Ornamental Section

INFLUENCE OF TEMPERATURE AND DURATION OF CURING, STORAGE, SHIPPING AND FORCING PERIODS ON CALADIUM GROWTH

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Abstract. **Freshly dug caladium tubers were stored for 7 weeks at 40, 50, 60, 70, 80, or 90°F. After storage tubers were evaluated for sprouting and subsequent growth. Lower storage temperatures reduced subsequent sprouting and growth. Tubers stored at 90°F sprouted earlier and produced larger plants than tubers stored at lower temperatures. Tubers stored at 40 and 50°F were cold-injured and failed to grow when planted.**

Tubers were stored for 0, 3, 6, and 12 weeks at 75°F and subsequently evaluated for sprouting and growth in controlled environmental chambers. Incidence of sprouting and shoots per tuber increased as storage period increased.

Tubers stored for 7 weeks at 75°F were planted in soil and placed in incubators at 50, 60, 70, 80, or 90°F. After 5 weeks, no roots or shoots were visible on tubers held at 50 or 60°F. Tubers held at 80°F had more shoots and roots than tubers at 70 or 90°F. Numbers of roots or shoots did not differ between tubers held at 70 or 90°F.

After 7 weeks storage at 75°F tubers were exposed to 32 or 42°F for 1, 3, and 6 days. After this cold exposure tubers were evaluated for subsequent sprouting and growth. Tubers subjected to 32°F for 6 days were cold-injured and did not sprout. Six days at 42°F or 3 days at 32°F inhibited tuber sprouting and growth. One day at 32°F or 3 days at 42°F inhibited tuber growth but not as severely as 3 days at 32°F or 6 days at 42°F.

Caladiums are grown commercially in Florida principally for their tubers. Tubers are dug from November to January and shipped to northern greenhouse growers for forcing as potted plants for spring holidays and as bedding plants. Difficulties encountered by the northern grower include delayed tuber sprouting, lack of uniformity in sprouting and variable results with regard to crop timing from year to year (1, 3, 4, 9). Information available on time required to produce a crop is inconsistent. Post (9) reported 6-8 weeks at a minimum of 65°F are necessary to produce a saleable plant, while Kiplinger (3) reported 8-10 weeks are needed. Poole and Conover (7, 8) recently demonstrated that minimum soil temperatures of 70, 80 or 90°F had little effect on number or size of leaves. However, they did not report the maximum or average soil temperatures. Most sources indicate bottom heat is necessary for rapid forcing (1, 3, 4, 9).

Little is known about effects of temperature during storage. Post (9) and Laurie *et al* (4) suggest that stored tubers be held at 60°F while Kiplinger (3) and others (1) suggest that tubers received in fall should be held at 70°F or higher temperatures until planted.

Some workers have observed that length of time the tubers are stored may influence subsequent growth. Post (9) and Sheehan (10) indicated that tubers are not known to possess a dormant period, but observed that tubers forced in January do not produce plants as quickly as those forced in May.

Cultural procedures during the forcing period may influence tuber growth. Scooping and inverting tubers increased the number of leaves but leaves were smaller than those of tubers not scooped or inverted (6, 7, 8). Fertilizer recom-

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mendations for forcing vary considerably (1, 3, 4, 9).

Conover and Poole (2) recently reported that increased nutritional levels increased the number of breaks and plant grade but did not affect leaf length. They indicated that high nutritional levels were partly able to overcome eye removal or inverted planting.

Objectives of this study were to determine the influences of temperature during curing, storage, shipping and forcing and the influence of storage duration on caladium tuber growth.

Methods and Materials

On February 8, 1972, 'Jesse Thayer' and 'Dr. Groover' caladium tubers were dug from commercial plantings in the Sebring-Lake Placid area. Tubers were graded and number 1 size (1.5-2.5 in diam) were used for experiments. Tubers were transported to Bradenton February 9. The following day, soil was washed from tubers, remaining roots removed and tubers were dipped in Benlate (1-½ lbs/100 gal for 15 min). Tubers were air-dried overnight at 75°F at 50-60% RH and experiments started Feb. 11. All tubers were handled in this manner except as noted below.

Experiment 1. Curing Temperatures. 'Jesse Thayer' tubers were cut to expose internal tissue with a flat surface area of 1-1.3 sq in. Ten tubers were placed in incubators at 50, 60, 70, 80 or 90°F. Tubers were rated for suberization after 72 hrs according to the following schedule 1 = no visible evidence of suberization (tissue remained yellow and showed no evidence of 'Chalking' or white suberized tissue), 2 = slight suberization, 3 = moderate suberization, 4 = heavy or completely suberized over cut area.

Experiment 2. Curing Procedure and Storage Temperature. 'Jesse Thayer' tubers were divided into 72 lots with 5 tubers in each lot. Six lots each were placed at 40, 50, 60, 70, 80 or 90°F for 7 weeks (Feb. 11-March 31). These were considered as non-cured stored tubers. The remaining 36 lots were held at 75°F, 50-70% R.H. for 1 week (Feb. 11-18). These were considered as cured tubers. Six lots of cured tubers were then placed at 40, 50, 60, 70, 80 or 90°F for 6 weeks (Feb. 18-March 31). The fresh weight of each lot (5 tubers) was determined initially and after 3, 5, and 7 weeks and data expressed as percent change in fresh weight. On March 31, each lot was planted in plastic flats (6.5 x 9 in) and grown in greenhouse maintained at minimum temperature of 70°F. Numbers of tubers with incipient sprouts (shoots) were noted after storage (March 31). Shoot height was recorded May 10, leaves graded May 23 and June 1, and number of leaves noted on June 15. Leaves were graded on the following schedule: 1 = shoot only, leaf not expanded, 2 = leaf unfolding to 2 in wide, 3 = 2-4 in wide, 4 = 4-6 in wide, 5 = 6-8 in, 6 = greater than 8 in. First shoot that emerged from soil was graded.

Experiment 3. Shipping Temperatures. 'Dr. Groover' tubers were stored 6 weeks (February 11 to March 24) at 75°F and 50-75% RH. On March 24, tubers were divided into 7 lots of 10 tubers each. Each lot of tubers was exposed to 32° or 42°F for 1, 3 or 6 days. A control lot was held at 75°F. Tubers were held at 75°F after cold exposure. On March 30 all tubers were planted in 4-in plastic pots and placed in a greenhouse held at a minimum of 70°F. Sprouting, leaf number and width were recorded at period intervals.

Experiment 4. Forcing temperature. 'Dr. Groover' tubers were stored February 11 to April 7 at 75°F 50-75% RH. Plastic flats of 5 tubers each with 3 replications were planted on April 7 and placed in incubators maintained at constant temperatures of 50, 60, 70, 80, 90°F. After 5 weeks, the number of emerged shoots was noted. Tubers were removed from soil and the number of roots and total number of shoots on each tuber were recorded.

Experiment 5. Storage Period and Root Removal. On January 18, 1973, 'Caroline Horton' caladium tubers were dug from a commercial planting in the Lake Placid area, graded for size and general vigor. Tubers (No. 1 grade) were transported to Bradenton January 19 and divided into 6 lots of 20 tubers each. On four lots, roots and leaf petiole bases were removed. Roots were left intact but leaf petiole bases were removed on the remaining 2 lots. Tubers were air-dried for 3 days at 75°F and 60-70% RH. One group of tubers each with and without roots was planted January 22. The remaining 3 lots without roots were stored 3, 6 or 12 wks. The lot with intact roots was stored for 12 weeks. During storage, temperature was maintained at 75°F and RH varied from 50-80%. Tubers were planted in 4-in pots containing peat moss and vermiculite mixture (50/50, V/V). Pots were held at 75°F for 5 weeks, and then placed in an air controlled environmental chamber for 7 wks. The environmental chamber was maintained at 82 ± 2°F during a 14-hr day and 74° ± 2°F during the night. Light was supplied by cool white fluorescent tubes at 1100 ft-c at pot

height. After 7 wk plants were 18-21 in tall. Light intensity at 20 in was 1500 ft-c. Number of leaves were recorded after 4 and 7 wks in environmental chamber. Tuber fresh weights and volume were recorded initially after tubers were washed and air dried for 3 days and again after each respective storage period. Tuber volume was determined by water displacement.

Results

Expt. 1. As temperature during curing increased, suberization increased (Table 1). Tubers subjected to 50°F showed no evidence of suberization while cut surface of tubers held at 90°F were completely suberized.

Expt. 2. Curing and storage temperatures affected weight loss and growth of tubers (Tables 2 and 3). Tubers stored at 40, 50, 60 or 70°F without prior curing lost more weight than cured tubers held at these respective temperatures. Curing had no influence on weight loss when tubers were stored at 80 or 90°F. After storage, tubers held at 40 or 50°F with or without curing had no shoots and failed to grow up to 10 weeks after planting. Tubers stored at 80 or 90°F with or without curing had more shoots, greater shoot emergence and larger leaves than cured tubers stored at 60 or 70°F. Tubers not cured and stored at 60°F did not sprout uniformly. When stored at 70°F, uncured tubers were slow to emerge and had smaller and fewer leaves than cured tubers.

Table 1. Influence of temperature during a 3 day curing period on degree of suberization of 'Jesse Thayer' caladium tubers.

Curing temperature (°F)	Suberization[z]
50	1.0
60	2.8
70	3.1
80	3.5
90	4.0

Table 2. Influence of curing for 1 week at 75°F and various storage temperatures for 6 weeks on percent weight loss of 'Jesse Thayer' caladium tubers.

Storage temperature	Curing procedure	Percent wt loss after (wks) 1	3	5	7
40°F	none	11	27	40	51
	1 wk at 75°F	19	24	29	33
50°F	none	16	43	59	65
	1 wk at 75°F	20	30	40	46
60°F	none	20	43	53	59
	1 wk at 75°F	17	28	34	39
70°F	none	18	32	38	41
	1 wk at 75°F	15	24	28	31
80°F	none	16	28	32	34
	1 wk at 75°F	18	28	32	34
90°F	none	19	28	31	33
	1 wk at 75°F	17	31	35	37

Expt. 3. Tuber growth was influenced by temperature during simulated shipping (Table 4). Tubers held at 32°F for 6 days failed to sprout when planted; no shoots were visible 67 days after planting. Tubers held at 32° for 1 and 3 days or at 42°F for 1, 3, or 6 days were slower to sprout and had fewer and smaller leaves than tubers not exposed to any cold treatments.

Expt. 4. Temperature after storage (during forcing period) greatly influenced caladium root and shoot growth (Table 5). On May 10 (33 days after planting), tubers forced at 80°F had more shoots above the soil than tubers forced at 70 or 90°F. No shoots or roots were visible on tubers forced at 50 or 60°F. More roots and shoots were present on tubers forced at 80°F than on those at 70 or 90°F.

Expt. 5. Length of storage influenced tuber sprouting and growth (Table 6). Freshly dug tubers which were replanted immediately developed new roots and shoots. As storage time increased, the number of leaves produced per tuber increased. Tubers stored 12 weeks and forced at 75°F for 5 weeks (prior to placing tubers in enviromental chamber) had several shoots visible above soil while all other tubers had no shoots visible. Removing roots prior to the storage period did not ultimately influence tuber growth. Tubers stored for 3 and 12 wks lost wt and decreased in volume (Table 7). Wt loss amounted to 16-26% but volume decreased 31% in 3 wks and 43% in 12 wks. Leaving roots intact on tubers did not reduce volume loss.

Discussion

Temperature during storage, shipping, and forcing had a profound effect on caladium growth. Optimum temperature for forcing tubers was 80°F. Tubers forced at 70 or 90°F did not grow as well

Table 3. Influence of curing for 1 week at 75°F and various storage temperatures for 6 weeks on growth of 'Jesse Thayer' caladium tubers.

Storage temperature	Curing procedure	No. tubers with shoots after storage 3/31	Shoot height (cm) 5/10	Leaf grade[z] 5/23	Leaf grade[z] 6/1	Leaves/tray 6/15
40°F	none	0	[y]			
	1 wk at 75°F	0	[y]			
50°F	none	0	[y]			
	1 wk at 75°F	0	[y]			
60°F	none	0	[x]			
	1 wk at 75°F	9	1.9	2.2	4.0	30.6
70°F	none	14	0.7	1.2	2.5	13.5
	1 wk at 75°F	13	1.5	2.4	3.8	31.2
80°F	none	23	2.8	3.0	3.4	25.8
	1 wk at 75°F	23	4.7	3.2	3.8	25.8
90°F	none	28	4.6	4.7	5.3	27.0
	1 wk at 75°F	30	4.1	3.7	5.7	29.4

[z]Leaf grade 1 = shoot only leaf not expanded, 2 = leaf unfolding to 2 in wide, 3 = 2-4 in, 4 = 4-6 in, 5 = greater than 6-8 in, 6 = greater than 8 in.

[y]Tubers held at these temperatures failed to sprout

[x]Tubers held at 60°F without curing did not grow uniformly and representative values were not obtained.

as those forced at 80°F. Tuber growth was slight at 60°F (Table 5). The suggested cultural practice of supplying bottom heat to tubers (1, 2, 3, 7) is valid and essential for rapid forcing.

Tubers are sensitive to cold during storage and shipping. Caladium growth was inhibited when tubers were exposed to 42°F for only 1 day. The longer the exposure period, the greater the inhibition of growth. Tubers stored for 7 weeks at 50°F failed to grow. Tubers not cured and stored at 60°F did not sprout uniformly and too few tubers sprouted to provide representative data. The growth-inhibiting phenomenon in caladiums might be considered as "chilling injury". The caladium is native to tropical America and many tropical plant species are sensitive to low temperature (5). Although tubers cured and held at 60°F eventually grew, growth was inhibited compared with cured tubers held at higher temperatures. The recommendation that tubers be held at 60°F before planting apparently is not appropriate (3, 7). Tubers should be stored at a minimum of 70°F. If tubers are to be held at 70°F, they should first be cured at 75°-85°F for several days to develop a suberin layer.

Curing helped prevent weight loss in tubers. Uncured tubers lost more weight during storage at 40, 50, or 60°F than cured tubers. This indicates

Table 4. Influence of low temperature for 1, 3 or 6 days during simulated shipment on ultimate sprouting and growth of 'Dr. Groover' caladium tubers.

Temperature (°F)	Duration (days)	No. tubers sprouted 5/10	5/23	Leaves/tuber 6/1	6/13	6/20	Leaf width (cm) 6/13	6/20
Control[y]		8	10	4.1	7.0	9.7	8.3	10.5
32	1	7	9	3.8	7.0	9.5	6.8	8.1
32	3	0	8	2.7	4.6	7.7	6.2	6.5
32	6	0	0	-[z]	-	-	-	-
42	1	4	9	3.7	6.6	8.2	7.8	8.5
42	3	7	9	3.2	5.8	7.8	7.6	8.0
42	6	2	5	1.8	3.9	5.3	4.4	4.5

[z]Tubers held at this temperature failed to sprout.

[y]Control tubers held at 75°F while other tubers were exposed to 32 or 42°F.

that curing is necessary to develop a suberin layer on the surface of freshly dug tubers to prevent moisture loss. Weight loss was greatest during the first 3 weeks after digging (Tables 2 and 7). Tubers held for 7 wks did not lose any more weight at 80 or 90°F than tubers stored at lower temperatures. The incidence of suberin is related to temperatures (Table 1). Tubers placed at 80 or 90°F formed a thick suberin layer that prevented loss of moisture.

True internal dormancy is not a characteristic of caladium because tubers freshly dug in the field grew satisfactorily when replanted in pots. A true internal dormancy would exist only if tubers did not grow when provided with proper external environment for growth. However, the length of storage influenced tuber growth. The longer the storage period, the more rapid the emergence of leaves. Removing roots prior to storage did not influence tuber growth. We removed all leaf petiole bases before tubers were stored. Possibly some adventitious and/or axillary shoots were accidentally removed during cleaning. Adventitious buds may have initiated in storage and after 12 wk storage more shoots would appear after tubers were planted. A "partial" dor-

Table 5. Influence of temperature during forcing period on number of roots and shoots of 'Dr. Groover' caladium tubers.

Temperature (°F)	Roots (No./tuber)	Shoots (No./tuber)	Visible shoots[z]
50	0	0	0
60	0	0.5	0
70	1.7	4.7	1
80	6.8	5.5	9
90	2.9	4.8	1

[z]Shoots visible above the growing medium. Total of 15 tubers planted at each temperature regime.

Table 6. Influence of storage period and root removal on growth of 'Caroline Horton' caladiums.

Storage period	Root removal	Shoots/tuber 5 wks (No.)	Leaves/tuber 9 wks (No.)	Leaves/tuber 12 wks (No.)
0	Removed	0	3.8	5.8
3 wk	Removed	0	5.3	6.2
6 wk	Removed	0	4.7	7.1
12 wk	Removed	2.3	3.9	7.9
0	Intact	0	4.5	5.1
12 wk	Intact	3.8	5.7	8.1

Table 7. Influence of storage period and root removal on changes in weight and volume of 'Caroline Horton' caladium tubers

Storage period	Root removal	Weight Initial (gms)	Weight After storage (gms)	Weight % change	Volume Initial (cc)	Volume After storage (cc)	Volume % change
0	removed	240			299		
3 wk	removed	263	221	-16	336	231	-31
6 wk	removed	248			338		
12 wk	removed	249	185	-26	314	179	-43
0	intact	369			430		
12 wk	intact	282	222	-21	389	218	-43

mancy may be present in tubers. This partial dormancy is not overcome by low temperature but may be related to tuber drying. Tubers typically lost 16 and 31% of their weight and volume, respectively, in 3 wks. It is possible that a partial dormancy may be related to biochemical changes. Volume loss of tubers amounted to 43% in 12 wk (Table 7). It is apparent that loss in tuber volume is not due entirely to loss of moisture.

Considering all the variables influencing tuber growth it would be difficult to develop a foolproof schedule for forcing caladiums. However, careful consideration should be given to temperature control to prevent chilling injury.

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