12	1.7	2.9	3.9
Teddy Bear	68	22.6	12	1.2	2.1	-[x]
Significance:						
$LSD_{0.05}$	2	0 6	1	0.2	0.3	NS
		Treatment main effect				
500.0	69	26.9	11	1.4	2.7	3.0
250.0	68	27.2	11	1.4	2.3	3.1
125.0	68	26.7	12	1.4	2.4	3.2
62.5	68	25.1	12	1.4	2.3	3.4
0	70	25.4	13	1.4	2.6	3.5
Linear (L)	NS	0.0187[w]	0.0024	NS	NS	NS
Quadratic (Q)	NS	NS	NS	NS	0.0097	NS
Cubic (C)	NS	NS	NS	NS	NS	NS

[NS] Nonsignificant.

[z] Seeds were sown on 12 Nov. 1998.

[Y] Foliar chlorosis rating 1-5, with 1 the least, determined at five (CL5), ten (CL10) and fifteen (CL15) days after placement in postproduction area.

[x] Insufficient plants were marketable at 15 days after placement in postproduction area for statistical analysis.

[w] P>F.

Table 3.3. Effect of cultivar and pot size on sunflower production and postproduction life. Data are means of 30 to 50 plants per treatment. Expt. 3.

Treatment	Sowing to anthesis [z] (days)	Height (cm)	Post-production (days)	CL5[y]	CL10[y]	CL15[y]
		Cultivar main effect				
Big Smile	52	15.2	15	1.6	2.3	3.3
Elf	86	36.8	10	1.3	2.0	3.5
Pacino	86	37.8	10	1.4	2.3	3.0
Sundance Kid	68	36.1	14	1.2	2.4	3.6
Sunspot	66	21.6	12	1.5	2.9	3.8
Teddy Bear	68	22.9	13	1.0	1.8	3.2
Significance:						
$LSD_{0.05}$	2	0.2	0.9	0.2	0.3	NS
		Treatment main effect				
10	71	27.9	13	1.3	2.2	3.4
13	71	29.5	13	1.3	2.4	3.6
15	71	27.9	12	1.4	2.4	3.4
Linear (L)	NS	NS	0.0030[x]	NS	NS	NS
Quadratic (Q)	NS	0.0059	0.0356	NS	NS	NS

[NS] Nonsignificant.

[z] Seeds were sown on 12 Nov. 1998.

[y] Foliar chlorosis rating 1-5, with 1 the least, determined at five (CL5), ten (CL10) and fifteen (CL15) days after placement in postproduction area.

[x] P>F.

Table 3.4. Effect of cultivar and 8-, 12-, or 16-h photoperiods on sunflower growth. Data are means of 10 plants per treatment. Expt. 4.

Cultivar	Photoperiod (hr)	Sowing to visible bud[z] (days)	Sowing to anthesis[z] (days)	Height (cm)	Nodes (no.)
Big Smile (BS)	8	29	56	16.6	10
	12	29	54	22.0	9
	16	29	61	27.9	11
Elf (E)	8	52	77	34.7	23
	12	57	82	44.4	26
	16	54	83	53.0	26
Pacino (P)	8	51	78	36.3	23
	12	54	80	42.2	24
	16	54	84	55.9	26
Sundance Kid (SK)	8	37	66	35.0	14
	12	35	65	39.3	13
	16	35	66	35.1	13
Sunspot (SS)	8	35	64	22.8	13
	12	34	63	27.4	12
	16	43	77	52.5	22
Teddy Bear (TB)	8	48	74	26.4	19
	12	46	72	31.3	16
	16	49	87	38.0	23

Significance:				
Cultivar (CV)	0.0001[y]	0.0001	0.0001	0.0001
Photoperiod (P)				
Linear (L)	0.0001	0.0001	0.0001	0.0001
Quadratic (Q)	NS	0.0001	0.0112	0.0001
P L*BS	NS	0.0001	0.0001	0.0235
P Q*BS	NS	0.0001	NS	NS
P L*E	NS	0.0001	0.0001	0.0062
P Q*E	0.0021	NS	NS	NS
P L*P	NS	0.0001	0.0001	0.0112
P Q*P	NS	NS	0.0129	NS
P L*SK	NS	NS	NS	NS
P Q*SK	NS	NS	NS	NS
P L*SS	0.0001	0.0001	0.0001	0.0003
P Q*SS	0.0001	0.0015	0.0001	0.0047
P L*TB	NS	0.0001	0.0001	0.0003
P Q*TB	0.0043	0.0001	NS	0.0001

[NS] Nonsignificant.

[z] Seeds were sown on 6 Dec. 1999.

[y] P>F.

Table 3.5. Effect of daminozide application and 5°C cold storage on sunflower postproduction life. Data are means of 5 plants per treatment. Expt. 5.

Cultivar	Daminozide (mg. L^{-1})	Storage time (wks)	Total postproduction life (days)	Post-treatment life (days)
Pacino	0	0	12	12
		1	19	12
		2	26	12
	8000	0	13	13
		1	18	18
		2	24	11
Teddy	0	0	11	11
Bear		1	18	11
		2	25	11
	8000	0	11	11
		1	19	12
		2	24	10
Significance:				
Cultivar (CV)			NS	NS
Daminozide (D)			NS	NS
Storage time (T)			0.0001[z]	NS

[NS] Nonsignificant.

[z] P>F.

Table 3.6. Effect of location, cultivar, daminozide, and 125 $mg.L^{-1}$ Promalin application at visible bud (VB), one week after visible bud (VB+1) or first flower color (FC) on sunflower days to flowering. Data are means of 10 plants per treatment. Expt. 6.

Location	Cultivar	Daminozide ($mg.L^{-1}$)	Time of Promalin application	Sowing to anthesis (days)[z]
North Carolina	Pacino	0	VB	62
			VB+1	62
			FC	64
		8000	VB	63
			VB+1	63
			FC	67
	Teddy Bear	0	VB	51
			VB+1	50
			FC	51
		8000	VB	50
			VB+1	51
			FC	53
Oklahoma	Pacino	0	VB	64
			VB+1	63
			FC	64
		8000	VB	62
			VB+1	63

		FC	67
Teddy Bear	0	VB	56
		VB+1	57
		FC	56
	8000	VB	58
		VB+1	58
		FC	60
Significance:			
$LSD_{0.05}$			1

[z] Seeds were sown on 12 Nov. 1998.

Table 3.7. Effect of location, cultivar and daminozide on sunflower height. Data are means of 30 plants per treatment. Expt. 6.

Location	Cultivar	Daminozide ($mg.L^{-1}$)	Height (cm)
North Carolina	Pacino	0	66.2
		8000	54.7
	Teddy Bear	0	41.7
		8000	35.6
Oklahoma	Pacino	0	49.6
		8000	41.7
	Teddy Bear	0	36.4
		8000	25.4
Significance:			
$LSD_{0.05}$			2.0

Table 3.8. Effect of location, cultivar and 125 $mg.L^{-1}$ Promalin application at visible bud (VB), one week after visible bud (VB+1) or first flower color (FC) on sunflower height and chlorosis rating after 5 days. Data are means of 20 plants per treatment. Expt. 6.

Location	Cultivar	Time of Promalin application	Height (cm)	CL5[z]
North Carolina	Pacino	VB	59.6	1.1
		VB+1	58.1	1.2
		FC	63.7	1.0
	Teddy Bear	VB	39.7	2.1
		VB+1	40.3	1.7
		FC	36.0	1.8
Oklahoma	Pacino	VB	49.2	1.0
		VB+1	41.7	1.0
		FC	46.4	1.1
	Teddy Bear	VB	32.4	1.8
		VB+1	31.4	1.5
		FC	29.0	1.1
Significance:				
$LSD_{0.05}$			2.5	0.2

[z] Foliar chlorosis rating 1-5, with 1 the least, determined at five (CL5) days after placement in postproduction area.

Table 3.9. Effect of daminozide and 125 $mg.L^{-1}$ Promalin applications at visible bud (VB), one week after visible bud (VB+1) or first flower color (FC) on sunflower postproduction life. Data are means of 40 plants per treatment. Expt. 6.

Daminozide ($mg.L^{-1}$)	Time of Promalin application	Postproduction (days)
0	VB	12
	VB+1	12
	FC	12
8000	VB	12
	VB+1	13
	FC	11
Significance:		
$LSD_{0.05}$		1

Table 3.10. Effect of cultivar and 125 mg.L^{-1} Promalin application at visible bud (VB), one week after visible bud (VB+1) or first flower color (FC) on sunflower postproduction life. Data are means of 40 plants per treatment. Expt. 6.

Cultivar	Time of Promalin application	Postproduction (days)
Pacino	VB	13
	VB+1	13
	FC	13
Teddy Bear	VB	10
	VB+1	12
	FC	11
Significance:		
$LSD_{0.05}$		1

Table 3.11. Effect of cultivar and 125 mg.L^{-1} Promalin application at visible bud (VB), one week after visible bud (VB+1) or first flower color (FC) on sunflower leaf chlorosis rating after 10 days. Data are means of 40 plants per treatment. Expt. 6.

Cultivar	Time of Promalin application	CL10[z]
Pacino	VB	3.0
	VB+1	3.0
	FC	3.0
Teddy Bear	VB	4.5
	VB+1	3.2
	FC	4.0
Significance:		
$LSD_{0.05}$		0.3

[z] Foliar chlorosis rating 1-5, with 1 the least, determined at ten (CL10) days after placement in postproduction area.

Table 3.12. Effect of location and cultivar on sunflower leaf chlorosis rating after 5 and 10 days. Data are means of 60 plants per treatment. Expt. 6.

Location	Cultivar	CL5[z]	CL10[z]
North Carolina	Pacino	1.1	2.8
	Teddy Bear	1.8	1.6
Oklahoma	Pacino	1.0	3.2
	Teddy Bear	1.5	3.1
Significance:			
$LSD_{0.05}$		0.1	0.2

[z] Foliar chlorosis rating 1-5, with 1 the least, determined at five (CL5), and ten (CL10) days after placement in postproduction area.

Table 3.13. Effect of location and 125 $mg.L^{-1}$ Promalin application at visible bud (VB), one week after visible bud (VB+1) or first flower color (FC) on sunflower leaf chlorosis rating after 10 days. Data are means of 40 plants per treatment. Expt.6.

Location	Time of Promalin application	CL10[z]
North Carolina	VB	4.1
	VB+1	3.4
	FC	3.8
Oklahoma	VB	2.8
	VB+1	2.7
	FC	3.0
Significance:		
$LSD_{0.05}$		0.2

[z] Foliar chlorosis rating 1-5, with 1 the least, determined at ten (CL10) days after placement in postproduction area.

Table 3.14. Effect of water, water plus surfactant (0.25% Tween 20) or 125 $mg.L^{-1}$ Promalin at visible bud on sunflower production and postproduction time. Data are means of 10 plants per treatment. Expt. 6.

Cultivar	Daminozide ($mg.L^{-1}$)	Treatment	Sowing to flowering[z] (days)	Height (cm)	Postproduction (days)	CL5[y]	CL10[y]	CL15[y]
Pacino	0	water	67	55.0	12	1.1	3.1	-[x]
		water + surfactant	62	53.6	13	1.0	3.1	-[x]
		Promalin	64	52.2	14	1.0	2.8	5.0
	8000	water	67	39.2	13	1.0	2.7	-[x]
		water + surfactant	63	36.0	14	1.0	2.7	-[x]
		Promalin	62	45.2	14	1.0	2.7	4.5
Teddy Bear	0	water	59	36.7	11	1.1	2.6	-[x]
		water + surfactant	56	32.6	12	1.6	3.0	-[x]
		Promalin	56	36.1	11	2.0	3.1	-[x]
	8000	water	62	22.1	11	1.1	3.6	-[x]
		water + surfactant	56	21.1	11	1.2	3.8	-[x]
		Promalin	58	28.7	10	1.5	2.7	-[x]
Significance:								
Cultivar			0.0001[w]	0.0001	0.0001	0.0001	0.0318	-[x]
Daminozide			0.0045	0.0001	NS	0.0001	NS	-[x]
Treatment			0.0001	NS	0.0056	0.0001	NS	-[x]
Interaction $LSD_{0.05}$			1	3.0	1	0.2	0.4	-[x]

[NS] Nonsignificant.

[z] Seeds were sown on 6 Dec. 1998.

[Y] Foliar chlorosis rating 1-5, with 1 the least, determined at five (CL5), ten (CL10) and fifteen (CL15) days after placement in postproduction area.

[x] Insufficient plants were marketable at 15 days after placement in postproduction area for statistical analysis.

[w] P>F.

Table 3.15. Effect of growth retardant and plants per pot on sunflower days to anthesis. Data are means of 40 plants per treatment. Expt. 7.

Growth retardant[z]	Plants per pot (no.)	Days to anthesis[y]
Control	1	70
	3	69
Daminozide	1	73
	3	71
Paclobutrazol	1	73
	3	69
Significance:		
$LSD_{0.05}$		1

[z] Plants were sprayed with water (control) or water + 8000 $mg.L^{-1}$ daminozide, or drenched with water + 2 $mg.L^{-1}$ paclobutrazol.

[y] Seeds were sown on 21 Dec. 1999.

Table 3.16. Effect of location and cultivar on sunflower days to anthesis. Data are means of 60 plants per treatment. Expt. 7.

Location	Cultivar	Days to anthesis[z]	Uniformity (days)[y]
North Carolina	Pacino	76	3
	Teddy Bear	64	2
Oklahoma	Pacino	77	6
	Teddy Bear	66	3
Significance:			
$LSD_{0.05}$		1	1

[z] Plants were sown on 21 Dec. 1999.

[y] Days from first flower to last flower to open within pot.

Table 3.17. Effect of location and growth retardant on sunflower flower diameter. Data are means of 40 plants per treatment. Expt. 7.

Location	Growth retardant[z]	Flower diameter[y] (cm)
North Carolina	Control	13.4
	Daminozide	13.0
	Paclobutrazol	13.4
Oklahoma	Control	12.3
	Daminozide	11.0
	Paclobutrazol	10.7
Significance:		
$LSD_{0.05}$		0.6

[z] Plants were sprayed with water (control) or water + 8000 mg.liter^{-1} daminozide (Dam), or drenched with water + 2 mg.liter^{-1} paclobutrazol (Pac).

[y] Average of two measurements, one perpendicular to the other, of open flowers with fully expanded petals.

Table 3.18. Effect of location and plants per pot on sunflower flower diameter. Data are means of 60 plants per treatment. Expt. 7.

Location	Plants per pot (no.)	Flower diameter[z] (cm)
North Carolina	1	14.2
	3	12.3
Oklahoma	1	11.0
	3	11.6
Significance:		
$LSD_{0.05}$		0.5

[z] Average of two measurements, one perpendicular to the other, of open flowers with fully expanded petals.

Table 3.19. Effect of location, cultivar and growth retardant on sunflower height. Data are means of 20 plants per treatment. Expt. 7.

Location	Cultivar	Growth retardant[z]	Height (cm)
North Carolina	Pacino	Control	37.2
		Daminozide	28.1
		Paclobutrazol	30.8
	Teddy Bear	Control	25.7
		Daminozide	17.6
		Paclobutrazol	18.7
Oklahoma	Pacino	Control	35.6
		Daminozide	26.5
		Paclobutrazol	21.1
	Teddy Bear	Control	23.9
		Daminozide	14.9
		Paclobutrazol	14.8
Significance:			
$LSD_{0.05}$			1.3

[z] Plants were sprayed with water (control) or water + 8,000 $mg.L^{-1}$ daminozide, or drenched with water + 2 $mg.L^{-1}$ paclobutrazol.

Table 3.20. Effect of location, cultivar and plants per pot on sunflower height. Data are means of 30 plants per treatment. Expt. 7.

Location	Cultivar	Plants per pot (no.)	Height (cm)
North Carolina	Pacino	1	44.3
		3	19.7
	Teddy Bear	1	21.3
		3	19.7
Oklahoma	Pacino	1	28.2
		3	27.3
	Teddy Bear	1	17.8
		3	18.1
Significance:			
$LSD_{0.05}$			1.1

CHAPTER IV

POTTED ORCHIDS: ESTABLISHMENT OF PRE-FINISHED BARE-ROOT *PHALAENOPSIS* PLANTS

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Additional index words: *Phalaenopsis* sp., light intensity, humidity

Abstract. Bare-root prefinished plants of a pink-flowered *Phalaenopsis* hybrid [*P.*'New Glade' x *Doritaenopsis* 'New Candy-Mount Beauty'] were grown in three potting media, under three light intensities and in low (45 ± 24%) or high (57 ± 24%) humidity environments. Plants grown in 2 perlite: 2 composted pine bark: 1 vermiculite (PEBV) had 2-4 fewer flowers per inflorescence than those grown in 2 pumice: 2 composted pine bark: 1 vermiculite (PUBV) or 9 composted pine bark: 1 peat moss (BAPM). Plants reached anthesis in 103 days when grown under no shade (790 $\mu mol.m^{-2}.s^{-1}$), and were marketable in 111 days, but were severely sun-damaged, while plants grown under 30 or 60% shade (375 or 230 $\mu mol.m^{-2}.s^{-1}$, respectively) had delayed flowering. Low humidity levels decreased the time to anthesis and production time, and increased stalk length (63 cm), compared to the high humidity environment (54.4 cm). None of the treatments were commercially useful to improve plant establishment (root growth).

Introduction

As the demand for orchid flowers for corsages has declined over the past few years, many orchid growers reduced cut flower production and market potted flowering orchids, among which the most popular is *Phalaenopsis*. For example, the USDA Florist and Nursery Crops Laboratory has developed a dwarf *Phalaenopsis* orchid with the goal of popularizing the orchid to non-orchid hobbyists (Griesbach, 1985). The flowers of the *Phalaenopsis* species are long lasting and plants flower for 2 to 4 months under favorable interior conditions. Consumers can handle *Phalaenopsis* orchids as with foliage plants and plants will reflower (Wang and Lee, 1994).

The production of orchids is expensive because they require up to 7 years to reach maturity (Dole and Wilkins, 1999). However, the shift from propagating orchids by seed to the purchase of mature or prefinished plants has contributed to the success of potted *Phalaenopsis* production and marketing. Flowering *Phalaenopsis* plants have become a short-term crop, requiring only 4-6 months production time (Wang and Lee, 1994). However, the major problem with using prefinished plants has been poor plant establishment of bare root plants in the container medium (R.Wolf and A. Blair, personal communications). New root development is delayed or does not occur, resulting in leaf yellowing and occasional death of the plant. Plants frequently produced low quality flower stalks when not well rooted.

Specific cultural details and experienced growers are needed to produce orchids. One of the major factor that affect root development is the planting medium (Genders, 1973). De Hertogh and Tilley (1991) showed that planting medium had variable effects on old and new basal roots and secondary root growth in *Hippeastrum* hybrids,

depending on the cultivar. Wang (1995a) tested different media and fertilization frequencies on *Phalaenopsis* 'Taisuco Kochdian' and showed that although the flowering date was unaffected, more flowers were produced with constant fertilization (1 $g.L^{-1}$ of 20-4.4-16.6 soluble fertilizer, twice a week) than with intermittent fertilization (same rate, once a week). The flowers of plants produced in PMC (equal volumes of #3 perlite, Metro Mix700 and charcoal) and RM (40% medium fir bark, 20% peat moss, 10% each of #3 and #2 perlite, 10% vermiculite and 10% ParGro Rockwool) were 10% larger than flowers of plants produced in bark (Wang, 1995a). Live moss (species nonspecified) has also been considered as a good media for *Phalaenopsis* plants because it provides adequate humidity, excellent aeration of the roots and nutrition; live moss nourishes blue green algae, which in turn fixes atmospheric nitrogen into amines, a natural source of fertilizer in nature (Fowlie, 1987).

Light is an important factor in the growth of *Phalaenopsis* orchids. Wang (1995b) noted that a minimum of 60 $\mu mol.m^{-2}.s^{-1}$ photosynthetic photon flux (PPF) was necessary to keep leaves healthy Fluorescent lights (400 $\mu mol.m^{-2}.s^{-1}$) yielded higher quality *Phalaenopsis* plants, with a larger plant diameter, than supplemental lighting (400 $\mu mol.m^{-2}.s^{-1}$) or normal greenhouse conditions (maximum 270 $\mu mol.m^{-2}.s^{-1}$) (Poole and Seeley, 1977).

Orchids are tropical plants and might require high humidity levels for better establishment. Gordon (1990) recommended humidity between 50 and 70% for optimal growth of *Phalaenopsis* plants.

The objective of our studies was to determine optimum production techniques for rapid, uniform, successful establishment of prefinished *Phalaenopsis* plants, by testing three different media, three light intensities and two humidity levels.

Materials and Methods

Phalaenopsis orchids of the cross *Phalaenopsis* 'New Glade' x *Doritaenopsis* 'New Candy-Mount Beauty' were received fully-grown (bare-rooted), with 3 to 5 fully expanded leaves per plant, and planted in 15-cm (0.9 L) diameter pots filled with a mix of 2 parts perlite, 2 parts composted pine bark and 1 part vermiculite (by volume), except for Expt. 1. The plants were grown in a corrugated polycarbonate-covered greenhouse set at 22/15°C day/night temperatures. Plants were fertigated twice a week with 250 $mg.L^{-1}$ N from a premixed commercial 20.0-4.4-16.6 fertilizer (Peter's Professional, Scott's Company, Marysville, Ohio). Each experiment consisted of three replications of six plants per treatment, for a total of 18 plants per treatment.

Media (Expt. 1). Plants were grown in 15-cm (0.9 L) diameter pots filled with three different media: 2 perlite: 2 composted pine bark: 1 vermiculite (PEBV), 2 pumice: 2 composted pine bark: 1 vermiculite (PUBV) or 9 composted pine bark: 1 peat moss (BAPM) (by volume). Eighteen single plant samples were used per treatment, and were arranged following a completely randomized design on the greenhouse benches.

Light intensity (Expt. 2). Plants were grown in PEBV under three different levels of shade: 0%, 30% or 60%, resulting in average light levels for the experimental period of 790, 375, or 230 $\mu mol.m^{-2}.s^{-1}$, respectively. Eighteen single plant samples were used per treatment.

Humidity (Expt. 3). Plants were grown in PEBV at two different average humidity levels: 45 ± 24 or 57 ± 24 %. Eighteen single plant samples were used.

Data collected included plant diameter (measured from leaf tip to leaf tip), number of healthy roots (at potting and termination), date of appearance of spike (elongating reproductive bud appearing at the base of the leaf), final inflorescence length, total number of flowers and buds, date of anthesis of the first flower, date of opening of third flower (sale date), flower size and crop uniformity (days from 20% to 80% of plants at anthesis). Data on roots and leaves formed were transformed to obtain only positive numbers prior to statistical analysis. Data were subjected to analysis of variance using the general linear models (GLM) procedure (SAS Institute, Cary, NC).

Results

Media (Expt. 1). Plants grown in BAPM had significantly more flowers (12) than the plants in PEBV (8) (Table 4.1). Media had no influence on other production factors.

Light intensity (Expt. 2). A curvilinear effect existed between shade level and days to anthesis and production time (Table 4.2). Plants grown under no shade reached anthesis in 103 days and were marketable 8 d later, while plants grown under 60% shade cloth reached anthesis in 136 days, but were still marketable 8 d later. Light intensity had no other effect on production of *Phalaenopsis* plants.

Humidity (Expt. 3). Plants grown in the low humidity environment reached anthesis earlier, had a longer inflorescence and were marketable sooner than plants under high humidity (Table 4.3). *Phalaenopsis* plants grown in an environment with 45% humidity flowered in 123 days, while those grown with 57% humidity flowered in 134 days. In a 45% or less humidity environment, *Phalaenopsis* plants had a 63-cm long

stalk (inflorescence), and only 54.4 cm in 57% or more humidity. Low humidity-grown plants were marketable in 129 d, 12 d earlier than the high humidity plants, which required 141 d. Humidity levels had no other effect on *Phalaenopsis* growth.

Discussion

Media. Plants grown in BAPM had two more flowers per stalk than plants in PUBV and four more than plants in PEBV (Table 4.1). Days to anthesis, stalk length and flower diameter were not affected by the composition of the medium. The production time was between 19 and 20 weeks, regardless of the medium. Even though the difference was not significant, the plants in BAPM and PUBV lost more roots (-8.9 and -8.1, respectively) than the plants in PEBV (-4.1). Perlite and vermiculite were previously recommended to be mixed with pine bark for growing *Phalaenopsis* plants to improve root medium drainage and aeration (Griesbach, 1985; Wang and Gregg, 1994). The medium containing only bark and peat moss had a tendency to stay too wet, inducing root rot, and eventually crown rot (personal observation), and the percentage of plant loss in BAPM was higher than in any other media (45%). Most plants lost leaves during the course of the experiment, but some leaves were replaced with new growth, with no significant influence of the medium composition.

Light intensity. Proper light intensity is needed for quality vegetative growth and for floral induction and development. Recommended light levels for *Phalaenopsis* plants are 240 to 400 $\mu mol.m^{-2}.s^{-1}$ (Dole and Wilkins, 1999). Time to anthesis and marketing were significantly delayed when the light intensity decreased from 790 $\mu mol.m^{-2}.s^{-1}$ to 230 $\mu mol.m^{-2}.s^{-1}$ (Table 4.2). Time to flowering in *Petunia* 'Express Blush Pink' was significantly delayed when PPF decreased from 13 to 6.5 $mol.m^{-2}.d^{-1}$ (Adams et al.,

1998). Flowering of *Hamelia patens* was also delayed under low light conditions (Armitage, 1995). Noordegraaf (1973) showed that decreased irradiance lowered the number of flowers per plant in *Anthurium*. In *Phalaenopsis* plants, number and size of the flowers were the same, regardless of the light intensity, which correlates with Wang (1995b) findings. Wang (1995b) showed that plants under 60 or 160 $\mu mol.m^{-2}.s^{-1}$ spiked faster than those under 0 or 8 $\mu mol.m^{-2}.s^{-1}$, which did not spike at all. No significant difference in the time to spike of the *Phalaenopsis* might have occurred because all light intensities tested were above 160 $\mu mol.m^{-2}.s^{-1}$ Although most of the plants lost some leaves and roots during the course of the experiment, the losses were not related to the light intensity under which the plants were grown. Light intensity did not affect the percentage of plant loss, even though the plants under no shade showed signs of sunburn, reducing the plant quality (personal observation).

Humidity. Time to flowering and marketing were decreased with low humidity levels, but flower number was unaffected (Table 4.3). High humidity has been shown to enhance vegetative growth in sweet pepper (*Capsicum annuum* L.) (Bakker, 1989) and Hand et al. (1996) showed delayed flowering in *Dendranthema grandiflora* Tzvlev in high humidity environments. However, increasing the air humidity decreased time to flowering in *Saintpaulia ionantha* Wendl., *Begonia* x *hiemalis* Fotch. and *Campanula isophylla* (Mortensen, 1986), and Gislerod and Mortensen (1990) reported for *Begonia* a larger number of flowers and shorter time to flowering when grown in high versus low relative humidity. In the current experiment, stalk length was significantly greater in the low humidity setting than in the high humidity setting, and stalks had more branches under the low humidity conditions (personal observation).

Conclusion. Adequate production techniques need to be found to significantly improve *Phalaenopsis* plants establishment. A key word in *Phalaenopsis* production is balance, and a precise control of the environment might be necessary to improve plant establishment and production. PEBV had both excellent drainage and aeration, which would be recommended for production. Plants should be grown under 30% shade and high humidity to reach their optimal quality.

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Table 4.1. Effect of 2 perlite: 2 composted pine bark: 1 vermiculite (PEBV), 2 pumice: 2 composted pine bark: 1 vermiculite (PUBV) or 9 composted pine bark: 1 peat moss (BAPM) on *Phalaenopsis* orchids. Means are an average of data from 18 plants per treatment, except for uniformity and loss which were based on three replications. Expt. 1.

Medium	Days to spike	Days to anthesis	Production time (days)	Uniformity[z]	Stalk length (cm)	Flowers (no.)	Flower diameter (cm)	Roots formed (no.)	Leaves formed (no.)	Change in plant diameter (cm)	Plant loss (%)
PEBV	89	124	134	19	55.0	8	7.9	-4.1	-0.7	7.4	22.2
PUBV	78	129	138	21	61.2	10	8.0	-8.1	-0.8	8.1	16.7
BAPM	72	134	143	22	54.2	12	7.7	-8.9	-1.3	7.2	44.6
Significance:											
LSD	NS	NS	NS	-	NS	2	NS	NS	NS	NS	-

[z] Days from 20% to 80% of plants flowering.

Table 4.2. Effect of 0, 30 or 60% shade providing 790, 375 or 230 $\mu mol.m^{-2}.s^{-1}$, respectively, on *Phalaenopsis* orchids. Means are an average of data from 18 plants per treatment, except for uniformity and loss which were based on three replications. Expt. 2.

Shade level (%)	Days to spike	Days to anthesis	Production time (days)	Uniformity[z]	Stalk length (cm)	Flowers (no.)	Flower diameter (cm)	Roots formed (no.)	Leaves formed (no.)	Change in plant diameter (cm)	Plant loss (%)
0	81	103	111	17	53.2	11	8.2	-4.7	-0.6	6.9	22.2
30	74	127	137	30	57.1	14	8.0	-4.6	-0.4	6.0	16.7
60	83	136	144	14	53.5	12	8.5	-4.1	-1.1	9.2	22.2
Significance:											
Linear	NS	0.0001	0.0001	-	NS	NS	NS	NS	NS	NS	-
Quadratic	NS	0.0175	0.0045	-	NS	NS	NS	NS	NS	NS	-

[z] Days from 20% to 80% of plants flowering.

Table 4.3. Effect of 45 and 57% humidity on *Phalaenopsis* orchids. Means are an average of data from 18 plants per treatment, except for uniformity and loss which were based on three replications. Expt. 3.

Humidity level (%)	Days to spike	Days to anthesis	Production time (days)	Uniformity[z]	Stalk length (cm)	Flowers (no.)	Flower diameter (cm)	Roots formed (no.)	Leaves formed (no.)	Change in plant diameter (cm)	Plant loss (%)
45	90	123	129	22	63.0	14	8.2	-7.4	-0.4	6.1	13.9
57	93	134	141	13	54.4	12	8.3	-8.0	-1.3	1.4	46.1
Significance:											
	NS	0.049	0.0304	-	0.0231	NS	NS	NS	NS	NS	-

[z] Days from 20% to 80% of plants flowering.

CHAPTER V

SUMMARY

GYNURA AURANTIACA

The vegetative stage is difficult to maintain in *Gynura*, as plants flower under a broad range of photoperiods and light intensities. Increasing shade level to 60% (230 $\mu mol.m^{-2}.s^{-1}$) and maintaining an 8-h photoperiod will delay flowering and allow successful maintenance of stock plants. Ethephon sprays, however, were not commercially useful due to excessive stunting at concentrations of 1200 $\mu L.L^{-1}$ or greater, and promotion of flowering at 600 $\mu L.L^{-1}$ or less.

HELIANTHUS ANNUUS

'Pacino' and 'Teddy Bear' were determined to be best cultivars for the production of potted sunflowers. One plant per 15-cm diameter pot gave excellent results, but three plants per pot might be more attractive to consumers. A spray of daminozide at 8,000 $mg.L^{-1}$ or a drench of paclobutrazol at 2 $mg.L^{-1}$ were very effective in reducing plant height and making plants suitable for pot production. Promalin was not commercially useful in extending postproduction life. A 12 hour-photoperiod is suggested for rapid flowering and moderate plant height. Excessive water stress decreased postproduction life, so automated watering should be used. Sunflowers have potential as a potted crop, even if the postproduction life is still too short.

PHALAENOPSIS HYBRID

Appropriate production techniques are required to improve *Phalaenopsis* plants establishment. A precise control of the environment needs to be established to provide *Phalaenopsis* plants with adequate humidity (57% or above), temperature, light intensity (375 $\mu mol.m^{-2}.s^{-1}$) and water to allow optimal growth. A medium composed of perlite, vermiculite and pine bark will provide good drainage and aeration, favor rapid root establishment and produce a high quality crop.

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