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TEMPERATURE AND DESICCATION AFFECT THE GERMINATION OF CHAMAEDOREA PALM SEED

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Abstract. **Highest total germination percentage (G), fewest days to 50% of germination (T_{50}), and shortest period in days between 10% and 90% germination (T_{90} - T_{10}) of *Chamaedorea* seed occurred when recently harvested seeds were germinated at constant 30°C. Two temperatures having 30°C means alternated at 12-hour intervals reduced G and increased the days to T_{50} and T_{90} - T_{10}, which delayed germination. Generally, no seeds germinated at constant 35°C, and G was greatly reduced when 35°C was alternated with 25°C or 30°C. Shortly after harvest, *Chamaedorea* seed contained 15% to 36% moisture content, depending on the species. Seed tolerance to reduced moisture content during 28 days storage varied by species. *Chamaedorea elegans* Mart. and *C. microspadix* Burret. seeds at harvest contained 20.4% and 35.6% moisture, and G declined 44% and 2% when seed moisture was reduced to 16.1% and 18.4% respectively during storage. *Chamaedorea radicalis* Mart. and *C. seifrizii* Burret. contained 15.0% and 24.5% moisture content at harvest, respectively, with G reduced 43% and 20% during storage at 11.1% and 19.3% moisture contents. The G of *Chamaedorea* seeds of all species was reduced after storage below 0°C, with further reduction as subzero temperatures declined.**

The palm genus *Chamaedorea* contains 133 species, with most native to tropical regions from Mexico to South America (Jones, 1984). Seeds harvested from plants in their native habitat are germinated by commercial producers of palms in Florida. Highest total germination of most *Chamaedorea* species occurs when seeds are sown immediately after harvest, although seed viability continues for 4 to 6 months (Poole and Conover, 1974; Read, 1962). The failure of seeds to germinate when received has been attributed by De Leon (1958) to improper handling or unfavorable environments during the shipment and storage of seeds. Palm seeds do not enter a state of dormancy when held at unfavorable environments after harvest, as do seeds of most dicot species (Loomis, 1958). *Chamaedorea* seeds have thin seed coats (testa) with the embryo embedded in the carbohydrate containing endosperm. The embryo is near the seed coat, which makes it subject to injury during handling, and storage at unfavorable temperatures or desiccation during shipping and storage. Nagao et al. (1980) reported that pre-soaking Alexandra palm (*Archontophaenix alexandrae* F. J. Muell.) seed in water for 3 days accelerated and increased total germination. The objectives of this research were to measure temperature and desiccation tolerances of seed during storage, and to determine the optimal temperature ranges for germinating seeds of four *Chamaedorea* species.

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Materials and Methods

Seeds of *Chamaedorea elegans* 'Neanthe bella' and *C. radicalis* were harvested from plants in their native habitat in Mexico in late Nov. 1993, stored at 20°C, and received in Gainesville, FL, 4 Jan. 1994. *Chamaedorea microspadix* seeds were collected in the Tampa, FL area on 27 Nov. 1993 and stored at 20°C. Seeds of *Chamaedorea seifrizii* (Bamboo palm) were collected 1 Dec. 1993 in South Florida and stored at 20°C. When received, four replications of 50 seeds of each species were weighed, dehydrated at 50°C for 72 hours in forced draft ovens, and reweighed after cooling to determine the seed moisture contents.

Seed handling and germination procedures

Seeds were cleaned immediately after harvest. In all studies, seeds were soaked in aerated deionized water for 5 days, surface dried, and dusted with captan before germination in moist Canadian peatmoss in Ziplok bags. Treatments in germination temperature studies contained four 100-seed replicates, with four 50-seed replications in the other studies. All seeds were germinated in incubators (Stults Scientific Engineering Corps, Springfield Ill.). Germination counts of seeds with radicle protrusion through the testa were made at 3-day intervals during 90 days. Total germination percentages (G), days to 50% of final germination (T_{50}), and germination span in number of days between 10% and 90% germination (T_{90} - T_{10}) were calculated as described by Furutani et al. (1985).

Germination temperatures

Imbibed seeds were germinated in dark incubators at constant 25°, 30°, or 35°C, while in a second study, seeds were germinated in darkness at 12-hour alternating temperatures of 25°/30°C, 30°/35°C, or 25°/35°C during 90 days. The design for both studies was a randomized block with data analyzed by analysis of variance (ANOVA). Separate analyses were made for each species. Differences among treatments were determined using Fisher's LSD procedure (Milliken and Johnson, 1984) at P = 0.05.

Seed moisture content during storage

Each of the four 50-seed replications per treatment were weighed, placed in 9-cm open petri dishes, and partially dehydrated at 35°C in forced draft ovens for 12, 24, 48, or 96 hours. Following dehydration, the replications were reweighed and immediately sealed in screw-capped 5-ml glass vials, 50 seeds per vial, and stored at 25°C for 4 weeks. After storage, seeds were reweighed, soaked, dusted with captan, and germinated at constant 30°C. For each species, the initial moisture content for recently harvested seed was used in calculating the moisture percentages for those seeds partially dehydrated. Germination data were analyzed for seed moisture

level by ANOVA, using a split plot with duration of dehydration as the main plot and seed moisture as the subplot.

Cold tolerance of seeds

Seeds were placed in 15 x 2.5 - cm petri dishes on wire screens supported by segments of tubing 1-cm above a chemical desiccant. Constant 22% RH was maintained in the sealed petri dishes by adding 50 ml of saturated potassium acetate to the bottom of each dish (Copeland, 1976). The seeds were in a refrigerated incubator at 20°C during the week of dehydration. Following partial dehydration, seeds were placed immediately in 10-ml sealed glass vials (50 seeds per vial) and immersed in polyethylene glycol-water (v/v) in controlled-temperature baths (Guy and Carter, 1984) at 10°, 5°, 0°, -5°, -10°, or -20°C. Bath temperatures were lowered 3°C/hour to final temperatures, kept 10 days, then increased 4°C/hour to 10°C. Following low-or subzero temperature treatment, seeds were germinated at constant 30°C as described previously. Germination counts were made every third day of seeds with radicle protrusion through the testa, and germination data were analyzed using the ANOVA from each species. Treatment differences were determined using Fisher's HSD procedure.

Results and Discussion

Wide variations in G, T_{50}, and T_{90} - T_{10} occurred among both constant and alternating germination temperatures for seeds of each *Chamaedorea* species. Higher G was achieved at constant temperatures than at alternating temperatures having the same means (Table 1). Similar trends also were found for T_{50} and T_{90} - T_{10} measurements. Constant 25° or 30°C temperatures during germination promoted the highest G for *C. elegans* and *C. microspadix*, but germination percentages were much lower at 25°C than 30°C for *C. radicalis* and *C. seifrizii*. (Table 1). The T_{50} and T_{90} - T_{10} values generally were similar for each species at constant 25°C and 30°C germination temperatures. Alternating 25°/30°C temperatures generally promoted higher G and lower T_{50} and T_{90} - T_{10} values than the other alternating temperature combinations used in our study (Table 1). Bewley and Black (1982) reported that mature seeds without dormancy have higher total germination at favorable constant temperatures than at corresponding alternating temperatures.

The germination of *Chamaedorea* seed is more rapid than the germination of most other palm species, but it still required 20 to 40 days to achieve 50% of final germination. Relatively high medium temperatures (25°C to 35°C) are necessary to promote the seed germination of palms (Broschat et al., 1986; Carpenter, 1988A). Carpenter (1988B) reported that *Butia capitata* (Mart.) Becc. seed required constant 40°C for 2 to 3 weeks and then 30°C thereafter for germination. Imbibed seeds of palms retain their viability during long periods of storage, without the seeds entering into a secondary dormancy. Seed germination of *Chamaedorea* is relatively rapid and uniform at favorable temperatures, but germination slows as temperatures become less favorable. Unfavorable temperatures delay germination, thus promoting highly irregular germination over a period of many months to several years.

No explanation can be given for the inhibition of *Chamaedorea* seed germination at 35°C. No seeds of *C. elegans*, *C. microspadix*, or *C. radicalis* germinated at 35°C constant temperatures, and only 18% G for *C. seifrizii*. Embryos appeared normal after the seeds were kept at constant 35°C for 60 days. Seeds of *C. microspadix* transferred to 30°C after 60 days at 35°C achieved 42% germination, but germination was highly irregular. Few seeds of each species germinated when 35°C for 12 hours daily was alternated with 30°C, and 35°C caused the reduced G at alternating 25°/35°C.

Table 1. Germination of *chamaedorea* seed under constant or alternating temperatures. A separate analysis was conducted with the data from each cultivar. Data are the means of 400 seeds germinated at 30°C during 90 days.

Species	Temperature[z] (°C)	Germination[y] G[x]	T_{50}[w]	T_{90}-T_{10}[v]
C. elegans	25	78 a	40 a	9 ab
	30	85 a	37 b	20 a
	35	0	-	-
	25-30	70 b	41 a	21 a
	25-35	48 c	36 b	16 b
	30-35	0	-	0
C. microspadix	25	88 a	11 c	10 a
	30	87 a	8 c	9 a
	35	0	-	-
	25-30	69 b	13 bc	11 a
	25-35	28 c	16 b	11 a
	30-35	7 d	23 a	
C. radicalis	25	29 b	17 c	15 c
	30	57 a	14 c	14 c
	35	0	-	-
	25-30	37 b	18 c	19 b
	25-35	10 c	28 b	25 a
	30-35	2 c	34 a	
C. seifrizii	25	19 c	25 b	17 c
	30	66 a	22 c	15 c
	35	18 c	25 b	28 a
	25-30	51 b	24 bc	21 b
	25-35	45 b	27 b	24 ab
	30-35	19 c	31 a	25 a

[z]Temperature alternations were every 12 hours.
[y]Mean separation for each species within columns by Fisher's LSD procedure, P=0.05.
[x]Percent total germination after 90 days.
[w]Days to 50% of final germination.
[v]Days from 10% to 90% germination.

Chamaedorea seeds have high moisture contents at harvest, with considerable variation among species (Table 2). *Chamaedorea elegans*, *C. radicalis*, and *C. seifrizii* had reduced total germination after seeds lost 20% to 25% of the moisture content at harvest. Seeds of *C. elegans* had little tolerance of desiccation, with total germination declining from 81% to 37% when seed moisture content at 20.4% at harvest was reduced to 16.1% during storage. No seeds of *C. elegans* germinated after storage at below 12.7% moisture content. *Chamaedorea microspadix* seed was more tolerant of desiccation, having no reduction in total germination until the seeds lost more than 50% of the moisture content at harvest (Table 2). The loss in total germination was found to approximate the extent of decline in seed moisture content, with few seeds germinating after storage at below 10% moisture.

Storing *Chamaedorea* seed at low moisture content delays subsequent germination (large T_{50} values) and causes irregular (larger T_{90} - T_{10} values) germination (Table 2). The lower the seed moisture level during storage the longer the delay and more irregular germination became. Thus, reduced total germination after seed dehydration was caused primarily by fewer seeds germinating during the 90-day germination peri-

Table 2. The effect of reduced moisture content of *chamaedorea* seeds during storage on germination. Seeds were stored at each seed moisture content for 28 days at 5°C, then germinated at 30°C during 90 days. Separate analyses were conducted with the data from the four 50 seed replications of each species.

Seeds			Germination[z]		
species	dehydration (hours)	moisture (%)	G[y]	T_{50}[x]	T_{90}-T_{10}[w]
C. elegans	0	20.4	81 a	38 b	21 b
	12	16.1	37 b	49 a	28 a
	24	12.7	9 c	47 a	30 a
	48	10.3	0	-	-
	96	7.9	0	-	-
C. microspadix	0	35.6	89 a	9 d	9 a
	12	18.4	87 a	11 d	8 b
	24	8.6	59 b	16 c	9 a
	48	7.4	37 c	21 b	10 a
	96	4.8	7 d	27 a	-
C. radicalis	0	15.0	60 a	14 b	16 b
	12	11.1	17 b	22 a	25 a
	24	9.7	5 c	-	-
	48	8.2	2 cd	-	-
	96	6.9	1 d	-	-
C. seifrizii	0	24.5	64 a	19 b	17 b
	12	19.3	44 b	20 b	19 b
	24	9.6	31 c	23 a	27 a
	48	6.5	14 d	24 a	30 a
	96	5.1	3 e	26 a	-

[z]Mean separation for each species within columns by Fisher's LSD procedure, P=0.05.
[y]Percent total germination after 90 days.
[x]Days to 50% of final germination.
[w]Days from 10% to 90% germination.

Table 3. Gemination of *chamaedorea* seed after low temperature storage for 10 days. A separate analysis was conducted with the data from each cultivar. Data are the means of 200 seeds germinated at 30°C during 93 days.

		Germination[z]		
Species	Storage temp (°C)	G[y]	T_{50}[x]	T_{90}-T_{10}[w]
C. elgans	10	62 a	41 b	22 b
	5	51 b	41 b	24 b
	0	53 b	48 a	24 b
	-5	19 c	50 a	36 a
	-10	0	-	-
	-20	0	-	-
C. microspadix	10	85 a	15 c	17 d
	5	84 a	16 c	19 cd
	0	77 a	17 c	20 c
	-5	61 b	20 b	28 ab
	-10	29 c	24 a	30 a
	-20	6 d	24 a	27 b
C. radicalis	10	51 a	14 b	11 b
	5	52 a	13 b	10 b
	0	48 a	13 b	10 b
	-5	41 b	14 b	10 b
	-10	30 c	15 ab	13 a
	-20	29 c	16 a	13 a
C. seifrizii	10	48 a	19 b	17 b
	5	43 a	21 b	18 ab
	0	26 b	25 a	19 a
	-5	0	-	-
	-10	0	-	-
	-20	0	-	-

[z]Mean separation for each species within columns by Fisher's LSD procedure, P=0.05.
[y]Percent total gemination after 93 days.
[x]Days to 50% of final germination.
[w]Days from 10% to 90% germination.

od of the study. After storage, all seeds were immersed in aerated deionized water for 5 days prior to germination. Embryos of desiccated seeds were fully hydrated after soaking, indicating that delayed germination resulted from physiological and biochemical changes that occurred during storage at low seed moisture content. Bewley and Black (1982) reported that little information has been found to explain the quantitative relationship between the environmental factors during seed storage and seed viability. The large reductions in seed viability after storage at 5% to 10% moisture levels were an indication that *Chamaedorea* seeds are recalcitrant. However, embryos of *Chamaedorea* seeds failing to germinate after storage at low moisture contents were not killed by desiccation, as occurs for recalcitrant seeds. Rather, embryos appeared normal after soaking following dry storage for 5 days. Hartmann et al. (1990) reported that grapefruit seed, previously classified as recalcitrant because drying the seed below 18% moisture content greatly reduced total germination, is orthodox in behaviors because seeds are not killed at this low moisture level. Our results indicate that after harvest and cleaning, *Chamaedorea* seed immediately should be stored in sealed moisture-proof glass jars or ziplock bags that keep seeds at moisture contents only slightly below when harvested. It is important to provide the constant humid environment while avoiding the complete hermetic sealing of containers, thus allowing some gas exchange.

Chamaedorea seeds stored at 5°C or 10°C had similar G, T_{50}, and T_{90}-T_{10} measurements as seeds stored at warmer temperatures (Table 3). Seeds of *C. microspadix* and *C. radicans* were tolerant of storage at O°C, but *C. elegans* and *C. seifrizii* had reduced G after storage. Seeds of *C. elegans* and *C. seifrizii* failed to germinate after storage at subzero temperatures, while the total germination of *C. microspadix* and *C. radicalis* declined as subfreezing temperatures declined (Table 3). Both T_{50} and T_{90} - T_{10} values increased indicating delayed and more irregular germination occurred, as seed storage temperatures were reduced (Table 3). Hartmann et al. (1990) associated the reduced and delayed germination of seeds after storage at subzero temperatures with the injury caused when free water formed ice crystals between cells.

Our results indicated that the best storage of *Chamaedorea* seeds was under humidities that maintain seed moisture contents near those at seed harvest with 5°C to 10°C storage temperatures. Higher humidities and temperatures than necessary to maintain the viability of the seed during storage increases the potential for disease. *Chamaedorea* seeds should be surface sterilized and dusted with fungicides prior to seed storage, with additional fungicide applied after soaking the seeds following storage.

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ROOT REGENERATION AND WATER STRESS OF BALLED-AND-BURLAPPED *QUERCUS LAURIFOLIA* (LAUREL OAK) PRE-TREATED WITH AN ANTITRANSPIRANT

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Abstract. **Two-inch caliper *Quercus laurifolia* Michx. (laurel oak) were sprayed or not with an antitranspirant 2 days prior to balling and burlapping. Harvested trees were transplanted in individual aluminum rings and backfilled with cypress sawdust. Trees were irrigated with 8 gal of water at 0500 hr daily. Shoot water potentials (Ψ_T) were measured diurnally from predawn to dusk prior to digging and 3 days after digging. Thereafter, Ψ_T was measured at 1300 hr weekly. Leaf samples were collected weekly from all surviving trees 8 hr after sunrise and analyzed for carbohydrate content. Eight weeks after digging, roots regenerated into the sawdust were harvested and dry weight measured. The antitranspirant initially increased tree water stress and leaf drop over untreated trees. Root regeneration was very poor for both treatments and not significantly different between treatments. Results suggest the antitranspirant was detrimental to health of laurel oaks dug in late fall.**

Fall digging of balled and burlapped (B&B) trees is preferred in northern areas of the U.S., but is often the season of the highest failure rates for nurserymen in central Florida. This is believed to be due to a low carbohydrate status in the harvested portion of a tree and very high vapor pressure deficits occurring in fall (Beeson, unpubl.).

Antitranspirants have been used to reduce transpiration in several studies (Davenport et al., 1972, 1973, 1975; Ponder et al., 1983). Reductions in transpiration would help counter high vapor pressure deficits. Yet for some species, application of antitranspirants have had little or negative effects (Ingram and Burbage, 1986; Williams et al., 1987). Most, if not all, film-forming antitranspirations reduce CO_2 gas exchange more than transpiration (Davies and Kozlowski, 1974). Such reductions in photosynthesis might counter any benefits of higher water status in terms of root regeneration. Root regeneration appears dependent on current photosynthesis (Van Den Driessche, 1987). The objective of this experiment was to determine if B&B trees pre-treated with an antitranspirant would have higher tree water status and greater root regeneration in the fall than untreated control trees.

Materials and Methods

In mid-Oct. 1992, 16 *Quercus laurifolia* (laurel oak) nursery trees were selected for uniformity and 2-inch trunk calipers and randomly assigned to the control or antitranspirant treatment. On 21 Oct., treated trees were sprayed with a 3.2% mixture of Anti-Stress 2000 (Polyer Ag, Inc., Fresno, CA) to run-off. The following day, tree water status was quantified by diurnal measurements of twig water potentials (Ψ_T) with a pressure chamber (Beeson, 1992).

On 23 Oct., trees were dug according to AAN standards, balled in untreated burlap and transported approximately 0.5 mile to the research center. There trees were placed into white aluminum rings on concrete pads and backfilled with cypress sawdust. Two low volume emitters (Robert's black, Roberts Irrigation Products, San Marcos, CA) were used per tree. Trees were irrigated daily at 0500 hr, supplying ca. 8 gal/tree.

On 26 Oct., diurnal Ψ_T were measured on all trees. Eight hours after sunrise, leaves were sampled from all trees and frozen at -112°F for starch analysis. Each proceeding week Ψ_T was only measured at 1300 hr only for those trees which had at least 2 leaves per twig. Leaf samples for carbohydrates were taken as previously described concurrent with Ψ_T measurements.

Leaf samples were oven dried and starch extracted using a hot ethanol procedure (Beeson, 1988). Starch fraction was enzymatically digested and quantified calorimetrically. On 16 Dec., trees were lifted and all roots on the outside of a ball collected. Roots were washed and oven-dried weight determined. Root dry weight was divided by trunk caliper to normalize differences in caliper.

Midday Ψ_T and the carbohydrate fractions were analyzed as repeated measurements. The two diurnal measurements of Ψ_T were used to calculate cumulative daily water stress (S_y) by integrating the area above the Ψ_T curves and taking the absolute value (Beeson, 1992). Both regenerated root weights and S_y were analyzed by analysis of variance.

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