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Evaluation of Clones, Container Types and Tissue Culture Media for Production of Calla Lilies as a Nursery Crop[1]

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Abstract

Studies were designed to determine if colored callas (*Zantedeschia sp.*) can be successfully grown as a spring color crop under field conditions in the Southeastern United States without substantial modification of greenhouse culture protocols and if yield of clean stock from tissue culture can be improved. Results indicate colored calla lily production in containers in hardiness Zone 8B can be successful, without making significant modifications to either existing greenhouse production guidelines or the environment used for woody plant container culture. Neither fiber nor deeper containers improved overall calla performance over traditional plastic pots. 'Garnet Glow' and 'Pink Persuasion' produced the most blooms over 6 weeks of evaluation and would be better adapted for the spring color market than 'Florex Gold' or 'Mango' which bloomed heavily for only two weeks. The disease index developed for this study indicated 'Mango', 'Florex Gold', 'Rubylite Pink Ice' and 'Majestic Red' suffered the most soft rot damage while 'Pink Persuasion', 'Garnet Glow' and 'Pot of Gold' had the least when using field grown tubers. Tissue culture propagation efficiency was improved, as reflected in propagule size, by increasing sucrose levels in production media from 30 g/liter up to 120 g/liter, thus speeding production of larger clean microtubers. Proper cultivar selection and strict adherence to a disease control program, as in greenhouse production, allow production of high-quality colored callas in the Gulf South as an outside container crop for the spring color market.

Index words: container type, *Zantedeschia.*, tissue culture, disease index, calla, production.

Significance to the Nursery Industry

The nursery industry has changed in the United States over the past decade with an increased emphasis on production of seasonal color. The definitions that once differentiated floricultural (greenhouse) crops from nursery (woody) crops have been blurred as crops have been moved out of greenhouses and produced in container nurseries that were once the exclusive domain of woody genera. Production of traditional floricultural crops without cover exposes crops to seasonal fluctuations in rainfall and temperature, which often dictates modifications in cultural regimes developed for greenhouse production.

Evaluation of seven calla cultivars indicated that cultivars developed for dual culture as either cut flowers or flowering pot plants generally had shorter flowering cycles than cultivars selected specifically for pot plant production. 'Pink Persuasion' and 'Garnet Glow' were determined to be the best cultivars evaluated in terms of flower production, duration of flowering cycle and disease resistance. Fiber and tall plastic containers generally did not improve production under ambient field conditions with supplemental irrigation as compared to traditional #2 plastic containers of equivalent size. Microtuber fresh weight was increased with sucrose levels up to 120 g/liter thus increasing yield of larger clean tubers for production. This modification to current tissue culture protocols that involve shoot multiplication, rooting and acclimatization under controlled conditions of light, temperature, humidity and sanitation should result in more economically efficient propagation of clean stock thus lowering liner costs and pesticide applications to control soft rot of tubers. Healthy high-bloom-count calla flowering pot plants can be produced outside in the spring in the lower southeastern United States (Zone 8B) without modification of established greenhouse cultural regimens.

Introduction

Calla lilies (*Zantedeschia sp.*) have been grown for cut flower production and as seasonal outdoor garden plants for many years (15). Approximately eight species are native to South Africa and are generally considered to be cold hardy in USDA cold hardiness zones from 8 to 10 (2). *Zantedeschia aethiopica* (L.) Spreng., the only evergreen species, is white flowered and propagated by stemless rhizomes. Other species, commonly referred to as colored callas because species vary in flower color, are deciduous and are propagated by tubers (13).

Breeding and planting stock production are currently centered in California (3) and New Zealand (18). Breeding conducted in California used primarily *Z. rehmannii* (Engl.) (pink flowers), *Z. albomaculata* (Hook.) Baill. (white flowers) and *Z. elliottiana* (Watson) (yellow flowers) to develop selections for container production that are produced from seed but marketed to growers as tubers. Breeding efforts in New Zealand were directed primarily at development of improved selections for field cut flower production propagated by division and tissue culture. An additional robust species, *Z. pentlandii* (Watson) Wittm. (yellow flowers), was also a component of New Zealand hybrids (18).

Production of calla lilies under greenhouse conditions as a pot plant and under field conditions (ground beds) as a cut flower have been evaluated extensively (11). Corr and Widmer (6) found that photoperiod and moderate fluctuations in temperature and light intensity had no significant effect on floral initiation or yield. Trigger levels of gibberellin are required for floral induction in tubers with sensitivity

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to exogenous applications varying with duration of storage (8). A pre-plant tuber soak with gibberellic acid (GA_3) increased number of flowering shoots with optimum rate varying with duration of exposure and variety (5, 9, 16, 19). Properly conditioned tubers can be flowered any time of the year if growing medium temperature is maintained at a minimum of 12.8C (55F) and air temperature is less than 25C (77F) (17). Flower yields were equivalent in full sun and 55% shade in Georgia with higher shade levels having an adverse effect on yield (1).

Production of colored *Zantedeschia* cultivars is more expensive than other herbaceous perennial crops because of the high cost of liners (tubers) and the disease control program required to prevent root diseases during production. Flowering size tubers ranging from 4 to 6 cm (1.5 to 2.4 in) produced by traditional field cultural techniques require a minimum of two 16-week growth cycles interrupted by a rest period (19). Tissue culture techniques can be used to shorten tuber production to one growth cycle if multiple smaller tubers are used to compensate for lack of tuber size and corresponding flowering potential as compared to larger field-grown tubers (7).

Bacterial soft rot caused by *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey is the most common and destructive disease of calla. The pathogen, a ubiquitous organism found in soil and water, is easily spread during field culture. Most tubers produced under field conditions are infected with the pathogen to some degree and must be treated with pesticide dips and drenches to reduce the potential of major crop loss (4, 10, 12). Manipulation of cultural practices (20) and selection of cultivars with increased resistance (17) lessen pesticide applications needed to diminish crop losses from soft rot.

When containerized calla production is moved from covered greenhouses to a field environment where rainfall and temperature are no longer under grower control, soft rot may prove more difficult to control. New Zealand calla cultivars have been bred for field ground bed cut flower culture (18), which may improve tolerance to weather fluctuations during production, compared to California cultivars, which are generally used for greenhouse pot production (3). Standard plastic nursery pots may maintain an environment more favorable to disease development than alternative designs. Deeper containers improve drainage while fiber containers moderate temperature variation in the root zone. Modifications to tissue culture protocols may result in more economically efficient propagation of clean stock thus lowering liner costs and pesticide applications to control soft rot of tubers. Studies reported in this paper were designed to determine if colored callas can be successfully (low disease loss and multiple flowers per container) grown as a spring color crop under field conditions in the Southeastern United States without substantial modification of greenhouse culture protocols. Variables evaluated to improve production include seven calla cultivars representative of New Zealand and California breeding programs, three container types which vary in drainage and moisture retention and modifications of sucrose levels in tissue culture media to stimulate microtuber production and speed clean-stock propagation.

Materials and Methods

Experiment 1. This experiment was conducted on an open container pad under ambient field conditions, with supplemental overhead irrigation as needed, at the South Mississippi Branch Experiment Station in Poplarville (USDA cold hardiness zone 8B) from the middle of April to mid-July 2001. Mean weekly low temperatures ranged from 10.8 to 22.4C (51.4 to 72.3F) and highs ranged from 25 to 33C (77.0 to 91.5F). Weekly rainfall totals ranged from 0 to 22.4cm (8.8 in) with a total of 55.9 cm (22 in) over 13 weeks. The objective of this experiment was to determine if container type and cultivar affects flowering and disease during outside spring calla production in the Gulf South.

Tubers of five New Zealand bred cultivars ('Florex Gold', 'Majestic Red', 'Mango', 'Pink Persuasion', 'Pot of Gold') and two California bred cultivars ('Rubylite Pink Ice', 'Garnet Glow') were obtained from a commercial supplier (Pacific Callas, Calabasas, CA). The California cultivars are listed as *Z. rehmannii* selections for pot culture and the New Zealand cultivars are indicated to be early-flowering interspecific hybrids adapted to either cut or pot culture. All cultivars were preconditioned by the propagator with a standard dip of copper oxychloride 50% wp at 3 g/liter (0.4 oz/gal) to reduce corm bacterial soft rot and 100 ppm gibberellic acid (GA_3) to stimulate flowering (10). Seven calla cultivars were planted [two 5–6 cm (2–2.25 in) diameter tubers per pot] on April 17, 2001, in three container types [#2 plastic pot {21.6 cm (8.5 in) D × 21.6 cm (8.5 in) H; V = 6.2 liters (375 in^3)}, #2 fiber pot {21.6 cm (8.5 in) D × 21 cm (8.25 in) H; V = 6.0 liters (366 in^3)}, plastic tree pot {15.2 cm (6 in) W × 40.6 cm (16 in) H; V = 6.2 liters (380 in^3)}] filled with an organic mixture comprised of pine bark:peat (3:1 v/v) supplemented with 0.45 kg/m^3 (1.0 lb/yd^3) Micromax (Scotts, Marysville, OH) and 1.8 kg/m^3 (4 lb/yd^3) dolomitic limestone. Pots were drenched with Root Shield® (Bioworks, Fairport, NY) at 0.23 kg/378.5 liters (8 oz/100 gal) at planting and top dressed with the medium rate (19g (0.67 oz) / #2 pot) of Osmocote 15–9–12 (15N–4P–10K), (Scotts, Marysville, OH). A three component drench program (Medallion® 28.3 g/378.5 liters (1 oz/100 gal.), Phyton-27® 0.43 kg/378.5 liters (15 oz/100 gal.), Subdue® 28.3 g/378.5 liters (1.0 oz/ 100 gal) was applied 7, 28 and 42 days after planting as recommended for control of soil pathogens during greenhouse production (10).

The number of fully open blooms per pot was recorded at approximately two-week intervals from June 5, when the first cultivars had salable color until July 9 when most buds had opened on all cultivars. The number of vegetative shoots per pot was counted on July 23 as an index of post-flowering tuber vigor. Each plant was checked and rated for physical symptoms of soft rot expressed as water soaked spotting on leaves and/or wilted shoots using a 5 class scale (1 = no disease, plant vigorous; 2 = 1 to 33% of leaves with spots; 3 = 34 to 66% of leaves with spots and/or sectional wilting of plant shoots; 4 = most leaves with spots and/or wilted yellow or dead shoots; 5 = 100% shoot destruction with rotted corm, dead plant).

A factorial design with randomized complete block arrangement consisting of 7 cultivars, 3 container types and 7 reps was employed. In order to meet the assumptions of normality and/or equal variances amoung treatments, count data and disease index ratings were square root transformed after adding 0.5 to each value prior to analysis. Data were subjected to analysis of variance using SAS statistical software version 8.1 (Cary, NC) to determine the significance of main effects and interactions. Treatment means were compared

using Tukey's HSD test at 5% probability. Non-transformed means are presented in tables but f-test and mean separations are based on transformed data.

Experiment 2. The objective of this experiment was to stimulate cormel (microcorm) production from subcultured calla plantlets *in vitro*. This technique will facilitate the production of calla propagules for direct planting, which eliminates the acclimatization step often required for the successful establishment of micropropagated plantlets.

Since no published tissue culture procedures for *Zantedeschia* were located, a published procedure for cocoyam (*Xanthosoma sagittifolium*), another aroid, was modified and evaluated (14). Calla lily 'Pink Persuasion' corms were obtained from a commercial supplier (Pacific Callas, Calabasas, CA) and soaked in a 0.2% (w/v) silver nitrate ($AgNO_3$) aqueous solution for 24 hr followed by a thorough rinse under running tap water. Corms were sealed in freshly opened 'Ziploc' bags (S.C. Johnson, Racine, WI) and placed on the laboratory bench at room temperature to initiate sprouting. Shoots were collected from the sprouted corms seven days after silver nitrate treatment and trimmed to obtain explants 0.4–0.5 cm long. Explants were disinfested with 20% (v/v) aqueous household bleach solution for 15 min followed by three rinses in sterile distilled water and then cultured.

Shoot multiplication. Shoot tip cultures were initiated on B5 basal medium (BBM) supplemented with dicamba (0, 0.3, 1.0 and 3.0 mg/liter) and TDZ (0, 0.1 and 0.3 mg/liter) in a factorial combination, B5 vitamins, 3% sucrose and 0.7% agar (Sigma). The pH was adjusted to 5.7 prior to autoclaving at 121C (250F) for 15 min. Media were dispensed into sterile Petri plates (100 mm × 15 mm) with each plate containing 20 ml. Cultures were placed in a growth room at 25 ± 2C illuminated with cool-white fluorescent lamps providing an average irradiance of 50 µmol $m^{-2}s^{-1}$ for 16 h per day. Highly organogenic calli and subsequent multiple shoot production were induced on media containing 0.1 mg/liter TDZ and 1.0 mg/liter dicamba or 0.3 mg/liter TDZ and 0.3 mg/liter dicamba. The two media were statistically equivalent so shoots generated were combined for subsequent propagation studies. Shoots were separated and further multiplied in BBM containing 0.05–1.0 mg/liter TDZ without agar (25 ml) in Magenta GA-7 containers (Magenta Corp. Chicago, IL). No statistical differences between treatments were detected so propagules were again consolidated. Plantlets with at least two fully expanded leaves were used for microtuber production.

Microtuber production. To facilitate rapid regrowth of shoots and microtuber production, plantlets were reduced in size by topping and trimming the roots. Plantlets that were trimmed were approx. 5–10 cm (2–4 in) tall. Trimming involved cutting back the long petioles and the crown to a final explant height of 2–2.5 cm (.75–1.0 in) and detaching the existing roots. Trimmed plantlets were then aseptically transferred into the BBM media (one explant per flask) supplemented with sucrose at 30, 60, 90, 120 or 180 g/liter in 50 ml liquid media in 250 ml Erlenmeyer flasks. Cultures were incubated as described earlier. Each sucrose treatment was replicated nine times and the experiment was repeated once. Due to contaminations in two treatments, only results of one experiment are presented. The numbers of new shoots and microtubers were subjected to analysis of variance using SAS statistical software version 8.1 (Cary, NC). Treatment means were compared using LSD test.

Results and Discussion

Experiment 1. Cultivar had a highly significant effect on flowering as indicated by the number of flowers counted per container on June 5, June 22 and July 9 as well as the combined count for the three dates (Table 1). 'Florex Gold' had

Table 1. Performance of seven calla cultivars grown in three container types as a nursery crop under field conditions in south Mississippi.

Treatment	Mean number of flowers/pot				Vigor (shoots/pot)	Disease index[z]
	June 5	June 22	July 9	3 Dates		
Cultivar[y]						
Florex Gold	10.9a	1.1de	0.3c	12.3ab	0.9d	4.0a
Garnet Glow	0.5d	7.9a	8.7a	17.1a	6.7a	2.4bc
Mango	6.8b	0.4e	0.0d	7.2c	1.2d	4.4a
Majestic Red	2.0c	2.6bc	0.5c	5.1c	1.0d	3.4ab
Pink Persuasion	6.5b	3.7bc	2.0b	11.6b	4.3b	2.2c
Pot of Gold	0.7cd	2.1cd	2.0b	4.7c	3.7bc	2.5bc
Rubylite Pink Ice	1.1cd	4.9b	2.1b	8.1c	2.1cd	3.7a
Pot type[y]						
# 2 Plastic	4.7a	3.8a	1.9ab	10.3a	2.6a	3.2a
# 2 Fiber	4.0a	2.8a	1.7b	8.5a	3.1a	3.4a
Tall Plastic	3.4a	3.3a	2.8a	9.5a	2.9a	3.1a
Significance[x]						
Cultivar	.001**	.001**	.001**	.001**	.001**	.001**
Pot	.100[NS]	.076[NS]	.023*	.112[NS]	.104[NS]	.755[NS]
Cultivar × Pot	.001**	.046*	.904[NS]	.031*	.001**	.036*

[z]Disease index: 1 = no disease, plant vigorous; 2 = 1 to 33% of leaves with spots; 3 = 34 to 66% of leaves with spots and/or sectional wilting of plant shoots; 4 = most leaves with spots and/or wilted yellow or dead shoots; 5 = 100% shoot destruction with rotted corm, dead plant.

[y]Means within a column having the same letters are not significantly different according to Tukey's HSD, $p < 5\%$.

[x]Pr > F; actual p values designated as Non-significant (NS) or significant at $p \leq 0.05$ (*) or 0.01 (**).

significantly more flowers than the other cultivars on June 5 with an average of 10.9 per pot while 'Mango' and 'Pink Persuasion' were second-tier performers with averages of 6.8 and 6.5, respectively. The count on June 22 indicated 'Garnet Glow' was best with an average of 7.9 while 'Rubylite Pink Ice' (4.9), 'Pink Persuasion' (3.7) and 'Majestic Red' (2.6) ranked second. At the third count on July 9, 'Garnet Glow' still ranked first with an average of 8.7 flowers. 'Pink Persuasion' (2.1), 'Pot of Gold' (2.0) and 'Rubylite Pink Ice' (2.0) ranked second.

'Garnet Glow' averaged more flowers per pot (17.1) than other cultivars tested when counts for the three dates were combined and analyzed. 'Florex Gold' (12.3) and 'Pink Persuasion' (11.6) were intermediate performers. 'Rubylite Pink Ice' (8.1), 'Mango' (7.2), Majestic Red (5.1) and Pot of Gold (4.8) were third echelon performers.

The New Zealand cultivars ('Florex Gold', 'Majestic Red', 'Mango', 'Pink Persuasion', and 'Pot of Gold') were selected for both cut flower and pot plant production. Two of the three best flowering New Zealand cultivars, 'Florex Gold' and 'Mango', produced 88 and 94% of total bloom, respectively, at the first count on June 5. The third cultivar, 'Pink Persuasion', produced 56% of its blooms by June 5 and an additional 32% by June 22. Cut flower crops are usually programmed to supply specific market windows such as a holiday. For flowering pot plants, extended color displays are preferred. It is difficult for dual-purpose cultivars to satisfy both these contradictory market demands. The flowering cycle of 'Florex Gold' and 'Mango' is too short for production as a spring flowering pot in the Gulf South, whereas the more extended cycle for 'Pink Persuasion' is acceptable.

The two California cultivars, which were selected exclusively for flowering pot plant production, had the desired extended color display but tended to flower later than the New Zealand cultivars. 'Garnet Glow' displayed 46% of its blooms on June 22 and 51% on July 9. 'Rubylite Pink Ice' displayed 60% of its flowers on June 22 and 25% on July 9.

Cultivars displayed significant differences in vigor as reflected in the number of vegetative shoots per pot and disease index when flowering was completed (Table 1). 'Garnet Glow' had significantly more shoots per pot (6.8) than the other six cultivars. 'Pink Persuasion' (4.3) and 'Pot of Gold' (3.7) were intermediate performers. 'Rubylite Pink Ice' (2.1) and 'Pot of Gold' were not statistically different. 'Mango' (1.2), 'Majestic Red' (1.0) and 'Florex Gold' (0.9) were equivalent in shoot number to 'Rubylite Pink Ice'. The disease index indicated 'Mango', 'Florex Gold', 'Rubylite Pink Ice' and 'Majestic Red' suffered the most disease damage. 'Garnet Glow' and 'Pot of Gold' had intermediate damage. 'Pink Persuasion' had the best disease index rating. Among the prolific flowering cultivars ('Garnet Glow', 'Florex Gold', 'Pink Persuasion', 'Mango') only 'Garnet Glow' and 'Pink Persuasion' maintained both vigor and low disease during the production cycle.

The production container had no significant effect on flowering for initial bloom counts made on June 5 (Table1). There was a highly significant cultivar × pot interaction, however, indicating that all cultivars did not respond to changes in container type in the same manner. Comparison of means for the three container types for each cultivar separately, indicated the overall trend was not reflected in the means for 'Garnet Glow' and 'Mango' where tall plastic containers averaged more than twice as many flowers as were produced in the #2 fiber containers. These two cultivars were selected for production in ground beds and the deeper pots probably more closely approximate the zone of root development under field production conditions than the fiber pots. 'Rubylite Pink Ice' averaged approximately 1.5 blooms per container for the #2 fiber and tall plastic containers but only 0.3 for the #2 plastic containers. Bloom counts ranked tall plastic containers 1 for 'Garnet Glow' when the general trend was to rank it 3. 'Rubylite Pink Ice' growing in the #2 plastic containers ranked 3 when the trend across clones was to rank 1.

No significant differences were detected for the three container types for the second bloom count on June 22. There was a significant cultivar × pot interaction which can be accounted for in part by rank changes of the various cultivars in the three container types. The largest changes occurred for bloom numbers of 'Florex Gold' and 'Majestic Red' where #2 plastic containers ranked 3 when the trend among all clones was to rank this container type 1.

Bloom counts for callas growing in #2 fiber and tall plastic containers were significantly different on July 9 while the counts for #2 plastic containers were equivalent to the other two container types. No significant differences in bloom counts due to container were detected when data for the three dates were combined. A significant cultivar × pot interaction is attributed to rank changes as reported by date.

Pot type did not have a general effect on plant vigor or disease index but there were significant cultivar × pot interactions. Examination of plant vigor and disease index means for each container type for the seven cultivars revealed that the interactions were due to variation in ranking of container type from 1 to 3 according to cultivar. 'Garnet Glow' and 'Rubylite Pink Ice' growing in tall plastic containers ranked 1 for vigor when the overall trend across cultivars was a rank of 3. The disease index for 'Pink Persuasion' and 'Pot of Gold' ranked #2 fiber containers 1 when the trend was a ranking of 3.

It is not practical for growers to fine tune calla production practices such as container type unless large quantities of a particular cultivar can be marketed. Results indicate that although some cultivars may have a modest positive response to one of the three container types evaluated at some point in the production cycle, fiber and tall plastic containers are generally no better than traditional plastic pots and there is no justification to change pot types for outdoor calla production.

Experiment 2. The objective of this experiment was to assess the role of sucrose in stimulating the production of microtubers of calla lily. Soaking the source material (tubers) in 0.2% $AgNO_3$ significantly reduced contamination often associated with the culture of shoot buds obtained from field grown corms. Highly organogenic callus initiation, proliferation and multiple shoot production were stimulated in media containing 0.1 mg/liter TDZ and 1.0 mg/liter dicamba or 0.3 mg/liter TDZ and 0.3 mg/liter dicamba. Explants cultured in other media containing TDZ, dicamba or their combinations failed to grow and subsequently senesced.

Sucrose at 120 g/liter significantly increased shoot fresh weight and microtuber fresh weight, while 90 g/liter enhanced new shoot production (Table 2.) compared to 30 g/liter, the amount used in standard culture media. There was an average of 3 new microtubers produced in responsive cultures containing sucrose at 120 g/liter. Regenerated microtubers

Table 2. Comparison of shoot and microtuber production of calla lily in B5 basal medium (BBM) supplemented with various concentrations of sucrose.

Sucrose (g/L)	Shoot fresh wt (g)	Microtuber fresh wt (g)	Number new shoots
30	2.50ab[z]	0.00c	0.44c
60	2.50ab	1.20bc	3.33b
90	1.92bc	1.70b	4.78a
120	4.05a	3.80a	3.22b
180	0.60c	0.37bc	0.44c

[z]Means within a column having the same letter are not significantly different according to t-test (LSD, $p < 5\%$).

were transferred out of tissue culture directly into peat moss for further growth, after which they easily established in a non-sterile organic potting mix comprising pine bark:peat (3:1 v/v) in the greenhouse. This protocol eliminates the costly and tedious acclimatization step often required when transferring plantlets from *in vitro* cultures to the greenhouse or field environment.

Propagation *in vitro* not only has the potential to rapidly increase the number of plants but also serves as an indexing tool to ensure production of clean planting material. Traditionally, calla lily is propagated and grown from tubers produced in pots or soil beds. This system of production has engendered the build-up and dissemination of the soil borne pathogen *Erwinia carotovora*, causal agent of calla tuber soft rot. The economic benefit of a clean stock program invariably outweighs the cost of such a program. Tissue culture derived microtubers not only represent the highest form of propagule sanitation, but are directly plantable and may offer the best form of propagule for a plug system adapted to automation while minimizing mechanical injury and disease incidence during production. Continued disease suppression during production could be sustained through diligent sanitation and application of new less costly technologies currently entering the market such as saprophytic competitive organisms and messenger proteins which serve as effective barriers to initial contamination.

Pot callas sell for a premium price because of uniquely shaded, bright colored flowers that attract consumer interest and stimulate sales. Colored callas have a deserved reputation as an expensive crop intolerant of poor production practices. Results of our studies indicate that proper cultivar selection and a conscientious disease prevention and control program facilitate calla production without modification of the customary field container production environment in the Gulf South. Tissue culture techniques presented for calla propagation may be incorporated into production programs to improve sanitation and reduce production expenses.

Literature Cited

1. Armitage, A.M. 1991. Shade affects yield and stem length of field-grown cut-flower species. HortScience 26:1174–1176.

2. Armitage, A.M. 1997. *Zantedeschia*, p. 1083–1085. Herbaceous Perennial Plants. Stipes Publishing, Champaign, IL.

3. Brown, J. 1990. California calla breeding. Herbertia 46:165–169.

4. Corr, B.E. 1993. *Zantedeschia* research in the United States: Past, present and future. Acta Hort. 377:177–187.

5. Corr, B.E. and R.E. Widmer. 1987. Gibberellic acid increases flower number in *Zantedeschia elliottiana* and *Z. rehmannii*. HortScience 22:605–607.

6. Corr, B.E. and R.E. Widmer. 1990. Growth and flowering of *Zantedeschia elliottiana* and *Z. rehmannii* in response to environmental factors. HortScience 25:925–927.

7. Dole, J.M. and H.F. Wilkins. 1999. *Zantedeschia*, p. 550–555. *In*: Floriculture; principles and species. Prentice Hall, Upper Saddle River, NJ.

8. Funnel, K.A. and A.R. Go. 1993. Tuber storage, floral introduction, and gibberellin in *Zantedeschia.* Acta Hort. 337:167–172.

9. Funnel, K.A., B.R. MacKay, and C.R. Lawoko. 1992. Comparative effects of Promalin and GA_3 on flowering and development of *Zantedeschia* 'Galaxy'. Acta Hort. 292:173–179.

10. Golden State Growers. 2000. Callafornia callas: Guidelines for pot growers. Golden State Bulb Growers, Watsonville, CA.

11. Kuehny, J.S. 2000. Calla history and culture. HortTechnology 10:267–274.

12. Kuehny, J.S., G.E. Holcomb, W.C. Chang, and P.C. Branch. 1998. Chemical treatments to control *Erwinia* soft rot in calla rhizomes. HortTechnology 8:353–356.

13. Letty, Cynthna. 1973. The genus *Zantedeschia*. Bothalia 11:5–26.

14. Nyochembeng, L.M. and S. Garton. 1998. Plant regeneration from cocoyam callus derived from shoot tips and petioles. Plant Cell, Tissue and Organ Culture 53:127–134

15. Post, K. 1959. *Zantedeschia* (calla), p.847–851. Florist Crop Production. Orange Judd Publishing, NY.

16. Reiser, R.A. and R.W. Langhans. 1993. Cultivation of *Zantedeschia* species for potted plant production. Acta Hort. 337:87–94.

17. Snijder, R.C. and J.M. van Tuyl. 2002. Evaluation of tests to determine resistance of *Zantedeschia spp.* (*Araceae*) to soft rot caused by *Erwinia carotovora* subsp. *carotovora.* European J. Plant Path. 108:565–571.

18. Welsh, T.E. 1990. The New Zealand calla. Proc. Intern. Plant Prop. Soc. 40:478–484.

19. Welsh, T.E. and J. Clemens. 1992. Protected cropping of *Zantedeschia* tubers and cutflowers in New Zealand. Acta Hort. 319:335–339.

20. Wright, P.J., G.K. Burge and C.M. Triggs. 2002. Effects of cessation of irrigation and time of lifting of tubers on bacterial soft rot of calla (*Zantedeschia spp.*) tubers. New Zealand J. Crop and Hort. Sci. 30:265–272.