Crop Reports

Calla History and Culture

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ADDITIONAL INDEX WORDS. *Zantedeschia*, botany, taxonomy, cultural requirements, pests, postproduction, postharvest

Calla is a tropical plant native to Africa extending from Cape Province to Eastern Orange Free State, Natal, Lesotho, Swaziland, Transvaal, Rhodesia, Malawi, Zambia, Angola, and into northern Nigeria (Letty, 1973; Tjia, 1985). The genus *Zantedeschia* was assigned to calla by Sprengel in 1826 in honor of Italian botanist Giovanni Zantedeschia (Letty, 1973).

There are many common names and several species. Common names include calla lily, pig lily, arum lily, aroid lily, zantedeschia, richardia, cape arum, cape lily, black-eyed arum, yellow arum, cuckoo-pint, jack-in-the-pulpit, lily of the Nile (Funnell, 1993; Hoogasian, 1992; Tjia, 1985). Other common names of calla include kleinvarkblom, varkblomme, varkore, aronskelke, persvarkoor, varkoorlelie, varkore (Funnell, 1993).

The genus *Zantedeschia* is a part of the Araceae family. There are seven recognized species and two subspecies of *Zantedeschia*: *Z. aethiopica* (L.) Spreng., *Z. rehmannii* Engl., *Z. jucunda* Letty, *Z. elliottiana* (Watson) Engl., *Z. pentlandii* (Watson) Wittm., *Z. odorata* P.L. Perry, *Z. albomaculata* (Hook.) Baill. subsp. *albomaculata*, *Z. albomaculata* (Hook.) Baill. subsp. *macrocarpa* (Engl.) Letty, and *Z. albomaculata* (Hook.) Baill. subsp. *valida* Letty. (Letty, 1973; Perry, 1989). Closely related genera are *Aglaonema* Schott., *Anthurium* Schott., *Caladium* Venten., *Dieffenbachia* Schott., *Epipremnum* Schott., *Monstera* Adans., *Nephthytis* Schott., *Philodendron* Schott., *Spathiphyllum* Schott., and *Syngonium* Schott. (Liberty Hyde Bailey Hortorum, 1976).

Calla have two different types of storage organs (Funnell, 1992). *Zantedeschia aethiopica* have stemless rhizomes and are an evergreen species. The remaining species have compact stems or tubers and are deciduous. The leaves are entire and born on a long petiole. The inflorescence is composed of a fleshy spadix bearing the true flowers, subtended by a single showy spathe (Corr, 1993; Corr and Widmer, 1987; Liberty Hyde Bailey Hortorium, 1976; Tjia, 1985).

Calla may be grown as outdoor garden plants, commercial cut flowers and more recently as flowering potted plants. Although this plant has not been widely grown commercially, there is an abundance of information on all aspects of calla and it continues to increase in popularity. *Zantedeschia elliotiana*, *Z. aethiopica*, and *Z. rehmannii* have been grown for cut flower production or outdoor garden plants for many years (Post, 1959). Since the 1980s, research has been conducted to determine the feasibility of using *Zantedeschia* species as flowering potted plants. In addition, many calla hybrids have been bred for forcing as flowering potted plants (van Scheepen, 1991). Funnell (1993) provides a list of 61 species and cultivars commercially available internationally. About 50% of flowering size calla tubers are produced in the United States, The Netherlands and New Zealand produce 45% and India, Sri Lanka, and Central America produce 5% (T. Lukens, personal communications). In the United States, more than 95% of calla are grown as flowering potted plants whereas in Europe about 80% to 85% are used as cut flowers.

Genetics and cultivar development

Natural species and hybrids of calla are diploid with 32 chromosomes (Cohen and Yao, 1996). There are a number of postfertilization incompatability barriers between species with most calla being self fertile. Development in the United States has been concentrated in California, Luther Burbank made crosses within the genus *Zantedeschia* and produced several new cultivars at the turn of the century (Welsh, 1991). In the 1940s and 1950s Shibuya (1956), also in California, conducted extensive intercrossing work with *Z. rehmannii*, *Z. albomaculata*, and *Z. elliottiana*. His breeding work produced spathe coloration covering almost the entire color scale along with variations in the shape and size of leaves and the tubers, the pattern and distribution of leaf spots, plant growth and plant heights. In New Zealand, breeding has been conducted by Brljevich of Maungaturoto in 1932, Matthews of Waikanae started collecting and breeding in 1946, and Harrison conducted breeding in the 1960s (Welsh, 1991). The Brown family of Central California began breeding calla in the 1940s; however, homogeneous seed strains were not readily obtained, and the new hybrids were sold as mixed hybrids for many years (Brown, 1990). The inability of growers to control bacterial soft rot [*Erwinia carotovora* subsp. *carotovora* (Jones) Bergey et al.] and poor seed collection, decreased demand, production and breeding in the 1960s and 1970s. Cultural techniques for preventing and suppressing disease infestation, the development

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of tissue culture, the development of true F_1 seed lines in the United States and a demand for wide range of plants and flowers has revived the calla industry and breeding programs. Current breeding programs select for use as flowering pot plants and cut flowers. Breeders are using the existing hybrids and species and are breeding for: plant height, a large number of spathes (multibranching), spathe size, ease of culture, disease resistance, ability to force, fragrance, stem strength and post production longevity (Brown, 1990; De Hertogh, 1996; Funnell, 1993). Golden State Bulb Growers (Watsonville, Calif.) has, for example, introduced 12 new true F_1 hybrid seed lines over the last 10 years (T. Lukens, personal communications). In addition, in vitro chromosome doubling of calla by induction of polyploid strains has been reported by Cohen and Yao (1996). The combinations of these efforts will potentially increase the range of hybrids that can be produced.

Species and cultivars

More than 10 species have been proposed for the genus *Zantedeschia* (Traub, 1948), later reduced to six (Letty, 1973). A recent addition brings the current number to seven (Perry, 1989), with two subspecies (Funnell, 1993; Letty, 1973). The species fall into two specific groups: 1) evergreen (plants with foliage that does not die down in the winter) and 2) deciduous (plants with foliage that dies to the ground during winter) (Letty, 1973; Tjia 1985).

The evergreen species *Z. aethiopica* with, ovate-cordate solid green leaves and white spathes at least 36 inches (100 cm) tall has long been used for cut flowers and container plants (Fig. 1). It flowers in summer and late fall into early spring in frost free areas (Letty, 1973; Dole and Wilkins, 1999; Tjia and Funnell, 1986). Cultivar selections include the dwarf selection 'Childsiana', 'Pink Mist' a pink spathe selection, and 'Green Goddess' with a green spathe. The species has naturalized (perennialized) in many countries, e.g., New Zealand, Australia, Mexico, and California. (Dole and Wilkins, 1999; Tjia, 1985). *Zantedeschia aethiopica* have solid green leaves and is the only species to have long, branched rhizomes. All other species have compact, disk-shaped stems referred to as tubers (Letty, 1973).

Zantedeschia rehmannii has deciduous, narrow, lanceolate leaves which are neither spotted nor lobed (Fig. 2). The 24 inch (60 cm) tall spathes bloom in summer and range in color from yellow to lemon yellow and pink to dark maroon (Letty, 1973; Funnell, 1993; Tjia, 1985).

Zantedeschia jucunda has deciduous, triangular-hastate leaves that are always spotted (Fig. 3). Spathes are golden yellow with a purple throat at the base and are summer blooming. This species is used mostly as a landscape plant (Letty, 1973; Funnell, 1993; Perry, 1989; Tjia, 1989).

Zantedeschia elliottiana has deciduous, orbicular-ovate leaves and yellow to gold colored spathes that are about 12 inches (30 cm) tall, blooming in the summer (Funnell, 1993; Tjia, 1989; Tjia, 1985; Letty, 1973).

Zantedeschia pentlandii (syn. *Z. angustiloba*) has deciduous, oblong-elliptic to oblong-lanceolate leaves usually without white spots (Fig. 4). Spathes can be white, cream, ivory, pale greenish yellow or yellow, usually with a purple blotch at the base, are up to 24 inches (60 cm) tall and bloom in the summer (Letty, 1973; Funnell, 1993; Tjia, 1989).

Zantedeschia odorata has deciduous, ovate to cordate leaves with milk-white spathes having a green base and sweet scent (Funnell, 1993; Perry, 1989).

Zantedeschia albomaculata has deciduous, triangular-hastate leaves and the spathe color ranges from creamy to straw colored to pale yellow, with purple interior bases; flower stems can be up to 18 inches (45 cm) tall (Funnell, 1993; Tjia, 1985).

Zantedeschia albomaculata sub. *albomaculata* has deciduous, oblong-hastate leaves, and a plant height of up to 30 inches (75 cm) (Fig. 5). The spathes are white, ivory, pale yellow, to coral pink, bloom in the summer and are not widely used commercially (Letty, 1973; Funnell, 1993; Tjia, 1989).

Fig. 1. ***Zantedeschia aethiopica*** **(L.) Spreng. (Letty, 1973).**

Fig. 2. ***Zantedeschia rehmanni*** **Engl. (Letty, 1973).**

Fig. 3. ***Zantedeschia juncunda*** **Letty (Letty, 1973).**

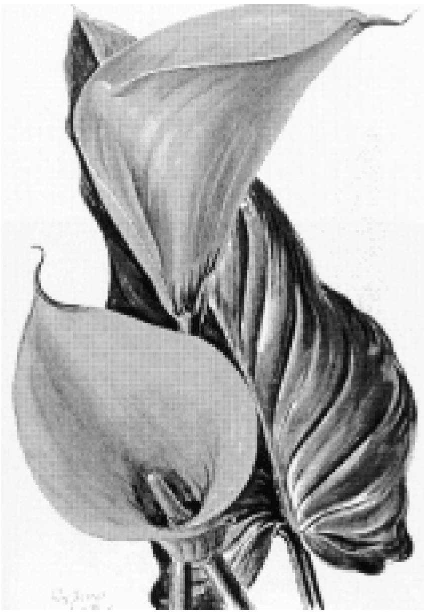

Fig. 4. *Zantedeschia pentlandii* (Watson) Wittm. (Letty, 1973).

Fig. 5. *Zantedeschia albomaculata* (Hook.) Engl. subsp. *albomaculata* showing two forms of leaf (Letty, 1973).

Fig. 6. *Zantedeschia albomaculata* (Hook.) Engl. subsp. *macrocarpa* (Engl.) Letty (Letty, 1973).

Zantedeschia albomaculata sub. *macrocarpa* has deciduous, triangular-hastate leaves that are sparsely speckled (Fig. 6). The summer blooming spathes are medium and are either cream or straw colored (Tjia, 1989; Letty, 1973).

Zantedeschia albomaculata sub. *valida* has deciduous, ovate-cordate to ovate-obicular-cordate leaves, and a plant height of up to 28 inches (70 cm) (Fig. 7). The spathes are ivory to cream colored with a purple area at the inside of the base and bloom in the summer (Letty, 1973; Funnell; 1993; Tjia, 1989).

In addition to the above, there are other cultivars and hybrids commercially available that have characteristics highly suited to flowering potted plant production (Table 1) (Funnell, 1993; Golden State Bulb Growers, 1994; van Scheepen, 1991).

Environmental requirements

The effects of light intensity, photoperiod, and temperature on flowering and growth habit of calla vary between species and cultivar. Light intensity has been studied on ‘Majestic Pink’, ‘Pink Perfection’, and ‘Pacific Pink’ (Armitage, 1991). These cultivars produced a similar flower number at ambient light and 55% shade; however flower number was significantly reduced at 67% shade. Flower stem number of ‘Black Magic’ decreased as light levels decreased from ambient to 55% shade and from 55% to 67% shade. ‘Best Gold’ accumulated more dry matter when grown under a combination of either low photosynthetic photon flux (PPF) and cooler temperatures or high PPF and warmer temperatures, which parallels the PPF diversity of its natural habitats (Funnell et al., 1998). In general, recommended light intensities are 2,500 to 5,000 fc (500 to 1000 $\mu mol\cdot s^{-1}\cdot m^{-2}$) (De Hertogh, 1996). In areas where high temperatures are problematic, light intensities can be reduced to 2,500 to 3,500 fc (500 to 700 $\mu mol\cdot s^{-1}\cdot m^{-2}$) and in cooler areas 4,000 to 4,500 fc (800 to 900 $\mu mol\cdot s^{-1}\cdot m^{-2}$) are suggested (Dole and Wilkins, 1999).

There has been some debate concerning dormancy and flowering of calla. Early studies suggested that there was no dormancy and that year-round production of flowers could be achieved in greenhouses or under protection as long as temperatures are above 60 °F (15.6 °C) and below 80 °F (26.7 °C) (Post, 1959; Wilkins, 1985). Rhizomes of *Z. aethiopica* ‘Childsiana’ 0.4 inches (1 cm) in size produced flowers that were smaller and shorter than flowers produced from larger rhizomes 0.75 to 1 inch (2 to 3 cm) (Welsh et al., 1988). They also found that the time of planting, either before or after drying the rhizomes, did not affect flower size or plant height. However, rhizomes of *Z. elliottiana* and *Z. rehmanii* replanted immediately after leaf removal, did not grow (Corr and Widmer, 1988). *Zantedeschia elliottiana* stored dry at 41, 64, or 75 °F (5, 18, or 24 °C) caused a significant reduction in flowering, but, there was no significant reduction in flowering when stored at 54 °F (12 °C) (Funnell et al., 1988). *Zantedeschia rehmannii* ‘Pink Satin’ produced the most flowers after dry storage at 41 °F (5 °C), with reduced flowering at the higher temperatures. Flowering was significantly greater for tubers that were

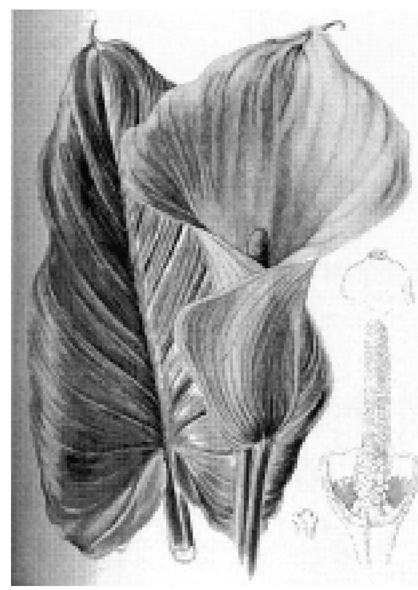

Fig. 7. *Zantedeschia albomaculata* (Hook.) Engl. subsp. *valida* Letty (Letty, 1973).

Table 1. *Zantedeschia* species and cultivars used for commercial production (T. Lukens, personal communications; van Scheepen, 1991).

Species and cultivar	Flower color
Z. aethiopica (L.) Sprengel	Green at base outside, otherwise white
Childsiana	White
Devoniensis	Large white
Gigantea	Sulphur-yellow with small purple-black blotch
Green Goddess	Green
Little Gem	Small white
Perle von Stuttgart	Small white
White Giant	Large white
White Superior	Large creamy white
White Swan	Ivory-white
Z. albomaculata (Hook.) Baill.	Dark purple inside base, elsewhere white, cream, straw-colored, greenish yellow, or rarely pink
Aurata	Yellow
Best Gold	Dark yellow
Black Eyed Beauty	Cream / white
Bridal Blush	Naples yellow
Cameo	Salmon to pale apricot
Candy	Dark pink
Carmine Red	Violet-purple
Crowbrough	White
Little Jimmy	Cream white
Z. albomaculata (Hook.) Baill. subsp. *albomacualta*	White, ivory or cream, rarely pale yellow or coral-pink
Z. albomaculata (Hook.) Baill. subsp. *macrocarpa* (Engl.) Letty	Cream or straw-colored
Z. albomaculata (Hook.) Baill. ×*elliotiana* (Wats.) Engl.	Yellow, with crimson blotch at the base
Hybrid Yellow or Golden Star	Bright yellow
Z. elliotiana (Wats.) Engl.	Bright golden-yellow
Galaxy	Dark Indian-lake
Golden Sun	Canary yellow
Harvest Moon	Lemon-yellow
Heart Glow	Fiery red
Z. elliottiana (Wats.) Engl. ×*adlami* Leichtlin	Sulphur-yellow, black blotch
Z. elliottiana (Wats.) Engl. ×*aethiopica* (L.) Sprengel Elliotiopica	
Z. elliotiana (Wats.) Engl. ×*albomaculata* (Hook.) Baill. subsp. *albomaculata* Taylori	Yellow with dark blotch
Z. elliottiana (Wats.) Engl. ×*pentlandii* (Wats.) Wittm.	
After Glow	Rounded, peach-orange, red in throat
Aztec Gold	Rounded, gold maturing to burnt orange
Black Magic	Rounded, clear-yellow, throat black
Crystal Glow	Pale pink
Golden Affair	Oval, clear yellow
Majestic Red	Pointed, rich deep red
Mauve Mist	Pointed, clear mauve
Pacific Pink	Oval pointed, slightly fluted, bright pink
Pastel Magic	Pointed with waved edge, clear lemon
Pink Persuation	Oval to pointed, rich pink
Pixie	Pointed, apricot
Regel Charm	Large pointed, blushed orange-red at maturity
Vanity Fair	Pointed, pale yellow with pink flush
Velvet Cream	Cream
Z. elliottiana (Wats.) Engl. ×*rehmanni* Engl. Flame	Yellow blushing red
Z. jucunda Letty	Bright golden-yellow with a dark purple area inside at base
Lavender Petite	Fuchsia-purple
Maroon Dainty	Violet-purple
Mrs. Roosevelt	Creamy yellow
Z. rehmannii Engl.	White to pink or dark purple
Carminea	Large, dark carmine
Crystal Blush	White dark purple (at pollen shed)
Gem Lavender	Lavender purple
Gem Rose	Deep rose
Little Suzy	Pink
Soft Glow	Barium-yellow
Tony	Aureolin
Z. rehmannii Engl. ×*albomaculata* (Hook.) Baill. subsp. *albomaculata*	Intense pink color
Z. rehmannii Engl. ×*elliotiana* (Wats.) Engl.	Brilliant red
Z. rehmannii Engl. ×*elliotiana* (Wats.) Engl. Ragionieri	White tinged pink
Z. rehmannii Engl. ×*pentlandii* (Wats.) Wittm.	Rounded, mauve-pink
Z. rehmannii Engl. ×*pentlandii* (Wats.) Wittm. Marguerita	Salmon-pink
Z. sp. Rubylike Rose	Deep rose
Z. sp. Rubylike Pink Ice	Cool pink (to lavender outdoors)
Z. sp. Garnet Glow	Bright hot pink
Z. sp.Treasure	Bronze orange
Z. sp. Mango	Orange red with bronze overlay
Z. sp. Super Gem	Deep rose (to rose-lavender outdoors)

moist-stored at the same temperatures. Thus, the optimum storage temperature and type of storage environment varies between *Zantedeschia* species. Although long term storage reduced the flowering potential of *Z. elliottiana* and *Z. rehmanii* 'Pink Satin', the time to emergence and flowering decreased for 'Best Gold' (Funnell and Go, 1993). It is assumed that reserve carbohydrate depletion is responsible for the flowering time span of various species and hybrids of calla (Dole and Wilkins, 1999).

Night interruption of calla caused a slight increase in flower number (data not reported) (Greene et al., 1932). A more recent study indicated that photoperiod (night interruption with a red to far-red ratio of 8:1) had no significant effect on the number of leaves or shoots, the number of leaves before first flower, date of first flower, or total number of flowers in the first growth cycle of *Z. elliotiana* and *Z. rehmannii*. However, plants grown with a night interruption were taller than those grown under short days (Corr and Widmer, 1990).

Calla can be forced to flower at any time of year if soil temperatures are maintained at 55 °F (13 °C) minimum and air temperatures are less than 77 °F (25 °C) (Welsh, 1991). However, *Z. elliottiana* grown at an air temperature of 70 °F (21 °C) flowered first, followed by those at 59 °F (15 °C). Plants grown at 50 °F (10 °C) did not flower until temperature was increased above 59 °F (15 °C) (Post, 1936). *Zantedeschia rehmannii* grown at an air–medium temperature of 68 / 77 °F (20 / 25 °C) flowered sooner and were taller with longer peduncles than those grown at 59 / 57 °F (15 / 14 °C) (Corr and Widmer, 1990). There was no effect of temperature, however, on any characteristic of *Z. elliottiana* growth. Golden State Bulb Growers (1999) recommend a set of temperature regimes for optimal growth and flowering: 1) from planting to 2-inch (5-cm) or 3-inch (7.6-cm) sprouts; 75 to 80 °F (24 to 27 °C) days and nights, 2) after leaf unfurling: 70 to 75 °F (21 to 24 °C) days: 55 to 65 °F (13 to 18 °C) nights, 3) flower coloring (use high light): 65 to 70 °F (18 to 21 °C) days 50 to 55 °F (10 to 13 °C) nights.

The induction of a floral state in calla requires a trigger level of gibberellin to proceed (Funnell, 1993). It has been suggested that storage of rhizomes may affect the gibberellin levels endogenously, sensitivity to exogenous levels of gibberellin, and / or the plants ability to absorb gibberellin (Funnell, 1993). The application of gibberellic acids (GA) is recommended for increased flowering of calla as a cut flower (Welsh and Clemens, 1992) and for flowering potted plants (Corr and Widmer, 1987; Funnell et al., 1992; Reiser and Langhans, 1993). However, commercially available forms of GA are not currently labeled for use on calla.

Cultural requirements

Traditionally, propagation of calla has been by division of rhizomes or tubers which was conducive to spread of viruses and bacterial diseases, especially *Erwinia* sp. (Brown, 1990; Welsh and Clemens, 1992). Hybridizing, cultural techniques for preventing or suppressing disease, increased seed production, and the use of tissue culture have radically changed production practices. In vitro or tissue culture techniques for propagation of calla are outlined by Cohen (1981) and Ruiz-Sifre et al. (1996).

To produce a tuber 1.5 to 2.4 inches (4 to 6 cm) in diameter (flowering size) two growing cycles of 16 weeks (minimum) of active growth followed by a rest period are required (Welsh and Clemens, 1992). While about 80% of tissue cultured tubers emerge and flower after one growing cycle, these are not large enough for a single tuber to produce a marketable 4-inch (10-cm) pot (Dole and Wilkins, 1999). The number of days between planting date and bloom decreases the later in the year the planting date (Golden State Bulb Growers, 1999).

After chemical treatment for disease (see Disease and Insect section), some cultivars should be treated with GA to increase the number of flowering shoots and flowers per shoot (Welsh and Clemens, 1992). Application of GA_3 (ProGibb, Abbott Laboratories, North Chicago, Ill.) at 50 to 100 ppm ($\mu L \cdot L^{-1}$) as a 30-min preplant dip increased stem number per tuber of *Z. elliotiana* and *Z. rehmannii* (Tija, 1985). Soaking tubers in GA_3 before planting increased number of shoot bearing flowers and the number of flowers per shoot (Corr and Widmer, 1987). In contrast, foliar sprays of GA_3 did not significantly affect plant growth or flowering. Application of GA_3 at 100 and 500 ppm as a 10-min dip of *Z. rehmanii superba* 'Pink', *Z. elliottiana ×maculata* 'Yellow' and *Z. albomaculata* 'White' tubers, increased flowering and flower number as treatment concentrations increased (Reiser and Langhans, 1993). Gibberellic acid at 25 ppm and Promalin (GA_{4+7} + BA, Abbott Laboratories, North Chicago, Ill.) at 100 ppm applied as a preplant dip to 'Galaxy', a *Z. rehmannii*-like selection, produced the greatest increase in total flower number (Funnell et al., 1992). A 10-s immersion of rhizomes was as effective as 1 or 30 min immersions at the GA_3 and Promalin concentrations used in the same experiment. Thus, quick dips or spray applications of rhizomes are feasible methods of treatment for increasing flower number of calla. For cut-flower production, GA at 150 ppm can be applied as a spray to established plantings after sprout emergence when leaves are unfurling or expanded (Golden State Bulb Growers, 1999). Soil beds or pots can be drenched with a 100 ppm GA solution during dormancy. Soil should be moderately wet at time of drench.

Calla should be planted about 2 inches (5 cm) below the surface of a well-drained and sterilized growing medium with high organic matter and a pH of 6 to 6.5 (Kuehny et al., 1996). Drench within 3 d of initial watering to control *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey, *Xanthomonas* Dowson, or *Rhizoctonia* DC, the three major pathogens contributing to the soft rot syndrome. A combination of three commercial products is recommended for best control of the three diseases, respectively: 1) streptomycin sulfate (Agri-Mycin 17, Marman USA, Tampa, Fla.) at 100 to 200 ppm [0.5 to 1 lb / 100 gal (0.6 to 1.2 $g \cdot L^{-1}$)], 2) fosetyl-Al (Aliette, Rhone-Poulenc Ag, Research Triangle Park, N.C.) at 13 fl oz / 100 gal (1.0 $mL \cdot L^{-1}$), 3) iprodione (Chipco 26019, Rhone-Poulenc, Research Triangle Park, N.C.) at 6.5 fl oz / 100 gal (0.5 $mL \cdot L^{-1}$).

Recommended planting densities and tuber sizes for producing salable pots are: 4-inch (10-cm) pot = 1 tuber 1.75 to 2 inches (4.5 to 5 cm) or 2 tubers 1.25 to 1.5 inches (3.2 to 3.8 cm) in diameter, 6-inch (15.25-cm) pot = 1 tuber 2.5 inches (6.4 cm) or 2 tubers 1.75 inches (4.5 cm) or 3 tubers 1.5 inches (3.8 cm) in diameter, 8-

inch (20.3-cm) pot = 3 tubers 2 inches (5 cm) in diameter (Golden State Bulb Growers, 1999). Plants can be grown pot-to-pot until leaves touch, and then spaced on 6-inch (15-cm) centers. Spacing needs may vary by cultivar.

Recommended planting densities and rhizome sizes for cut flower production remaining in the field for 2 to 3 years are: 1.5- to 1.75-inch (3.8- to 4.3-cm) tuber = 5-inch (12.7-cm) centers, 1.75- to 2-inch (4.3- to 5-cm) tuber = 6-inch (15.2-cm) centers, 2- to 2.5-inch (5- to 6.4-cm) centers, and 2.5-inch (6.4-cm) tuber and up = 8-inch × 10-inch (20.3- × 25.4-cm) center (Golden State Bulb Growers, 1999).

Calla grown as flowering pot plants should be fertilized with a complete liquid feed of 100 to 200 ppm N of a nitrate-nitrogen based fertilizer (Golden State Bulb Growers, 1999; Kuehny et al., 1996). A 5-month, controlled-release fertilizer (23N–7.8P–30.7K) was incorporated in a 50 pine bark : 30 pumice : 20 peat (by volume) medium at 0.5 and 2 lb / yd^3 (0.30 and 1.20 $kg \cdot m^{-3}$) of N and 0.08 and 0.14 and 0.54 lb / cubic yard (0.32 $kg \cdot m^{-3}$) P (Clemens et al., 1998). A greater flower number, greater bloom fresh weight, more advanced shoot development, shorter time to flower, and greatest plant survival was indicated at the low N level of *Z. albomaculata* 'Starlights'. It is important not to overwater the medium before shoot emergence. It must be kept moist and not allowed to dry completely. If the tubers are too wet the incidence of disease can increase.

Field grown calla require N and K in the greatest amounts and broadcast rates of 268 lb N, 40 lb P, and 357 lb K per acre (300 kg N, 45 kg P, and 400 kg K per hectare) are suggested for production of *Z. elliottiana* (Clark and Boldingh, 1991). This should be applied as a slow-release or soluble fertilizer, either as a basal dressing or immediately after planting before the emergence of shoots.

No pinching, disbudding or support is required. A plant growth regulator (PGR) however, may be necessary for height control when calla are grown as flowering potted plants (Kuehny et al., 1996). To be effective, PGRs must be applied as a drench for uptake by the root system. Foliar sprays are not adequately metabolized and the PGR efficacy is minimal. Optimal growth inhibition was achieved with a drench of 4 mg a.i. Bonzi (paclobutrazol, Uniroyal Chemical, Middlebury, Conn.) / per 6.7-inch (17-cm) pot (28,350 mg = 1.0 oz), while A-Rest (ancymidol, SePRO, Carmel, Ind.) at 1, 2, 3 or 4 mg a.i. / 6.7-inch pot had no affect (Tjia, 1987). A soil drench of 0.5% or 1.0% solutions of paclobutrazol when shoots were 0.75 and 1.2 inches (2 and 3 cm) long, significantly limited plant height of *Z. rehmannii* and limited flower number if not treated with GA_3 (Corr and Widmer, 1991). A 10-min GA_3 preplant soak however, overcame the effect of paclobutrazol. A combination of a 100-ppm, 10-min GA_3 preplant soak and a drench of 2 mg a.i. per 6-inch (15-cm) pot of paclobutrazol was suggested for producing a quality crop of *Z. Rehmanii superba* 'Pink' and *Z. albomaculata* 'White'. Sumagic (uniconzole) at 2 mg a.i. per 6-inch pot also produced satisfactory results (Reiser and Langhans, 1993). Drenches of 0.5 to 4 mg a.i. per 6-inch (15-cm) pot of paclobutrazol are recommended by Golden State Bulb Growers (1999) before shoots are 2.5 inches (5 cm). A preplant spray of 1.8% Promalin at 100 ppm (1.3 tablespoons / gal, 5.5 $mL \cdot L^{-1}$) mixed with copper hydroxide 37.5% at 3 tablespoons / gal (20 $mL \cdot L^{-1}$) or copper oxychloride 50 WP at 0.4 oz / gal (3 $g \cdot L^{-1}$) is currently recommended for quality production of calla (Kuehny et al., 1996; Beckman and Lukens, 1997).

For cut flower production, the safest and most effective preemergent herbicides for *Zantedeschia* are terbumeton / terbuthylazine at 1.34 and 2.67 lb / acre (1.5 and 3.0 $kg \cdot ha^{-1}$), simazine at 1.78 lb / acre (2.0 $kg \cdot ha^{-1}$) or oxadiazon at 1.34 lb / acre (1.5 $kg \cdot ha^{-1}$) (Ingle and Bussell, 1991).

Diseases

The most common disease of calla is a bacterial soft rot caused by *Erwinia carotovora* subsp. *carotovora* (Kuehny et al., 1998; Corr, 1990; Corr, 1993). This bacteria causes a foul-smelling rot of rhizomes or tubers, leaves and flowers, and infected plants will topple at soil level. Before planting, tubers can be immersed in a disinfectant or antibiotic to control erwinia infection (Reiser and Langhans, 1993). Tubers treated with sodium hypochlorite, streptomycin and chloramphenicol also had reduced erwinia problems (Tjia and Jierwiriyipant, 1988). A 30-min 200-ppm streptomycin dip provided the best control of erwinia of calla tubers, while a 1-h 10% formaldehyde dip was second best (Kuehny et al., 1998). Chemical treatments did not affect days to emergence or final plant growth.

Other lesser diseases are crown rot (*Pellicularia filamentosa* Cooke), which causes a soft decay of the lower half of the main rhizome or tuber and thick feeding roots. *Cercospora richardiaecola* Atk., C. callae Peck & G.W. Clinton, and *Phyllostricta richardsoniae* Ellis & Evech. affect leaves, stalks and flowers. Symptoms of root rot (*Phytophthora richardiae* Buisman) appear on the lower or outer leaves at the same time plants begin to flower. Storage rot (*Pythium ultimum* Trow) is most common on *Z. rehmannii* and *Z. elliotiana*. Tomato spotted wilt virus may also infect calla with symptoms of chlorotic to pale white streaks and circular lesions becoming necrotic between the veins of leaves (Pirone, 1978).

Insects

There are few insects that disturb calla. The grape mealybug (*Pseudococcus maritimus* Ehrhorn), longtailed mealybug (*P. longispinus* Targioni Tozzetti), bulb mite (*Rhizoglyphus echinopus* Fumouze & Robin), banded greenhouse thrip (*Hercinothrips femoralis* O.M. Reuter) and greenhouse thrip (*H. haemorrhoidalis* Bouche) are among the insects that have been reported to damage calla (Pirone, 1978).

Mealybugs are soft-bodied insects that produce a waxy powder over their bodies and have preferred feeding sites on the inside of the leaf sheaths of calla (Powell and Lindquist, 1997). Bulb mites have pearly white bodies and move slowly on short, reddish legs. Plant injury through feeding damage has been suggested as a mode for secondary infection of plant pathogens such as those mentioned previously (Powell and Lindquist, 1997). Thrips may feed on developing leaves and flowers, expanded leaves and flowers, and on pollen of calla. These feeding habits will cause distortion of flowers and leaves or the appearance of silvery areas on leaves (Powell and Lindquist, 1997). Transmission of tospoviruses tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV) by thrips on calla have not been reported.

Physiological disorders

Gibberellic acid treatments can cause flower deformities including misshapen spathes, double spathes and colored leaves (partially initiated flowers) by up to 15.5% at 100 and 22% at 500 ppm (Reiser and Langhans, 1993). Similar results have also been reported by Corr and Widmer (1991). The use of Promalin may not induce as many deformed spathes (Golden State Bulb Growers, 1999).

Postproduction and postharvest

FLOWERING POTTED PLANTS. *Zantedeschia aethiopica* 'Childsiana' removed from the greenhouse when the spathe was green and at least partially enclosed by the leaf sheath and then held at 75-fc (5 $\mu mol \cdot s^{-1} \cdot m^{-2}$) for 12 h at 68 °F (20 °C), produced quality flowers for 26 d with only 13% not developing (Plummer et al., 1990). Plants removed from the greenhouse when the spathe was white, fully open but with no pollen shed had a postproduction life of only 11 d. Hybrids stored at 37 to 39 °F (3 to 4 °C) had good post production life for 7 d and quality plants were retained 8 d after they were removed from postproduction storage (Nowak and Rudnicki, 1990).

CUT FLOWERS. The best method of harvesting calla flowers is to cut the stems as far down the plant as possible. A plant should be harvested when the spathes are 0.75 to fully open and about 1 d before pollen shed. When flowers are harvested and placed in water only, the stems tend to split. This can be prevented by adding sugar at 0.4 oz / gallon (40 $g \cdot L^{1}$) and 100 ppm 8- hydroxyquinoline citrate and pulsed in this solution for 8 to 12 h and hardened at 41 to 50 °F (5 to 10 °C) overnight (Tjia, 1985). The flower life of *Z. aethiopica* was 6 to 7 d, while *Z. elliottiana* began to turn green after 7 to 8 d (Tjia and Funnell, 1986). Ethylene had no effect on the regreening of *Z. elliottiana* 'Best Gold', and 'Helen O'Connor' and no detectable ethylene was produced by the three hybrids (Funnell and Downs, 1987).

Conclusion

Callas are a minor flowering pot plant and cut flower that continue to increase in popularity and offer the industry and the public an alternative in the floriculture market. A great deal of research has helped establish a good set of production protocols so that calla can be produced with relatively few problems. Continued breeding work has helped improve disease resistance, flower number, flower size and plant height. Although there are a large number of calla species and hybrids available, producers should be careful to select those calla that have been bred for improved disease resistance and plant quality, and purchase bulbs from a reputable source. Areas of further research include continued improvement of disease resistance and chemical treatments, determining the factors that control bud dormancy and floral inititiation, and development of programs for year-round production of calla.

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