Growth Inhibition of Caladium by High Temperature

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Abstract. Nonplanted Caladium $\times$ hortulanum Birdseye 'Candidum' tubers were exposed to 26 (control), 38, 43, or 48C for 1, 2, or 3 days. Then tubers were planted and forced in a glasshouse for 4 weeks at 18 to 33C (air). Leaf emergence from tubers exposed to 48C for 1 or 2 days required 3-12 days longer than leaf emergence from control tubers. No leaves emerged from tubers treated at 48C for 3 days. Exposing tubers to 38C for 3 days or 43C for 1 day did not affect subsequent plant growth. Exposing tubers to 43C for 2 or 3 days or 48C for 1 or 2 days resulted in plants with reduced shoot fresh weights and fewer leaves ≥ 15 cm. In a second experiment, planted tubers were forced for 10 days at 26C so that roots had developed to the edge of the pot and shoots had emerged to the soil surface. These planted (sprouting) tubers were exposed to 43C for 0, 4, 8, 12, 16, 20, or 24 hours/day for 1, 3, or 5 days and then forced for 7 weeks in a glasshouse. With 3- or 5-day treatments, days to leaf emergence increased as the hours of exposure to 43C increased. Only 33% of planted tubers exposed to 43C for 24 hours/day for 5 days sprouted. Tubers exposed to 43C for ≤ 12 hours/day for 3 days produced plants of similar or greater height, numbers of leaves ≥ 15 cm wide, and shoot fresh weights, but additional hours of daily exposure decreased these plant characteristics. At 5 days, plant height, number of ≥ 15 -cm-wide leaves, and shoot fresh weight decreased linearly with increased hours of exposure of tubers to high temperature.

Caladium tubers are generally stored under controlled conditions with optimal temperatures ranging from 21 to 27C (Harbaugh and Tjia, 1985; Marousky and Raulston, 1973). Marousky and Raulston (1973) reported that caladium tubers forced at 26C produced higher quality plants than tubers forced at 21 or 31C. Conover and Poole (1973) reported that, although shoot growth was best at 31C, the root systems of caladiums forced at 31C were smaller than those of plants grown at 21 or 26.5C. In general, the literature suggests that caladium tuber storage and forcing should be within an optimal range of a low of 18C night to a high of 26.5C day (Evans et al., 1992; Wilfret, 1993).

Soil temperatures between 38 to 50C occur frequently during container production of many ornamentals (Ingram, 1981), causing a reduction in plant growth (Fretz, 1971; Ingram et al., 1986). Muzzell and Joiner (1966) found that exposing caladium tubers to 40C for 2 weeks before forcing reduced subsequent leaf count, plant grade, and leaf color intensity compared to plants grown from tubers held at 22C. Growers have reported poor-quality caladiums being forced commercially in heat tents

or under high temperatures in greenhouses. This research was conducted to evaluate sprouting and growth characteristics of caladiums after short-term exposure of nonplanted or planted tubers to high temperatures.

Materials and Methods

Air temperature effects on nonplanted tubers (Expt. 1). 'Candidum' caladium tubers from 4 to 6 cm in diameter (commercially classified as no. 1 size tubers) were exposed to 26 (control), 38, 43, or 48C ± 1 C for 1, 2, or 3 days. Tubers dug 17 Jan. 1991 were stored 24 weeks at 24 to 26C and had developed ≈ 2.5 -cm-long shoots. After treatment, tubers were planted in 11-cm square pots (650 cm³) in 1 Florida peat : 1 fine sand : 1 horticultural vermiculite (by volume) amended with (kg·m⁻³) 5.9 dolomitic limestone, 3 hydrated lime, 0.6 superphosphate with frits (FTE-503). Three grams of Osmocote 14N-6.2P-11.6K controlled-release fertilizer (Grace-Sierra, Milpitas, Calif.) was applied to the soil surface of each pot after emergence of leaf sheaths. Plants were grown in a fan-and-pad-equipped glasshouse with air from 18C night to 33C day. Exterior paint excluded $\approx 80\%$ light, and the midday photosynthetic active radiation was between 400 and 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. A capillary mat subirrigation system supplied water to each pot.

There were 10 tubers per experimental unit and three replications in time. The number of days for the first leaf to emerge and unfurl was recorded. Plant height, shoot fresh weight, and the number of leaves divided into leaves < 15 cm wide and ≥ 15 cm wide were recorded 4 weeks after planting. Means were separated

by Dunnett's test ($P \leq 0.05$) for comparison of means with a control.

Medium temperature effects on planted tubers (Expt. 2). 'Candidum' caladium tubers 4 to 6 cm in diameter were dug 21 Jan. 1992 and stored for 10 to 12 weeks at 24 to 26C. Tubers were subsequently planted in pots 9 cm in diameter (430 cm³) and grown at 24 ± 2 C in a growth room for 10 days. At this stage of growth, roots had developed to the edge of the pots and leaf sheaths were just emerging from the soil. These planted tubers then were exposed to 43 ± 1 C soil for 0, 4, 8, 12, 16, 20, or 24 h·day⁻¹ for 1, 3, or 5 days. Planted tubers not exposed to high temperatures were maintained at 21 ± 1 C. After exposure to these treatments, the planted tubers were grown in a glasshouse for 7 weeks with conditions similar to those of Expt. 1.

There were three tubers per experimental unit with three replications in time. Number of days for the first leaf to emerge and plant growth data were subjected to regression analyses.

Results and Discussion

Experiment 1. Exposure of tubers to 38 or 43C, regardless of duration, did not significantly affect the days to leaf emergence as compared to tubers exposed to 26C (Table 1). Exposure of tubers to 48C for 1 or 2 days resulted in a 3- and 12-day delay in leaf emergence, respectively, when compared to leaf emergence of control tubers. When tubers were exposed to 48C for 3 days, leaves failed to emerge.

Plant height was reduced only when tubers were exposed to 48C for 2 days or 43C for 3 days (Table 1). The number of leaves < 15 cm wide increased for tubers exposed to 43C for 3 days. The number of leaves ≥ 15 cm wide and shoot fresh weights decreased for tubers exposed to 43C for 2 or 3 days or 48C for 1 or 2 days.

Experiment 2. The number of days to leaf emergence was unaffectedly exposing planted tubers to high temperature for 1 day, but it increased as the duration of 43C exposure increased to 3 or 5 days (Table 2). Only 33% of the planted tubers exposed to 43C for 24 h·day⁻¹ for 5 days sprouted. Therefore, trend analyses for measured variables for the 5-day exposure were performed without this treatment.

Plant height increased as hours that planted tubers were exposed to high temperature increased for 1 day. Plant height decreased when planted tubers were exposed for 3 days to 43C more than 12 h·day⁻¹. At 5 days, plant height decreased with increasing hours of exposure to 43C.

The number of leaves < 15 cm wide increased linearly with an increase in daily high-temperature exposure of planted tubers for 5 days but not at 1 or 3 days. The number of leaves ≥ 15 cm wide decreased when planted tubers were exposed to 43C for ≥ 16 h·day⁻¹ for 3 days, and a linear decrease in large leaves occurred as hours of daily exposure increased for 5 days.

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Table 1. Response of nonplanted 'Candidum' caladium tubers to 26 (control), 38, 43, or 48C for 1,2, or 3 days. Plant growth data recorded 4 weeks after tubers were planted in pots and forced in a glasshouse.

Temp (°C)	Leaf emergence (days)			Plant ht (cm)			No. leaves <15 cm			No. leaves ≥15 cm			Shoot fresh wt (g)		
							Days of exposure								
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
26	14	13	15	27	28	28	1.5	1.8	1.4	1.9	2.0	1.7	46	46	39
38	15	13	14	27	28	28	1.5	1.3	1.6	1.9	2.2	1.6	42	48	38
43	15	15	18	25	26	21 ^z	2.3	2.0	2.3 ^z	2.0	1.5	0.4	35	36 ^z	20 ^z
48	17 ^z	25 ^z	--- ^y	22	19 ^z	---	2.1	1.5	---	0.9 ^z	0.4 ^z	---	23 ^z	12 ^z	---

^zValues in columns significantly different from the control (26C) treatment by Dunnett's test, $P < 0.05$.

^yTubers exposed to 48C for 3 days did not emerge.

Table 2. Response of planted (sprouting) 'Candidum' caladium tubers to 43C for 0, 4, 8, 12, 16, 20, or 24 h-day⁻¹ for 1, 3, or 5 days.

Hours/day at 43C	Leaf emergence (days)			Plant ht (cm)			No. leaves <15 cm			No. leaves ≥15 cm			Shoot fresh wt (g)		
							Days of exposure								
	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
0	36	32	38	23	2	31	2.1	2.7	0.2	2.6	2.4	3.4	37	31	42
4	29	32	34	21	25	22	3.3	2.1	2.5	2.8	2.0	1.7	34	34	28
8	36	33	38	24	24	21	3.2	1.5	3.0	2.1	2.3	1.7	32	36	28
12	38	36	40	26	26	21	2.5	2.0	2.0	2.2	2.2	1.6	37	37	20
16	33	40	44	26	19	17	3.1	2.8	3.0	2.2	1.4	0.7	34	21	14
20	36	38	48	25	21	11	1.5	1.2	4.9	1.7	1.6	0.3	33	21	12
24	35	50	--- ^y	27	19	---	1.6	2.0	---	1.9	0.2	---	31	6	---
Significance ^x	NS	L	L	L	Q	L	NS	NS	L	NS	Q	L	NS	Q	L
r ²	---	0.37	0.52	0.21	0.60	0.73	---	---	0.32	---	0.61	0.62	---	0.81	0.78

Tubers were planted and forced at 24C for 10 days. Roots had developed to the edge of the pot, and leaf sheaths were at the soil surface when planted tubers were exposed to high temperatures.

^yOnly 33% of the tubers exposed to 43C for 24 h-day⁻¹ for 5 days had sprouted by the end of this study; thus, this treatment was removed from the regression analyses.

^xLinear (L) or Quadratic (Q) regression equations nonsignificant (NS) or significant at $P < 0.05$.

Shoot fresh weights were similar for plants grown from tubers exposed to 43C for all exposure times for 1 day. Shoot fresh weight decreased when planted tubers were exposed to high temperature for ≥ 16 h-day⁻¹ for 3 days. A linear decrease in shoot fresh weight resulted from an increase in daily hours of exposure after 5 days.

In summary, much attention has been given to low-temperature stress on caladiums because growth of this tropical crop is inhibited by temperatures below 16–18C when storing tubers (Marousky, 1974), shipping prefinished potted plants (Harbaugh, 1990), and forcing (Evans et al., 1992). In our study, caladium growth was also inhibited when tubers were exposed to short-term supraoptimal air and soil temperatures. With nonplanted and planted tubers, air or soil temperatures = 43C for 2 or 3 days and exposure times longer than 12 h-day⁻¹ caused significant delays in sprouting and reduced plant quality as measured by plant

height, number of large leaves, and shoot fresh weight. Higher temperatures (48C for 3 days) or longer exposure (43C for 5 days) completely inhibited sprouting.

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