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CULTURE OF BANANA-LILIES

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Additional index words. Nymphoides aquatica, wetland plant, water conservation areas, aquarium plants.

Abstract. **A mixture of Osmocote (18-6-12), Esmigran, and dolomite fertilizers, or Vigoro All-purpose fertilizer (6-10-4) was used to evaluate growth of *Nymphoides aquatica* (S. G. Gmel.) Kuntze collected from the Everglades Water Conservation Area 3A. *N. aquatica* plants were cultured outdoors in cement tanks with a surface area of 3.1 m by 6.1 m at a water depth of 54 cm. Vigoro at a rate of 285 g per 1.0 m² placed as a layer 7 cm below the surface of culture pans filled with sand produced an average of 175 floating leaves per plant after 28 weeks of growth. Osmocote at rates of 228 g, 456 g, and 912 g per 1.0 m² resulted in similar numbers of floating leaves as the Vigoro. Plants cultured for one growing season with these fertilizers produced banana-lilies that ranged in dry weight from 0.04 to 6.71 g, and 73% of them were considered suitable for sale.**

The banana-like clusters of fleshy tuberous roots (Figure 1), commonly called banana-lilies in the ornamental aquatic nursery industry, are the overwintering structures of the floating leaved aquatic plant *Nymphoides aquatica* (S. G. Gmel.) Kuntze. Each of the plant's floating leaves (Figure 2) is capable of producing one cluster of these fleshy tuberous roots, and a single bud is present with each cluster. Banana-lilies are attractive and long-lasting decorative plants in aquariums but aquarium conditions are generally not favorable for mature plant development.

Plant collectors gather banana-lilies from wild populations. The banana-lilies are then either sold or held for sale at a later date. Recent governmental rule changes being proposed by the State of Florida may limit collection of banana-lilies from public bodies of water. Information is therefore needed on culture of banana-lilies to meet the demands of the ornamental aquatic nursery industry if wild collection becomes restricted. Also, information on culture of banana-lilies is needed since little is known of the impact of harvesting banana-lilies on the life cycle of these Florida native aquatic plants. The objectives of this study were to examine populations of *N. aquatica* plants growing in the Everglades Water Conservation Area 3A (hereinafter referred to as EWCA3A) and to evaluate the influence of fertilizer on their growth in outdoor culture tanks.

Materials and Methods

Field Studies. Leaf width measurements (Figure 3) were made on populations of *N. aquatica* plants growing at six sites in the EWCA3A. Measurements were made on July 20, 1993 to 487 leaves at Site 1 and 138 leaves at Site 2. On July 22, measurements were made on 155, 144, and 232 leaves, respectively, at Sites 3, 4, and 5. For Site 6, on August 5 measurements were made on 306 leaves, and 42 banana-lilies were collected for dry weight measurements.

Growth Studies. N. aquatica plants were cultured outdoors at the Fort Lauderdale Research and Education Center (coordinates 26°05'N and 80°14'W) in cement tanks with a surface area of 3.1 m by 6.1 m and pond water at a depth of 54 cm (large tanks) or in cement tanks with a surface area of 0.8 m by 2.2 m at a depth of 0.6 m (small tanks). Pond water flowed into the tanks at the surface of one end and out from bottom drains at the other at a rate

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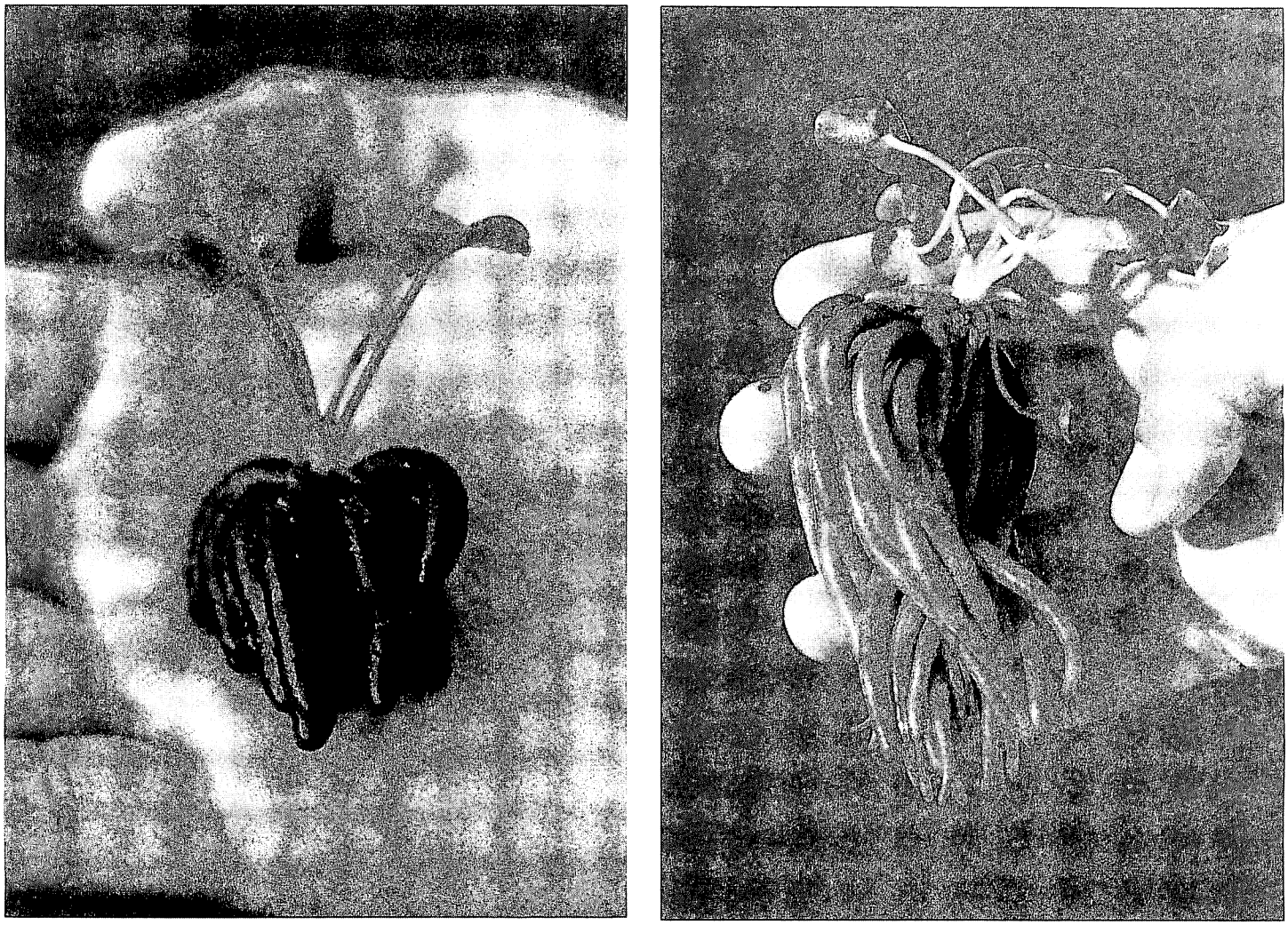

Figure 1. Two different sizes of banana-lilies ready for use as decorative plants in aquariums.

that allowed a complete exchange every 24 hours. Banana-lilies collected from the EWCA3A were cultured in non-porous plastic pans (dimensions of 30.5 cm in length by 25.4 cm in width by 15.2 cm in depth, equivalent to a surface area of 0.08 m^2) filled to a depth of 12 cm with coarse builders sand amended with fertilizer. Fertilizer was placed as a layer 7.0 cm below the surface of the sand. Water temperatures were recorded during the culture periods as previously described by Sutton (1986).

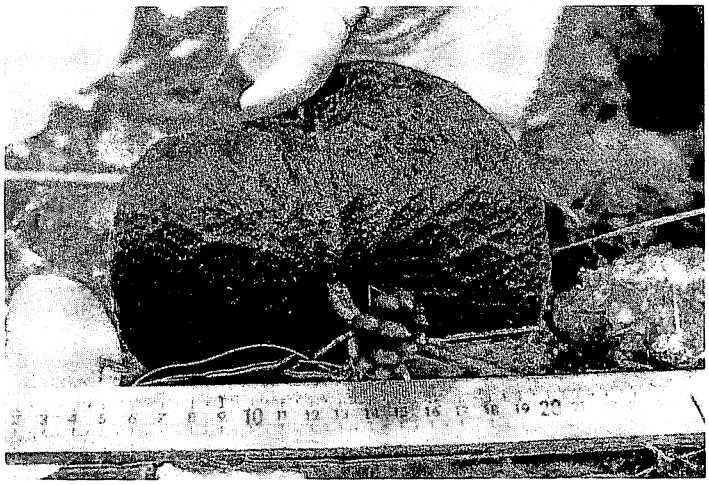

Figure 2. Underside of a leaf of *Nymphoides aquatica* showing early development of the fleshy tuberous roots that will eventually become a banana-lily.

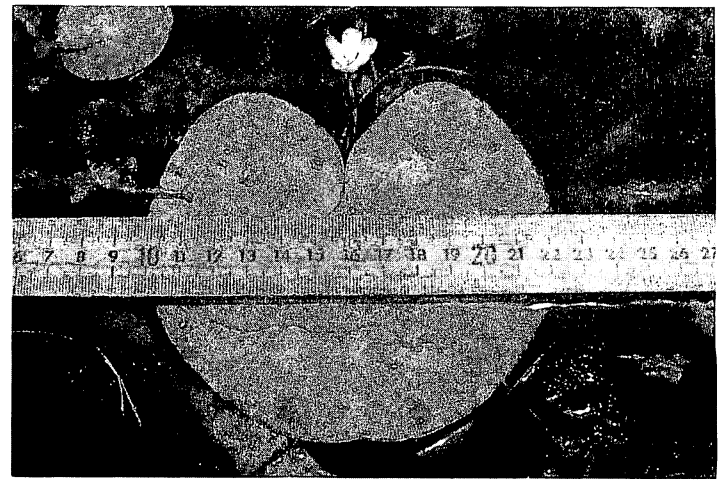

Figure 3. Leaf of *Nymphoides aquatica* showing the manner in which leaf width measurements were obtained by measuring leaf width at its widest point. This figure also shows the location of a flower attached to the leaf.

To study the influence of fertilizer on growth of *N. aquatica*, seven fertilizer treatments were prepared by adding a mixture of 20, 40, or 80 g of Osmocote (18-6-12), with 0.39 g of Esmigran, and 2.43 g of dolomite; 5, 25, or 50 g of Vigoro All-purpose fertilizer (6-10-4); or sand alone (control) to each of four pans. The pans were placed in a large tank and arranged in four rows placed perpendicular to the flow of water with the seven fertilizer treatments randomized within each row. On March 1, 1990, each pan was planted with one *N. aquatica* plant and allowed to grow until September 13, 1990 (28 weeks) at which time the number of leaves on each plant was counted.

On May 20, 1992, in a large tank one *N. aquatica* plant was planted in each of four pans containing 25 g of Vigoro, 20 g of Sierra (17-6-10), or a mixture of 20 g of Osmocote with 0.39 g of Esmigran, and 2.43 g of dolomite. Planting and arrangement of pans in the tank were as described in the previous culture period. The plants were allowed to grow until February 11, 1993 after which the tank was drained and the number of banana-lilies counted and dried at 60 C.

N. aquatica plants, supplied by a local aquatic plant nursery, were cultured in small tanks by placing one plant in a pan containing either 25 g of Vigoro or 20 g of Sierra. Two tanks were used for each fertilizer treatment. The plants were planted February 24, 1993, and number and width of floating leaves for each plant was determined after 14 and 28 weeks of growth.

Frequency distributions were determined for leaf width of *N. aquatica* plants and banana-lilies in the EWCA3A, number of banana-lilies produced during the May 20, 1992 to February 11, 1993 culture period in a large tank, and width of floating leaves for plants cultured in the small tanks. Number of leaves after 28 weeks of growth for the March 1, 1990 planting date in a large tank and number of leaves in the small tanks were statistically analyzed using General Linear Models (GLM) procedures of the Statistical Analyses System (SAS Institute Inc., Cary, NC 27511) for personal computers. Means separation was accomplished with the Duncan-Waller Empirical Bayes LSD procedure (Peterson, 1985).

Results and Discussion

Leaf width measurements conducted on six populations of *N. aquatica* growing in the EWCA3A averaged 9.0 ± 2.3 cm and ranged in size from a low of 1 cm at Site 4 to a high of 16 cm at Site 3 (Figure 4). Dry weight of 42 banana-lilies collected at Site 6 on August 5, 1993 averaged 1.74 g each with a low of 0.45 g and a high of 3.61 g (Figure 5).

Nymphoides aquatica plants cultured in outdoor tanks in pans with only sand had very poor growth as compared to plants in sand amended with fertilizer (Figure 6). Growth as measured by the number of floating leaves per plant showed significant increases after 16 and 28 weeks of culture. Plants in sand averaged 17 leaves per plant after 28 weeks of growth while plants in sand amended with 25 g of Vigoro had an average of 175 leaves per plant. At the 28-week culture period, no differences were noted in the number of leaves for plants in sand amended with 25 g of Vigoro or 20 g of Osmocote. Production of leaves during 28 weeks of growth was severely reduced for plants grown with 50 g of Vigoro per culture pan, while plants in pans

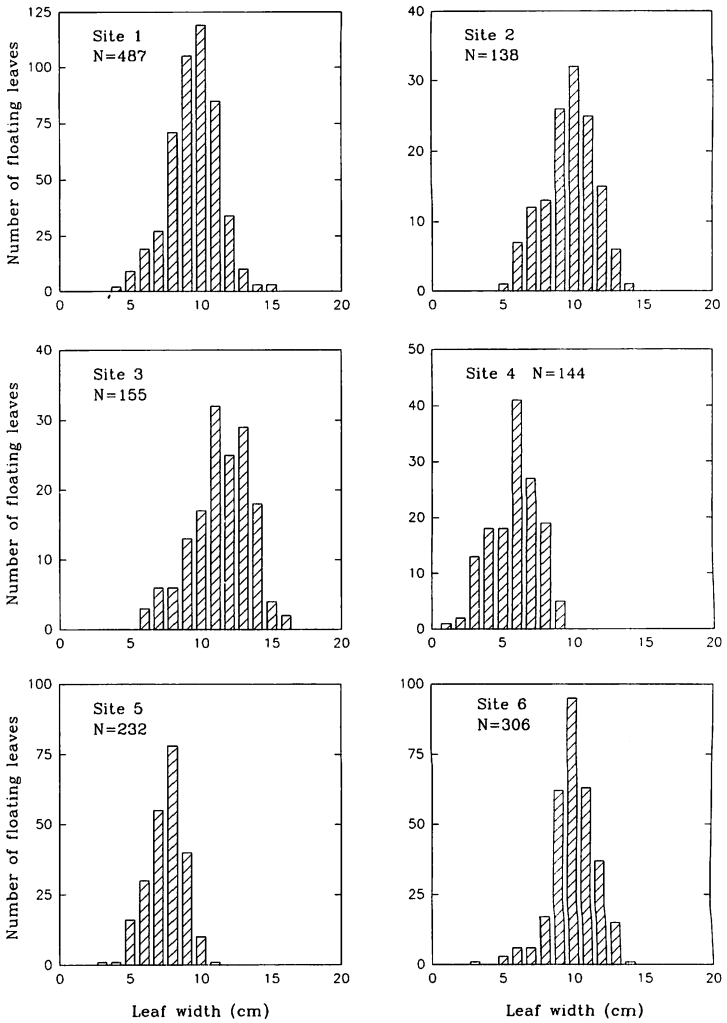

Figure 4. Leaf width measurements of six populations of *Nymphoides aquatica* growing in the Everglades Water Conservation Area 3A.

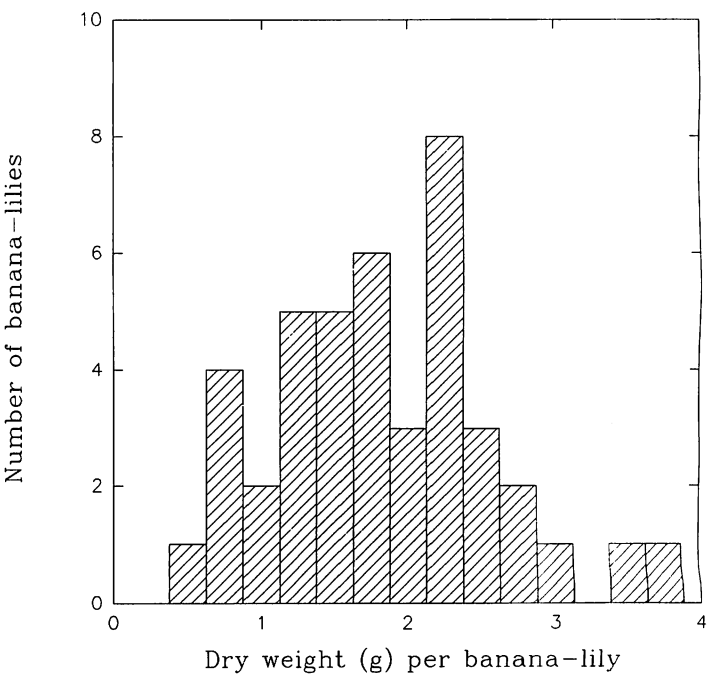

Figure 5. Dry weight of banana-lilies collected from Site 6 in the Everglades Water Conservation Area 3A.

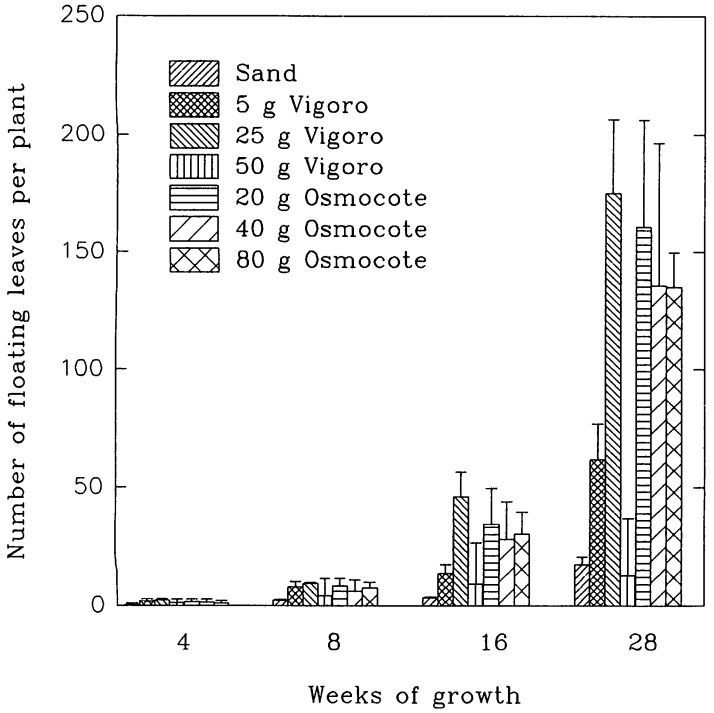

Figure 6. Influence of two fertilizers at three different concentrations on growth of *Nymphoides aquatica* cultured in outdoor tanks as determined by the number of floating leaves per plant.

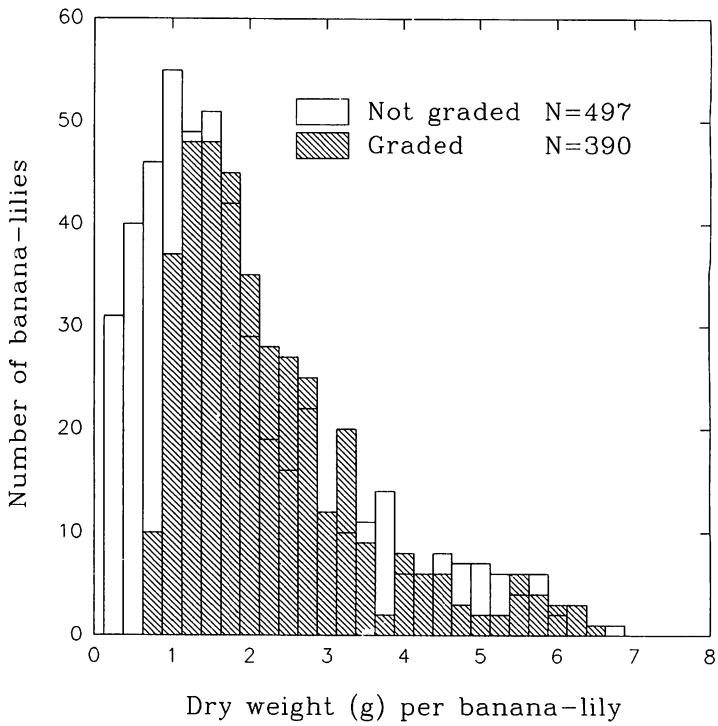

Figure 7. Histogram of banana-lilies cultured in outdoor tanks. Graded banana-lilies represent those sorted by a local aquatic plant nursery grower and deemed suitable for sale as aquarium plants.

with either 40 or 80 g of Osmocote were not significantly different from those cultured with 20 g of Osmocote.

Eight *N. aquatica* plants cultured from May 20, 1992 to February 11, 1993 in sand amended with fertilizer produced a total of 1242 banana-lilies. A portion of these banana-lilies, 390 collected without any sorting, deemed suitable for sale by a local aquatic plant nursery owner (McClane, personal communication) averaged 2.1 ± 1.2 g each and ranged in weight from a low of 0.6 g to a high of 6.4 g (Figure 7). These banana-lilies were similar in weight distribution to another group of 497 termed "not graded".

A comparison of number of leaves of *N. aquatica* plants cultured individually in tanks with either 25 g of Vigoro or 20 g of Sierra resulted in similar production of floating leaves during the first 14 weeks of growth (Table 1). After 28 weeks of growth, the number of leaves was higher on plants cultured with 20 g of Sierra as compared to those in the pans with 25 g of Vigoro.

These data show the feasibility of culturing *N. aquatica* plants in sand amended with fertilizer for production of banana-lilies. Width of floating leaves and dry weight of banana-lilies collected from natural populations were similar in size and weight to those cultured with commercial fertilizer. Factors responsible for size of banana-lilies are unknown but may be related to the time of year they are produced and size of the leaf on which they are growing. Additional studies will be needed to help supply information on production of banana-lilies for the ornamental aquatic plant industry.

Table 1. Number of floating leaves of *Nymphoides aquatica* plants cultured in outdoor tanks with two different fertilizers. Each tank held one plant in a pan filled with sand and amended with either 25 g of Vigoro or 20 g of Sierra. Each value is the mean of leaves for two plants.

Growth period and fertilizer treatment	Number of floating leaves[z]
1. 14 weeks of growth	
A. Vigoro	10.8 a
B. Sierra	10.2 a
2. 28 weeks of growth	
A. Vigoro	7.1 c
B. Sierra	8.4 b

[z]Means followed by the same letter are not significantly different at the 5% level according to Duncan's New Multiple Range Test.

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Proc. Fla. State Hort. Soc. 106:336-338. 1993.

PROMOTING THE RAPID GERMINATION OF NEEDLE PALM SEED[1]

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Additional index words. seed scarification, alternating temperatures, germination temperatures.

Abstract. **Two procedures are reported for promoting high total germination percentages and the rapid and uniform seed germination of needle palm (*Rhapidophyllum hystrix* (Pursh) H.A. Wendle and Drude). Under sterile conditions, removal of the sclerotesta and cap covering the cavity containing the embryo by scarification promoted 98% total germination (G), with average time of 1.3 weeks to achieve 50% of final germination (T_{50}). Using the second procedure, seed scarification was not needed. Seeds were soaked in distilled water 7 days at 30°C, with the water changed daily for adequate aeration. After soaking, the seeds were germinated in moist peatmoss at alternating 40°C for 6-hours and 25°C for 18-hours daily. The treatment promoted 80% G and T_{50} of 2.4 weeks. The results indicated that fully hydrated embryos of needle palm seed can readily penetrate the thick-walled seed coats, but needed an initial stimulus to promote embryo growth. Daily 40°C for 6 hours provided by 40°/25°C alternating temperatures was best for promoting seed germination. The seeds have no light requirement for germination.**

Needle palm *Rhapidophyllum hystrix* (Pursh) H.A. Wendle and Drude is a low, bushy palm with single to multiple trunks and medium foliar texture, that reaches a mature height of 2 to 3 meters. It is native to the coastal plains of southeastern United States with distribution from central Florida north to Georgia and West to Mississippi (Shuey and Wunderlin, 1977). Seeds of *Rhapidophyllum* require from 6 months to 2 years to germinate (Clancy and Sullivan, 1988; Popenoe, 1973; Shuey and Wunderlin, 1977; Wagner, 1982). Clancy and Sullivan (1988) reported that seed scarified after stratification required 435 days for the first seed to germinate, and 530 days from sowing to 14.3% germination. Wagner (1982) obtained 6.7% germination 195 days after sowing and reported that seed scarification did not increase total germination or promote earlier germination. No comparison of needle palm seed germination at various temperatures has been reported. The purposes of this research were: 1) to evaluate the effectiveness of several methods of mechanical seed scarification in promoting germination, and 2) to determine if alternating germination temperatures of non-scarified seeds stimulated the germination of needle palm seeds.

Materials and Methods

Scarification of stratified and non-stratified seed. Seeds of needle palm were collected from natural stands in north central Florida during the fall of 1990 and 1991. Recently harvested seeds were mechanically scarified by removing with a scalpel 2 × 2 mm portions of the sclerotesta to: a) expose the endosperm in areas away from the embryo, b) show the embryo cap, or c) remove the cap covering the cavity containing the embryo (Fig. 1); a fourth treatment contained non-scarified seed. Each treatment consisted of four 15-seed replications. These four treatments were repeated later using seed stored 12 months at 100% relative humidity (RH) and 5°C. Both recently harvested and stored seeds were surface-sterilized before scarification by successive immersion in 50% (V/V) ethanol for 1 minute, and 2.6% sodium hypochlorite solution for 12-minutes followed by three rinses in sterile deionized water (Kane et al., 1988). After scarification, seeds were placed in moist sterile peatmoss which had previously been autoclaved twice at 105°C for 1-hour. Each replication of 15 seeds was then sealed in a Kapak Heat Sealed Pouch (Kapak Corp., Minneapolis, MN). Seeds were germinated in four incubators at 30°C, with counts made weekly of germinated seeds having cotyledonary petiole emergence (Fig. 2). Total germination percentages (G) and average times in weeks to achieve 50% of final germination (T_{50}) were calculated according to Furutani et al. (1985). The design for the study was four randomized complete blocks of four treatments each. The data were analyzed by analysis of variance (ANOVA) and treatment means were compared using Tukey's HSD procedure.

Germination temperatures. Seeds used in these studies were recently harvested and not scarified or stratified. All seeds were soaked in distilled water (DW) seven days at 30°C, then surface dried, dusted with captan, placed in moist peatmoss in Ziplok bags, and germinated in incubators (model CB-1, Stults Scientific Engineering Corp., Springfield, IL). In a preliminary study, seeds were germinated at constant 20°, 25°, 30°, 35°, or 40°C. No stimulus of germination was found, with total germination percentages ranging from 0% to 8% during 20 weeks. In a subsequent study, comparisons of germination were made among 12-hour alternating temperatures of 20°/25°C, 20°/30°C, 20°/35°C, 20°/40°C, 25°/30°C, 25°/35°C, or 25°/40°C. Later, germination was compared at 25°C and 40°C constant temperatures with 6, 12, or 18-hour alternating temperatures at 25°C and 40°C. In both studies, weekly germination counts were made of seeds having cotyledonary petiole

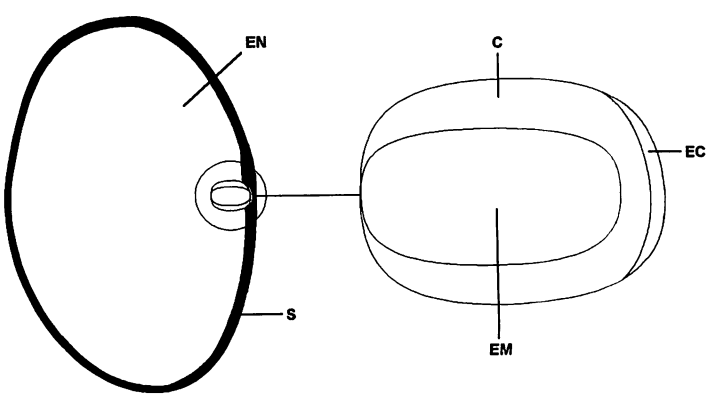

Figure 1. Longitudinal section showing needle palm structure: S = sclerotesta, C = cap, EM = embryo, EN = endosperm, EC = embryo cap.

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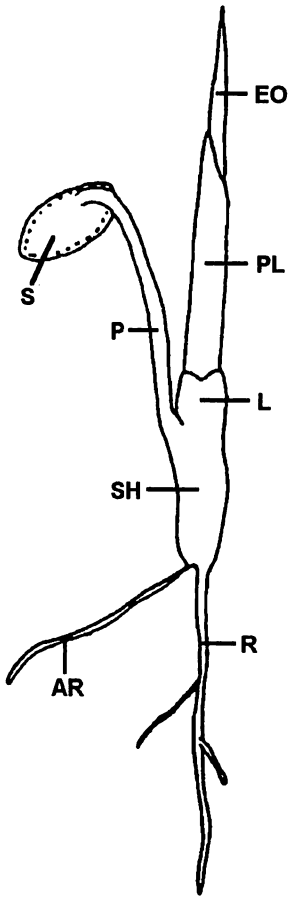

Figure 2. Structure of a recently germinated seedling of needle palm: EO = eophyll, PL = plumule, L = ligule, P = cotyledonary petiole, S = seed coat, SH = cotyledonary sheath, R = primary root, AR = adventitious root.

emergence through the sclerotesta. Total germination percentages (G) and days to 50% of final germination (T_{50}) were calculated, and data were analyzed using analysis of variance and treatment means were compared using Tukey's HSD procedure.

Results and Discussion

The stratification of needle palm seed for 12 months at 5°C and 100% RH increased total germination only when scarification allowed the sclerotesta or embryo cap to remain (Table 1). Stratification did not increase germination of non-scarified seeds nor of seed scarified by removing the cap covering the embryo and the sclerotesta above it, the latter having 98% and 96% germination for fresh and stored seed, respectively. The T_{50} values for seeds recently harvested or stratified were similar (Table 1). Non-scarified seed had larger T_{50} values than seeds scarified to expose the cap or to remove the cap covering the embryo. Removing the cap covering the embryo resulted in faster germination than leaving the cap intact (Table 1).

Alternating 12-hours at 40°C daily with 20°C or 25°C was found to increase needle palm seed total germination (Table 2). No differences in G occurred among alternating temperatures 20°/25°C, 20°/30°C, and 20°/35°C, or between 25°/30°C and 25°/35°C. Highest G (43%) resulted from 12-hour alternating 25°C with 40°C (Table 2). Trends for T_{50} were similar to G from 12-hour alternating temperatures. Fewer weeks were required to achieve T_{50} when 40°C was alternated with 20°C or 25°C, with the smallest T_{50} from 40°/25°C.

Seeds receiving 6-hours at 40°C daily alternated with 18-hours at 25°C promoted 80% total germination, while 12-hours 40°/25°C had 47% G (Table 3). Eighteen hours at 40°C daily reduced G to 10%, while constant 40°C prevented germination of the seeds. Alternating 6-hours at 40°C with 18-hours at 25°C stimulated more rapid germination, which resulted in the smallest T_{50} values (Table 3).

Table 1. Final germination percentage and weeks required to achieve 50% of final germination (T_{50}) of needle palm seeds stored 0 to 12 months at 5°C and 100% RH prior to several methods of mechanical scarification.

	Seed stratification (months)			
	0	12	0	12
	Germination		T_{50} values	
Treatment	(%)[z]	(%)[z]	(weeks)[z]	(weeks)[z]
Nonscarified	7.3 c[z,y]	12.3 d	11.3 a	9.0 a
Scarified to endosperm	10.5 c	56.0 c[x]	9.8 ab	6.3 ab
Scarified over embryo cap	23.2 b	79.5 b[x]	9.0 b	5.8 b
Scarified to remove cap	98.3 a	96.5 a	1.3 c	1.5 c

[z]Means in each column followed by the same letter are not different at the 0.01 level of significance as determined by Tukey's HSD procedure.
[y]Values represent the means of 60 seeds during a 20-week germination period.
[x]Denotes stored seeds had a significantly ($P < 0.01$) higher mean percent germination than nonstored seeds.

Table 2. Germination of needle palm seed under 12-hour alternating temperatures. Data are the means of 60 seeds during a 20 week germination period.

Alternating temp (°C)	Germination	
	G[z] (%)	T_{50}[y] (weeks)
20/25	5	8.6
20/30	7	8.0
20/35	10	7.2
20/40	25	5.3
25/30	12	7.3
25/35	15	5.9
25/40	43	3.8
Tukey's HSD, 5%	6	1.5

[z]Percent total germination.
[y]Days to 50% final germination.

Table 3. Germination of needle palm seed under 6, 12, or 18-hour alternating 25°C and 40°C temperatures. Data are the germination means of 160 seeds during 20 weeks.

Temperature		Germination	
25C (hours/day)	40C	G[z] (%)	T_{50}[y] (weeks)
24	0	13	8.0
18	6	80	2.4
12	12	47	3.5
6	18	10	4.8
0	24	0	—
Tukey's HSD, 5%		8	1.1

[z]Percent total germination.
[y]Days to 50% final germination.

Lengthening the daily period at 40°C to 12 or 18-hours delayed germination and increased T_{50} values.

Our research has identified two procedures for promoting high total germination of needle palm seeds rapidly and uniformly. Each procedure indicated a different probable cause for the poor germination of this seed. The scarification study indicated that needle palm seeds have a physical dormancy imposed by the thick-walled, tightly-packed sclereid cells of the sclerotesta. Removing the cap and sclerotesta covering the embryo cavity from seeds allowed the embryos to rapidly imbibe water and become fully hydrated. Embryo hydration promoted the emergence of the cotyledonary petiole from half the seeds (49%) within 1.3 weeks. The rapid germination of seeds without stratification at 5°C for 6 months indicated that at harvest seeds have mature embryos, and the embryos contain no chemical capable of inhibiting germination.

The results of our scarification study supported past reports that needle palm seeds have a physical dormancy permitting 7% to 14% total germination during 6-months to 2-years (Clancy and Sullivan, 1988; Popenoe, 1973; Shuey and Wunderlin, 1977). Constant warmth (30° to 35°C) after seed scarification was necessary to promote the emergence of the cotyledonary petiole. Carpenter (1988a) and Wagner (1982) have reported 30° to 35°C are required for germination and seedling growth of several palm species.

In our second study, seeds without scarification were soaked in DW for 7 days at 30°C; the water was changed daily to provide adequate aeration. After soaking, seeds were germinated in moist peatmoss at alternating 40°C for 6-hours and 25°C for 18-hours daily, and achieved 80% total germination. These results indicated that sufficient water penetrated the thick-walled, tightly-packed sclereid cells of the sclerotesta during 7 days of soaking at 30°C to fully hydrate the embryo. Although the cap covering the embryo cavity and the sclerotesta appear as physical barriers to embryo emergence, our results indicated that fully hydrated embryos emerge rather rapidly. The mean T_{50} was 1.3 weeks when seeds were scarified by removing the cap covering the embryo cavity and the sclerotesta above it, while hydrated non-scarified seeds germinated at alternating 40°C (6-hours) and 25°C (18-hours) had T_{50} of 2.4 weeks.

Our results cannot explain the rapid emergence of the cotyledonary petiole at constant 30°C after seed scarification, while 30°C failed to promote the germination of non-scarified seeds after hydration. Also, a few non-scarified seeds germinated at constant 35°C and none germinated at 40°C, but alternating 40°C for 6 or 12-hours daily with 25°C promoted high total germination. Possibly 40°C for short periods gives the promotive stimulus needed for the germination of needle palm seed. Carpenter (1988b) reported that imbibed *Butia capitata* (Mart.) Becc. palm seeds required constant 40°C for 3 weeks to terminate the dormancy of the seed, while 35°C under comparable conditions failed to promote germination.

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THE BLACK OLIVE (*BUCIDA BUCERAS* L.), A TROPICAL TIMBER TREE, HAS MANY FAULTS AS AN ORNAMENTAL

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Additional index words. bucaro, bullet wood, ucar.

Abstract. **The black olive (*Bucida buceras* L.) is native to the Yucatan peninsula and along the coast of Mexico, Central America and northern South America to the Guianas; the Bahamas, and the Greater and Lesser Antilles as far as Guadeloupe. Salt tolerant, the black olive grows in coastal swamps, wet inland woods, and on river banks, and tolerates dry limestone areas of South Florida. The tree is sturdily erect with tiered, whorled, often thorny branches, at first horizontal and later drooping. It is prone to producing suckers at the base. The elongated main branches bend downwards, making the tree top-heavy. Other drawbacks include the tree's need for regular pruning and its susceptibility to several pests and over two dozen diseases. *Philaphedra* scale causes the black olive to lose all its leaves; the mite *Eriophyes buceras* prevents normal fruit development, causing long, string beanlike galls. Both galls and leaves are high in tannin that stains sidewalks, vehicles, white roofs and cement decks. Black olives are best used for their excellent timber rather than as ornamentals.**

The black olive tree, *Bucida buceras* L. (syn. *Terminalia buceras* Wright) and the only other member of the genus, the Spiny Bucida, *B. spinosa* Jennings, belong to the family Combretaceae, which includes the familiar buttonwood (*Concocarpus erectus* L. and var. *sericea* Forst. ex D. C., Silver Buttonwood: also *Laguncularia racemosa* L., the white mangrove, and *Terminalia catappa* L., the tropical or Indian almond.