

‘UF-404’—Dwarf, Red Caladium for Container-forcing and Sunny Landscapes

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Caladiums [*Caladium ×hortulanum* Birdsey, Araceae Juss.] are ornamental aroids widely used as pot and landscape plants for their colorful foliage and ease in growing (Evans et al., 1992; Harbaugh and Tjia, 1985). Tens of millions of caladium tubers are used annually by the worldwide ornamental industries with 70% to 80% forced in containers and 20% to 30% directly planted in the landscape. More than 95% of the tubers used worldwide are produced in central Florida.

Based on leaf shape (fancy or heart-shaped and lance) and predominant leaf color (white, red, pink, and multicolored), commercial caladium cultivars are often separated into eight groups (Bell et al., 1998; Wilfret and Hurner, 1982). Historically, fancy-leaved caladium cultivars have dominated the market. However, during the past two or three decades, the demand for lance-leaved cultivars has increased steadily; growers producing tubers planted greater than 50% more acres of lance-leaved cultivars in 2003 than in 1998 (Bell et al., 1998; Deng et al., 2005).

The compact growth habits of lance-leaved cultivars make them more adaptable to different types and sizes of containers compared with fancy-leaved cultivars, and they are easier and less expensive to ship as potted plants. A popular red lance-leaved caladium cultivar has been ‘Red Frill’, which accounted for ≈70% of the acreage of red lance-leaved cultivars according to the 1998 survey of the Florida caladium growers (Bell et al., 1998). Unfortunately, ‘Red Frill’ and

many other lance-leaved cultivars produce small tubers (Wilfret, 1983), making tubers unprofitable to grow and leading to a considerable shortage of tubers for the market demand. Developing new red lance-leaved cultivars with tuber yields exceeding those of ‘Red Frill’ has been an important objective in our caladium breeding program.

Native to the New World’s tropical region, caladiums inherently are very susceptible to injury by low temperatures. Chilling injury (CI) can occur to caladium leaves when temperatures are 15.5 °C or lower (Harbaugh, 1990). This sensitivity to low temperatures can lead to increased production costs for heating in greenhouse production of potted caladium plants and restricts geographic and seasonal use of caladiums in the landscape.

In recent years, there has been considerable interest in developing new caladium cultivars resistant to CI. Toward this objective, the University of Florida’s Institute of Food and Agricultural Sciences caladium breeding program released ‘Florida Red Ruffles’. This cultivar develops multiple vibrant red leaves and is much improved in tuber yield and resistance to CI compared with other commercial lance-leaved cultivars. It has become the new standard for red lance-leaved caladium cultivars.

‘UF-404’ is an attractive, new red lance-leaved cultivar with a novel coloration pattern (bright red with white blotches scattered between main veins) (Fig. 1). It has been similar or superior to ‘Florida Red Ruffles’ in tuber yield, pot plant quality, and landscape performance. With numerous brightly colored, wide, and lance-shaped leaves that are resistant to sunburn, ‘UF-404’ is well suited for forcing in various size containers, for producing hanging baskets, and for planting in sunny or shady landscape locations. Its tubers are well branched and do not require de-eying for forcing in small- or medium-sized pots (11.4 to 15.3 cm) (Fig. 1), and its leaves are more resistant to CI than leaves of ‘Florida Red Ruffles’.

‘UF-404’ was developed from a 2003 cross between ‘Florida Blizzard’ (Harbaugh et al., 2002) and ‘Florida Red Ruffles’ (Wilfret, 1991) (Fig. 2) and initially selected as GCREC-3270 in 2004. ‘Florida Blizzard’ was used as the female parent for its plant vigor, unique leaf coloration pattern, and high tuber yield, whereas ‘Florida Red Ruffles’ was used as the male parent for its bright color, compact growth habit, excellent sunburn tolerance, and chilling resistance. ‘Florida Blizzard’ was developed from a cross between ‘Aaron’ and ‘White Christmas’ and was released for commercial production in 2002. ‘Florida Red Ruffles’ resulted from a cross between ‘Red Frill’ and a progeny of ‘Red Frill’ × ‘Candidum Junior’. The ancestry of ‘Aaron’, ‘Candidum Junior’, ‘Red Frill’, and ‘White Christmas’ is unknown.

Description

Descriptions of color [e.g., Royal Horticultural Society (RHS) 200B] for plant parts are based on comparison with the Royal Horticultural Society Color Chart (Royal Horticultural Society, 1986). Plants used for describing color were grown in 11.5-cm containers in a 45% shaded greenhouse from No. 1 (3.8 to 6.4 cm in diameter) de-eyed tubers.

‘UF-404’ plants grown for ≈4 months in full sun in ground beds had an average height of 27 cm. Jumbo-sized tubers (6.4 to 8.9 cm in diameter) are multisegmented, bearing four to seven dominant buds. Tuber surfaces are brown (RHS 200C) with the cortical area yellow–orange (RHS 10C). Leaves are sagittate–cordate, up to 25 cm long and 18 cm wide, and slightly undulate with two lobes one-seventh to one-eighth of the leaf length. The upper surface has dark green (RHS 136B) margin, up to 10 mm wide, bordering the entire leaf except for the basal leaf valley where it is grayed-green (RHS 194B). The central and main veins are grayed-purple (RHS 185B) and often connect marginally with a thin (less than 1 mm wide) grayed-purple vein (RHS 184A) that parallels the leaf margin. Interveneal areas are variable in color, gray–purple (RHS 184C) near the leaf center to yellow–green (RHS 147), grayed-orange (RHS 166A) toward the margin, and have irregular blotches variable in color, from yellow–white (RHS 158C), to red (RHS 54D), or red–purple (RHS 65D), occurring on up to 85% of the leaf blade and marginal area. The undersurface has a yellow–green (RHS 147B) margin, up to 15 mm wide, and red–purple (RHS 59D) veins. The central and main veins are covered with grayed-white (RHS 155B) wax. Interveneal areas are variable in color and have irregular blotches, variable in color, occurring on up to 85% of the center and marginal area. Petioles are 3 to 5 mm and grayed-purple (RHS 187A) at the apex, and the colors diffuse into a dark grayed-purple (RHS 187A) at the base that is ≈7 mm in diameter. The upper portion of the

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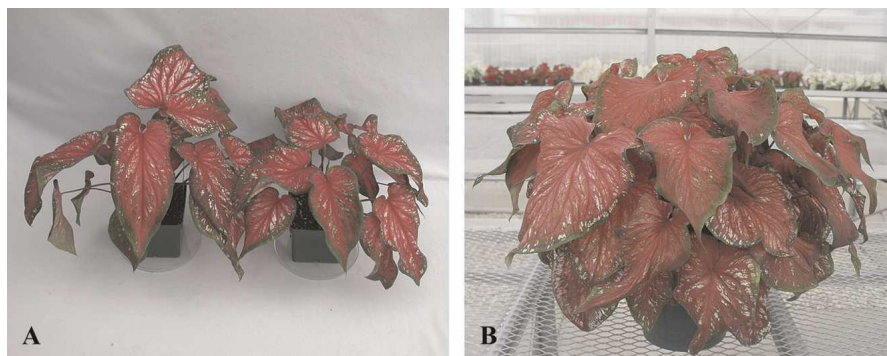


Fig. 1. 'UF-404' plants forced in containers. (A) Plants from one intact (left) or one de-eyed (right) No. 1 tuber (3.6 to 6.4 cm in diameter) planted in an 11.4-cm square pot and photographed 8 weeks after planting. (B) Plants from three intact Jumbo (8.9 to 11.4 cm in diameter) tubers planted in a 25.4-cm standard pot and photographed 10 weeks after planting.

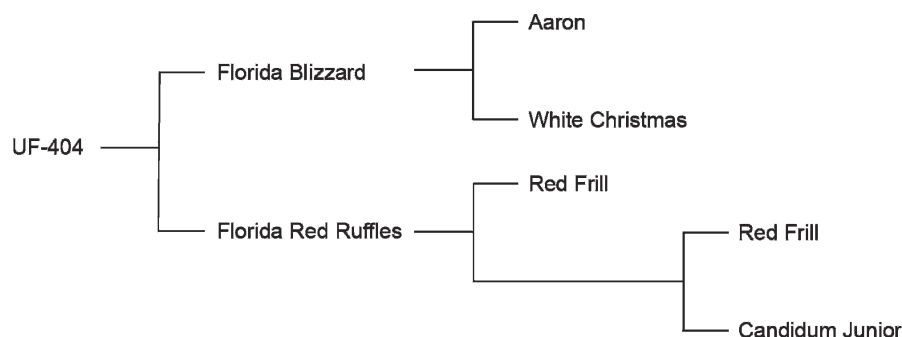


Fig. 2. Pedigree of caladium cultivar UF-404.

petiole below the apex is covered with gray-white wax (RHS 155B).

The largest leaf on plants grown in a 45% shaded greenhouse produced from an intact number one tuber in an 11.4-cm pot averaged 25 cm long and 17 cm wide 8 weeks after planting. When grown from 2.54-cm tuber propagules in ground beds with full sun, leaves measured ≈ 4 months from planting averaged 24 cm long and 14 cm wide.

Performance

'UF-404' was evaluated for tuber production and plant performance at the Gulf Coast Research and Education Center in Wimauma, FL, in 2006 and 2007. Three commercial cultivars, Red Frill, Florida Red Ruffles, and Florida Sweetheart, were included as control plants (checks). The soil was an EauGallie fine sand with $\approx 1\%$ organic matter and a pH of 6.2. In 2006, raised ground beds (91 cm wide, 20 cm high) were fumigated on 30 Mar. with a mixture of 67% methyl bromide and 33% chloropicrin (by volume) at a rate of 196 kg·ha⁻¹ and covered with white-on-black plastic mulch. Caladium seed pieces (tuber pieces, ≈ 2.54 cm \times ≈ 2.54 cm \times ≈ 2.54 cm) were planted in the beds 11 Apr. with 15-cm spacing between rows and in rows. A constant water table was maintained below the beds using the seep irrigation system (Geraldson et al., 1965). Osmocote 18N-2.6P-10K 8- to 9-month

controlled-release fertilizer (Scotts Co., Marysville, OH) was applied to the bed surface when shoot tips were emerging from the soil with N at 336 kg·ha⁻¹. In 2007, the beds (71 cm wide, 21 cm high) were fumigated on 3 Apr. using the same fumigant mixture (196 kg·ha⁻¹). Caladium seed pieces were planted 16 Apr. with 25.4 cm between-row spacing and 15.2 cm in-row spacing. A drip irrigation system was used to provide water (≈ 6 mm per day) and 6N-0.8P-3.9K soluble fertilizer with N at the rate of ≈ 1.9 kg·ha⁻¹·d⁻¹ (total N at 290 kg·ha⁻¹ per growing season).

Field plots were arranged in randomized complete blocks with three replications each year. Thirty propagules were planted in each plot in Apr. 2006 and Apr. 2007, and tubers were dug in Dec. 2006 and Jan. 2008, respectively. Tubers were graded by maximum diameter: No. 2 (2.5 to 3.8 cm), No. 1 (3.8 to 6.4 cm), Jumbo (6.4 to 8.9 cm), Mammoth (8.9 to 11.4 cm), and Super Mammoth (greater than 11.4 cm). Production index, an indicator of economic value of the harvested tubers, was calculated for each plot as follows: N (No. 2) + 2N (No. 1) + 4N (Jumbo) + 6N (Mammoth) + 8N (Super Mammoth), in which N = number of tubers in each grade from each field plot. An analysis of variance was conducted in SAS (SAS Institute, 2003) to compare the performance of 'UF-404' with that of 'Red Frill' and 'Florida Red Ruffles', the two major red lance-leaved cultivars, and 'Florida Sweet-

heart', the most popular lance-leaved cultivars in all colors (Deng et al., 2005).

In 2006, 'UF-404' produced similar numbers of marketable tubers (44 to 52) as 'Florida Red Ruffles' and 'Florida Sweetheart', but 'UF-404' had the greatest tuber weight and the highest production index with its tuber weight 95% and 68% greater than 'Florida Red Ruffles' and 'Florida Sweetheart' and production index 56% and 39% higher than 'Florida Red Ruffles' and 'Florida Sweetheart', respectively (Table 1). 'UF-404' was superior to 'Red Frill' in tuber weight (3.9 \times), production index (2.3 \times), and marketable number of tubers (1.3 \times).

In 2007, 'UF-404' was similar to 'Florida Red Ruffles' and 'Florida Sweetheart' in tuber weight, production index, and marketable tubers, and it was superior to 'Red Frill' in all these assessments. In tuber size distribution, the majority (60% or more) of tubers for 'UF-404' were in the categories of No. 1, Jumbo, or Mammoth, which was similar to 'Florida Red Ruffles' and 'Florida Sweetheart'. 'UF-404' produced larger tubers than 'Red Frill', which had the majority (greater than 90%) of tubers in the No. 1 and No. 2 categories.

Landscape performance of cultivars grown under full-sun conditions was evaluated in 2006 and 2007 on the same plots used for evaluating tuber production. Plants were evaluated three times (July, August, and September) in each growing season on a scale of 1 to 5 with 1 being very poor (few leaves and lack of vigor) and 5 being excellent (full plants, numerous leaves, and bright color display). Leaf sunburn tolerance was also evaluated three times in each growing season on a scale of 1 to 5 with 1 being very susceptible to sunburn (leaves having numerous sun-damaged areas or holes) and 5 being resistant to sunburn (no visible sun-damaged areas). Approximately 4 months after planting, plant height, number of leaves, and foliar characteristics were measured on three randomly chosen plants in each plot.

All cultivars tested produced a similarly high number of leaves typical of lance-leaved plants (Table 2). 'UF-404' plants were taller (5 to 12 cm taller) and had larger leaves (4 to 10 cm longer and 1 to 6 cm wider) than those of control plants. With the multiple, larger leaves, 'UF-404' formed full plants with excellent color display, resulting in higher performance ratings than the checks in most of the comparisons. In sunburn tolerance ratings, 'UF-404' was similar to 'Florida Red Ruffles' and 'Florida Sweetheart' (4.0 to 4.4 through the growing season) and was better than 'Red Frill' in August and September.

The suitability of 'UF-404' for container forcing was evaluated by forcing tubers in 11.4-cm containers. No. 1 tubers were planted either intact or de-eyed in a peat/vermiculite mix (VerGro Container Mix A; Verlite, Tampa, FL) on 26 Mar. 2007. The study was conducted in a greenhouse with 45% light exclusion during the summer in Wimauma, FL. Average daily temperatures ranged from a low of 16 °C at night to 29 °C

during the day during the experiment. Potted plants were placed on metal benches in the greenhouse in 10 randomized complete blocks. Plant height, number of leaves, foliar characteristics, and plant quality were recorded 8 weeks after planting.

'UF-404' produced excellent pot plants regardless of tuber treatments (intact or de-eyed) (Table 3). When tubers were planted intact, 'UF-404' sprouted 30 d after planting, which was similar to the sprouting

time of 'Red Frill' (32 d), but 9 to 13 d earlier than 'Florida Red Ruffles' and 'Florida Sweetheart'. When tubers were de-eyed, there was no significant difference in sprouting time between 'UF-404' and 'Florida Red Ruffles' and 'Florida Sweetheart'. 'UF-404' sprouted 6 d later than 'Red Frill' when tubers were de-eyed.

Intact or de-eyed plants of 'UF-404', 'Florida Red Ruffles', and 'Red Frill' were similar in height and a little taller than those

of 'Florida Sweetheart'. Although it produced similar numbers of leaves as the control plants, 'UF-404' had larger leaves, 4 to 10 cm longer than all control plants and 4 to 6 cm wider than 'Florida Sweetheart' and 'Red Frill'. 'UF-404' and 'Florida Red Ruffles' were not significantly different in leaf width at the eighth week after planting. With multiple, bright-colored leaves, containerized 'UF-404' plants received the highest (4.5 to 4.9) quality ratings when

Table 1. Tuber weight, production index, marketable tubers, and tuber grade distribution of 'UF-404' and three commercial caladium cultivars when they were grown in replicated field trials (2006 and 2007)^a.

Cultivar	Tuber			Distribution of marketable tubers (%)				
	Wt (kg)	Production index	Marketable (no.)	Super mammoth	Mammoth	Jumbo	No. 1	No. 2
Year 2006								
UF-404	4.7 a	155 a	52 a	1	11 a	31 a	47	11
Red Frill	1.2 d	68 c	39 b	0	0 b	1 b	67	32
Florida Red Ruffles	2.4 c	99 bc	44 ab	0	7 a	21 a	30	43
Florida Sweetheart	2.8 b	111 b	50 ab	1	3 ab	20 a	49	27
LSD ($\alpha = 0.05$)	0.4	34	12	NS	7	14	NS	NS
Year 2007								
404	2.8 a	105 a	37	0	3	21	51	25
Red Frill	1.9 b	66 b	39	0	0	8	45	47
Florida Red Ruffles	2.7 ab	84 ab	42	0	1	20	41	38
Florida Sweetheart	3.3 a	84 ab	46	0	3	29	31	38
LSD ($\alpha = 0.05$)	0.7	24	NS	NS	NS	NS	NS	NS

^aValues presented are means of three replications with 30 propagules planted in each field plot. The production index is an indicator of economic value of the crop harvested and is calculated as follows: N (No. 2) + 2N (No. 1) + 4N (Jumbo) + 6N (Mammoth) + 8N (Super Mammoth), where N = number of tubers in each grade. Tubers graded by maximum diameter: No. 2 (2.5 to 3.8 cm), No. 1 (3.8 to 6.4 cm), Jumbo (6.4 to 8.9 cm), Mammoth (8.9 to 11.4 cm), and Super Mammoth (greater than 11.4 cm). Tuber distribution data (%) were transformed using the formula arcsine [square root (percentage/100)] before analysis of variance and mean separation.

NS = nonsignificant ($P = 0.05$). Numbers in the same column followed by the same letter are not significantly different by least significant difference (LSD) ($P = 0.05$).

Table 2. Plant characteristics, performance, and sunburn tolerance of 'UF-404' and three commercial cultivars (checks) when planted in ground beds under full sun (2006 and 2007)^a.

Cultivar	Plant ht ^y (cm)	Leaves ^y (no.)	Leaf length ^y (cm)	Leaf width ^y (cm)	Performance rating ^x			Sun tolerance rating ^w		
					July	August	September	July	August	September
UF-404	27 a	25	24 a	14 a	4.0 ab	3.5 a	4.3 a	4.0	4.4 a	4.4 a
Red Frill	14 d	21	15 c	8 c	4.2 a	2.6 bc	2.3 c	4.3	3.8 b	3.3 b
Florida Red Ruffles	19 c	23	18 b	11 b	3.5 b	2.5 c	3.0 b	4.3	4.2 a	4.4 a
Florida Sweetheart	21 b	22	20 b	13 a	3.5 b	3.2 ab	3.4 b	4.2	4.1 a	4.2 a
LSD ($\alpha = 0.05$)	2	NS	2	2	1.6 ^v	0.6		0.5	NS	0.3

^aValues presented are means of three replications per year.

^yData were taken in Aug. 2006 and 2007, \approx 4 months after tubers were planted in April each year, and averaged of two growing seasons (2006 and 2007).

^xPlants were rated on a scale of 1 to 5 with 1 being very poor, 3 fair and acceptable, and 5 being excellent in plant vigor, fullness, and color display.

^wPlants' sunburn tolerance was rated on a scale of 1 to 5 with 1 being very poor, 3 fair and acceptable, and 5 being excellent without showing any signs of leaf burn or resulting holes on leaf surfaces.

^vSignificant only at $P < 0.10$.

NS = nonsignificant ($P = 0.05$). Numbers in the same column followed by the same letter are not significantly different by least significant difference (LSD) ($P = 0.05$).

Table 3. Plant sprouting, characteristics, and quality ratings for 'UF-404' and three commercial cultivars when tubers were forced in 11.4-cm containers and plants were grown in a 45% shaded glasshouse at Wimauma, FL (2007)^a.

Cultivar	Days to sprout ^b		Plant ht (cm)		Leaves (no.)		Leaf length (cm)		Leaf width (cm)		Quality rating	
	Intact	De-eye	Intact	De-eye	Intact	De-eye	Intact	De-eye	Intact	De-eye	Intact	De-eye
UF-404	30 c	38 a	18 a	16 a	10	12	25 a	20 a	17 a	14 a	4.5 a	4.9 a
Red Frill	32 bc	32 b	17 a	16 a	10	18	18 b	16 b	11 b	10 b	3.2 b	3.9 b
Florida Red Ruffles	38 ab	40 a	16 a	17 a	8	13	17 b	18 b	13 ab	12 ab	3.3 b	4.3 b
Florida Sweetheart	43 a	39 a	10 b	12 b	6	16	15 b	16 b	11 b	11 b	3.0 b	4.2 b
LSD ($\alpha = 0.05$)	8	6	4	2	NS	NS	5	2	4	2	0.8	0.5

^aValues represent the means of 10 plants produced from intact or de-eyed No. 1 (3.8 to 6.4 cm in diameter) tubers planted individually per container. Data were taken 8 weeks after planting.

^bNumber of days from planting to the first unfurled leaf.

NS = nonstatistically significant at $P < 0.05$. Mean separation within column by least significant difference (LSD) ($P = 0.05$).

compared with the three control cultivars (3.0 to 4.3).

'UF-404' was also evaluated for its resistance to CI following a previously reported procedure (Deng and Harbaugh, 2006). Mature leaves were excised from \approx 3-month-old potted plants and exposed to 7.2 °C for 3 d in the growth chamber. The leaves were then held at ambient temperature for 10 to 11 d before individual leaves were examined for signs of CI (chlorotic and necrotic areas) and assessed for percentage of leaf area injured. Four chilling tests were conducted in June to Aug. 2007 with four replicates in each test. 'Florida Red Ruffles' and 'Candidum' were used as the chilling-resistant and chilling-susceptible controls, respectively. Leaves of 'UF-404' had less area injured by the chilling treatment than both 'Candidum' and 'Florida Red Ruffles', indicating 'UF-404' has better chilling resistance than the current cultivars (Table 4).

Recommendation

'UF-404' is a new red lance-leaved cultivar with a unique coloration pattern. It has good tuber yields, especially for a lance-leaved cultivar. It sprouts earlier than most cultivars and quickly develops many wide lance leaves that are bright red. These characteristics make it well suited for container forcing and landscape use. De-eyeing is not required for producing quality pot plants in containers, although de-eyeing can increase leaf number and results in shorter plants with smaller leaves. 'UF-404' has excellent resistance to leaf sunburn and can be used in sunny as well as shady locations in the landscape. It has better chilling tolerance than 'Florida Red Ruffles'.

Although extensive research and evaluations of these cultivars have been performed on small acreages, growers are encouraged to plant only limited quantities of 'UF-404' until they have gained experience in pro-

Table 4. Sensitivity of 'UF-404' and two commercial cultivars to chilling injury caused by exposing to 7.2 °C for 3 d.

Cultivar	Leaf area injured (%) ^z	Leaf injury score ^y
UF-404	43 c	7.4 c
Candidum	90 a	9.8 a
Florida Red Ruffles	63 b	8.5 b
LSD ($\alpha = 0.05$)	3	0.7

^zPercentage of leaf area injured was assessed 10 to 11 d after chilling. Data on percent leaf area injured were transformed using the formula arcsine [square root (percent leaf area injured/100)] (Deng and Harbaugh, 2006) before analysis of variance and mean separation.

^yScores were made on a scale of 1 to 10: 1 = no injury, bright and healthy as the control; 2 = some discoloration or yellowing; 3 = 1% to 2%; 4 = 3% to 5%; 5 = 6% to 10%; 6 = 11% to 20%; 7 = 21% to 35%; 8 = 36% to 55%; 9 = 56% to 75%; and 10 = 76% to 100% of the total leaf area injured. Numbers in the same column followed by the same letter are not significantly different by least significant difference (LSD) ($P = 0.05$).

ducing this cultivar. Standard postharvest treatment of tubers is recommended (Harbaugh and Tjia, 1985) and preplant hot water treatment of tubers (Rhodes, 1964) is encouraged to prolong their life.

Availability

The caladium cultivar 'UF-404' will be sold and marketed under the trade name Dr. Brent. A plant patent application will be submitted to the U.S. Patent and Trademark Office and plant patent rights assigned to the University of Florida, Board of Trustees. Propagation and distribution will be licensed by the Florida Foundation Seed Producers, Inc., P.O. Box 110200, Gainesville, FL 32611. Information on tuber availability and propagation agreements can be obtained from the Florida Foundation Seed Producers, Inc.

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