o-hydroxydiphenyl, provided 50% recovery, as compared to an 80% for metalaxyl, 90% for fosetyl aluminum, and 0% for the inoculated control.

There were no toxic effects observed with fosetyl aluminum and metalaxyl at these test rates on the flowers, leaves, or roots of *Cattleya skinneri*.

These results indicate that the new systemic chemicals are far superior to the presently used standards. The fosetyl aluminum compound provides orchid growers with a method of protecting their plants that is less messy and cumbersome than plant dips.

At present, metalaxyl has an EPA approved label for its use on ornamentals and is available on the market, however fosetyl aluminum is not available for homeowner use.

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PROPAGATION AND GROWTH OF CYCADS—A CONSERVATION STRATEGY[1,2]

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Abstract. **Cycads, an endangered group of ancient gymnosperms, are much in demand for indoor and outdoor landscapes but generally commercially unavailable or excessively expensive. Large scale production of these plants is frequently hampered by difficulty in propagation, scarcity of seeds, and slow rate of growth. Micropropagation attempts have been unsuccessful for the most part and division of field-collected plants is not only inadequate, but irresponsible and results in aggravating the endangered status of these taxa. This paper reviews the methods of hand pollination to increase seed set and addresses the cause of poor and erratic germination resulting from a hard seed coat, immature embryo, or a lack of pollination and/or fertilization.**

Cycads are poorly known in horticulture, in part because they are infrequently grown by nurseries. Their scarcity in the trade, however, is caused by a general lack of horticultural information, unavailability of seeds, which are inherently slow to germinate, and in most species, lingering growth. Unscrupulous collectors dig thousands of plants from native habitats without regard for their antiquity and endangered status (2) risking the destruction and decimation of cycads. It is difficult to defend the concerns and needs of tomorrow against the material interests of some nurseries and the ambitions of a few overzealous private collectors. Such businesses and individuals follow the edict of the Brazilian delegate in the U.N. Conference on the Environment (1), who declared "we cannot afford to think of the next generation." In a recent letter to the editor of The Cycad Newsletter, Tang (28) quoted Dr. Dennis Stevenson as having mentioned shipment of 25,000 plants of a newly described species (*Ceratozamia norstogii* Stevenson) into the U.S., resulting in complete decimation of 1 of only 2 known populations of this taxon. Tang (28) further stated that during the same period 20,000 zamias were exported from the Dominican Republic. A registry of the most threatened plants in Mexico includes 10 species of which 4 are cycads; *Ceratozamia miqueliana* Wendl., *Dioon edule* Lindl., *D. spinulosum* Dyer, and *Zamia furfuracea* L.f. (29). Hedberg (18) has directly accused horticulturists of threatening plants of *Encephalartos* and *Stangeria* by hiring local people who "are apt to really exterminate the species concerned." Closer to home, Ward (31) has listed *Zamia floridana* A. DC. and *Z. umbrosa* Small [both considered *Z. pumila* subsp. *pumila* by Eckenwalder (15)] as threatened. He points out that "what was once an abundant plant in certain areas of Florida is now uncommon or even absent. Although exploitation for the production of starch has now ceased, the plant is much used for horticultural plantings, and many nurseries find it expedient to obtain their stock from the wild rather than by commercial propagation."

Horticulturists are not in a position to stop the devastation of cycad habitats which is occurring due to agricultural and industrial development in various countries. They are, however, capable of propagation and cultivation of these and other rare and endangered plants.

We can take two positive steps to ensure existence of germplasm for the future and prevent further destruction of these plants and their ecosystems:

1. Encourage and support such living museums as Fairchild Tropical Garden financially and by donation of rare cycads or other plants. In the long run, the favor is returned by production of seeds and other propagules. This will also ensure the survival of living specimens for future generations of mankind.
2. Discourage collection and importation of living plants but encourage mass production, when possible, as is commonly done with *Z. furfuracea, Cycas revoluta* **Thumb.**, and *C. circinalis* L. As stated by Tang (28), "this may be a method of flooding the market and satiating the demand."

The main objective of this paper, is to provide fundamental information on propagation and growth of cycads based on our research findings and what little is available in the literature. The suggestions and remarks which follow are not all-inclusive, and other approaches may be more successful.

Pollination and Seed Set

The major cause of cycad scarcity in nurseries is want of seed for propagation. Lack of pollinators or inefficiency of pollen transfer from microsporangiate to megasporangiate cones may be responsible for scant seed production. Chamberlain (8) postulated that cycads are wind-pollinated. Several instances of insect pollination, however, have been reported in various taxa (3, 5, 23, 24, 25, 30).

Bierhorst (4) suggested that inefficiency of pollination in

[1]Florida Agricultural Experiment Stations Journal Series No. 5119.
[2]The use of trade names does not imply endorsement of that product by the Department of Ornamental Horticulture or IFAS over similar material.

cycads is due to rapid release of the entire pollen content of a cone. Under cultivation, receptivity of the female cone does not always coincide with the release of pollen, which is often wasted. Large quantities of pollen may be collected and refrigerated until needed. Female cones are receptive when a sticky pollination drop exudes from the micropylar end of the ovule and megasporophylls are loose enough by virtue of the cone axis elongation to allow penetration of the pollen. Artificial pollination may be accomplished at this time by lightly sprinkling the pollen grains on the female cones. The pollination drop soon dries and the pollen grains are drawn into the pollen chamber (4). Except for certain taxa which may be beetle-pollinated (23, 24, 30) and *Cycas* which are probably largely wind-pollinated, all other genera would have to be hand-pollinated to assure production of viable seed.

In some instances, even hand pollination does not guarantee viable seed production. For example, in *Encephalartos,* seeds often enlarge quite normally but lack an embryo (personal observation). Fairchild Tropical Garden's success in producing seed of the rare and endangered plant *Microcycas calocoma* (Miq.) A. DC. is testimony to the importance of such undertakings and the significance of the role botanical gardens play in species conservation. Establishment of a pollen bank by The Cycad Society is another step toward conservation of cycads.

Propagation

Seeds of cycads have an outer fleshy coat (sarcotesta) which encloses an inner stony layer (sclerotesta). The embryo is embedded in female gametophyte tissue, often improperly referred to as endosperm. As the embryo matures and enlarges, food is transported to it from the gametophyte tissue via the suspensor.

In germination of seed, 3 separate dormancies are involved; the fleshy coat which has an inhibitory effect, the stony layer which is thick and prevents entry of water into the seed, and the embryo, which has to mature before the seeds germinate. The embryo in the majority of cycads is not fully mature at the time of seed abscission (12). In several species removal of the fleshy coat is sufficient to allow germination, provided seeds are collected only after the cones have fallen apart. Several species of *Dioon, Macrozamia, Lepidozamia,* as well as *Zamia loddigesii* Miq. and *Z. fischeri* Miq., are among those that germinate without difficulty. This occurs because the embryo is mature, despite thickness of the sclerotesta.

Thickness of the sclerotesta, however, is a major obstacle to germination in species whose embryos are still early in stages of development, although seeds may appear fully mature. Extreme examples of this occur in *Encephalartos* and *Cycas.* Dyer (14) and Giddy (16) have suggested storing seeds of *Encephalartos* for 6 months before planting. Current research with 5 species of *Cycas* (Dehgan et al.—unpublished data) also indicates the necessity of storage. The same may be said for *Z. floridana* and *Z. furfuracea* (10, 11, 33).

Embryo development may be hastened by treating the seeds with H_2SO_4 to reduce thickness of the sclerotesta and gibberellic acid (GA_3) to stimulate growth of the embryo. Times of exposure to either chemical vary among species. For example, *Z. floridana* requires 60 min of H_2SO_4 treatment followed by 48 hr of GA_3 soak (10), whereas *Z. furfuracea* requires only 20-25 min of H_2SO_4 and 24 hr of GA_3 (11). *Cycas revoluta* and *C. circinalis* also benefit from H_2SO_4 and GA_3 treatment, however, seeds may be injured, therefore seed storage is suggested. Seeds germinate best when stored at 45-50°F for 6 months.

A widely accepted view among cycad growers is that floating seeds are inviable, whereas sinking seeds are viable. While this is true for most cycads, recent work of Dehgan and Yuen (12) showed that seeds of *Cycas circinalis-C. rumphii* complex float regardless of viability. Restricted distribution of other cycads effectively precludes existence of buoyant seeds. Although flotation is a reliable means of determining seed viability of some cycads, rattling of the female gametophyte tissue, which is indicative of its separation from the sclerotesta, is most symptomatic of inviable seeds.

Vegetative propagation may also be accomplished with plants that produce adventitious buds on leaf scales (27). Many species of *Cycas, Dioon,* and *Encephalartos* produce these buds and potentially plants may be propagated from them. A number of species with branched subterranean stems such as *Zamia* are often dug up and divided. Root or stem discs are another potential source of new plants and were reported by Coulter and Chrysler (9). Roots of *Z. furfuracea* have also been successfully propagated by this method (D. Burch, personal communication).

Micropropagation attempts with female gametophyte tissue (13, 21, 22), embryo (6), entire seeds (32), and newly emerging leaf tips (Sheehan, unpublished data) have been in progress for some time. Although some success has been reported, no truly practical method as yet exists for mass production. This method must be pursued much more vigorously than it has been in the past. By providing less expensive genetically uniform plants, needs of the landscape industry will have been met. Individual collectors will therefore no longer be able to instigate destruction of the few plants which remain in their natural habitat.

Growth

The problem of slow growth and development in cycads has been largely ignored. Yet, it is the primary cause of their demise in the wild and their consideration by nurserymen as economically unprofitable. Only Smith (26) has reported significantly improved leaf growth and number with additional nitrogen levels.

Symbiotic nitrogen fixation by the blue green algae associated with coralloid roots of cycads has been reported to occur at a significant rate (17, 20). The positive effect of nitrogen (N) fixation is indicated by prolific regeneration and rapid growth of leaves following fire or severe winter damage. Estimates of N fixation by coralloid roots range from 18.8 kg N/ha (20) to 35 kg N/ha (17). Fixed N contributes significantly to growth of plants as well as the ecosystem in which they occur. Since N is fixed and utilized in ammoniacal form, increasing the rate of N in nitrate form decreases the amount fixed, resulting in poor growth (7).

A significant controlling factor in nutrient availability is the soil pH. Hewett (19) reported occurance of the highest density of healthiest *Zamia* plants in Florida where soil pH exceeded 6.0. Frequency of such populations, however, was limited by calcium oxide concentrations of less than 1,000 ppm and large soil particle size which reduced soil moisture. Formation of N-fixing nodules is directly affected by Ca, available moisture, and soil pH. Addition of N from combined sources (nitrate and ammonia) also tends to reduce nodule formation and N fixation (7). Thus, under cultivation where various factors may be controlled, fertilization should consist of only one form of N. Preliminary experimental results indicate application of N in ammoniacal form is preferable to the nitrate N. Seedling growth in particular seems to be affected by the nitrogen source as indicated by the number of episodic growth flushes, which are not as clearly defined and regulated as those of mature plants.

Clearly, growth of cycads is negatively affected by severe reduction of soil moisture. Under cultivation the problem is often one of frequent irrigation resulting in reduced soil oxygen level and directly affecting N utilization. To this end, experiments with various media have shown the following soilless mixes to result in the best growth under nursery management practices of frequent or automatic irrigating systems.

1 part by volume Metro-Mix 500 (W. R. Grace Co., Cambridge, MA) or a similar soilless mix

1 part by volume sharp sand

1 part by volume perlite

1 part by volume pine bark

5 lb./yd^3 of dolomite and 3 lb./yd^3 of Perk micronutrients are also added.

The above mix is recommended for zamias of the more mesic habitats (e.g., *Z. floridana, Z. loddegesii, Z. fischeri,* etc.), all species of *Bowenia, Cycas, Macrozamia,* and *Lepidozamia* as well as *Stangeria eriopus* (Kunze) Nash. and some *Ceratozamia.*

In a second mix intended for the more xeric taxa (e.g. *Z. furfuracea,* all *Encephalartos, Dioon,* and some *Ceratozamia*), the perlite is replaced by gravel size "Solite" (a highly porous fired clay from Florida Solite Company, Green Cove Springs, FL). Osmocote may be surface applied after transplanting.

Both mixes have excellent draining and nutrient-holding capacity. A problem associated with these mixes, however, is the rapid extension of the single primary root characteristic of all cycads. To overcome this problem, the root may be severed near the shoot junction and the seedling dipped in 2,000 ppm indolebutyric acid for 5 sec at transplanting time. This will cause 2 to 3 primary roots to develop, each having several secondary branches and numerous root hairs (Dehgan and Johnson—unpublished data). The media must be moist for the first 2 wk to prevent desiccation of the leaves.

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