HANDBOOK OF CYCAD CULTIVATION AND LANDSCAPING

By William Tang

Above: *Encephalartos* sp. adorning a plaza in Pretoria, South Africa. This setting is popular for weekend weddings. Below: *Cycas siamensis* planted among boulders at Nong Nooch Orchid Wonderland near Pattaya, Thailand.

Cover: (Upper left) Bonsai of *Zamia furfuracea*. (Upper right) Foliage of *Encephalartos munchii*. Photos: L. Miyano. (Below) *Zamia furfuracea* (right) and *Dioon spinulosum* (left) planted among rocks and palms. **Figure 1.** (Above) Leaf of *Bowenia spectabilis* in cultivation. **Figure 2.** (Below left) Male cone of *Ceratozamia nortogii* ("plumosa" form). **Figure 3.** (Below right) Female *Cycas seemannii* in cultivation in Hawaii. Note the "skirt" of sporophylls with ripening seed from previous seasons and the new flush of sporophylls at the stem apex.

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INTRODUCTION

Cycads are ancient plants with a fossil history reaching back a quarter billion years. At first glance they resemble palms, but botanists classify them with gymnosperms such as pines and other conifers. A closer look will reveal that they are neither like palms nor conifers. Cycads are a distinct group of plants with a beauty and character all their own. They range from small plants with underground stems to large plants with trunks that may reach more than 30 feet in height. Most of the 250 or so species have tough leathery leaves, which may be armed with spines. With the exception of one genus, cycads reproduce by cones. They are dioecious, having separate sexes, and plants produce either male or female cones, but never both together.

Cycads have a tremendous potential as ornamental plants. In warm temperate, subtropical and tropical areas they are unusual and attractive additions to the landscape or home garden. They grow well as potted plants, where their trunks and symmetrical foliage make a striking display. This handbook is an overview of the major points of cycad cultivation and landscaping. The information enclosed comes from many published and unpublished sources. Recommendations on cultivation are gathered from many amateur as well as commercial growers of cycads.

REVIEW OF THE GENERA

There are 11 recognized genera of cycads found in warm temperate to tropical regions of the world. Their ornamental leaves display a wide range of shapes and textures and their cones are often brightly colored.
Bowenia: This genus is found along the coasts of Queensland in N.E. Australia. There are at least two species, all forest dwellers. The stems are subterranean and the leaves are thrice divided (**Fig. 1**). In cultivation they should be potted in a very sandy soil mix.
Ceratozamia: This genus occurs from Mexico to Belize and Guatemala. There are more than a dozen species found in subtropical pine forests, tropical lowlands and montane forests (**Fig. 2**). Most prefer shade. Some species from high altitudes have strong tolerance for frosts and are among

the most promising cycads for cultivation in warm temperate zones.

Chigua: This rare tropical lowland rainforest genus with two species is found in Colombia. Its leaflets have a central midrib, but otherwise it is very similar to *Zamia*.

Cycas: The widest ranging of all cycad genera, with populations from Madagascar across through Micronesia. The greatest diversity is found in north Australia and Southeast Asia. *Cycas* is distinctive in that female plants do not form cones, but produce a clump of sporophylls (**Fig. 3**). Male cones are similar to those of other cycads. Its leaflets have a distinct midrib. There are over 50 species.

Dioon: Ten or more species of *Dioon* inhabit Mexico and Honduras. They produce hairy cones and their foliage has a waxy coating that give them a plastic look (**Fig. 4, Cover**). They are highly ornamental as pot plants and some species are frost tolerant.

Encephalartos: This genus is found through much of sub-Saharan Africa. Most species have attractive trunks and spiny foliage (**Fig. 16, Cover**). The feature that sets this genus apart from other cycads is its great diversity of cone colors and cone textures (**Figs. 5, 16, 17**). There are over 50 described species.

Lepidozamia: Two species are found in the wet coastal forests of eastern Australia. Unlike most cycads, *Lepidozamia* are not spiny. They are fast growing with magnificent foliage and trunks (**Fig. 6**) and are surprisingly adaptable and resistant to frosts. They are excellent as landscape plants.

Macrozamia: This Australian genus with over 20 species, usually inhabits dry eucalypt forests on sandy soils. Both foliage and cones may be armed with sharp spines (**Fig. 14**). This is mainly a warm temperate group of plants and some species are tolerant of cold winters.

Microcycas: A single species occurs in western Cuba (**Fig. 7**). It likes warmth and humidity and does well on limestone soils. Seedlings are difficult to grow, however, once established, plants will show rapid growth (for a cycad).

Stangeria: This genus has a single, variable species with fern-like leaves. It occurs along the subtropical east coast zone of South Africa. It is one of three cycad genera with a leaflet midrib. The stem is subterranean and, unlike most genera, is not covered with an armor of leaf bases.

Zamia: This genus ranges through much of the New World tropics from Central to South America, including the islands of the Greater Antilles and Florida. Its 50 or more species are found from rainforest to seasonally dry habitats. Most are small, but some rainforest species will grow quite large if given the right conditions. Zamias require warmth and moisture during the growing season and are best suited for the humid tropics and subtropics. In other areas they should be kept as greenhouse plants. Zamias have the widest diversity of leaf shapes and textures among cycads (see **Cover**). Their stems, which may be subterranean or aerial, are bare of leaf bases.

Figure 4. (Upper left) *Dioon edule* var. *angustifolium* in cultivation in Hawaii. Photo: L. Miyano. **Figure 5.** (Upper right) Male cones of *Encephalartos natalensis* (Vryheid form with woolly crown). **Figure 6.** (Lower left) *Lepidozamia hopei* with female cone. **Figure 7.** (Lower right) Male cone of *Microcycas calocoma*. Note the scale leaves at the stem apex below the cone.

Figure 8. (Upper left) Seedling of *Dioon edule* pulled out of its sand dune habitat in Veracruz, Mexico. Note the long taproot with secondary roots emerging from its sides. This specimen is producing a new leaf. **Figure 9.** (Upper right) A mass of coralloid roots at the soil surface in a cultivated *Encephalartos ferox*. At the right (**Arrow A**) some have been cut open to reveal dark rings of blue-green algae inside. The orange roots at the left are newly formed and have not yet been infected with the symbiotic algae. **Arrow B** points to an emerging stem bud. **Figure 10.** (Lower left) Cut away view of the trunk of *Cycas seemannii* (New Caledonia form) showing a starchy central pith with a ring of vascular tissue (wood). This is bounded by a starchy layer called the cortex. An outer layer of old leaf bases helps to protect the stem. **Figure 11.** (Lower right) A stem of *Encephalartos transvenosus* with its leaves cut off. Note the mucilage that has plugged the wounds.

ROOTS

Cycads have three types of roots: 1) taproot, 2) secondary roots and 3) coralloid roots. After germination the first act of growth by a cycad seedling is to send down a single long taproot (**Fig. 8**), anchoring it and allowing it to reach moisture deep in the ground. If the taproot is prevented from proper development in a pot-bound plant, or if it is severed during transplanting, it may not reform. Instead the cycad may produce a mass of smaller roots. A mass of small roots is desirable for a potted plant, but not for one planted in the open ground and subject to high winds. Secondary roots sprout from the main root and grow sideways or down (**Fig. 8**). Preliminary surveys of wild cycads show that these roots have a symbiotic relationship with beneficial fungi called vesicular-arbuscular mycorrhizae (or VA mycorrhizae). This type of symbiosis is also widespread among flowering plants. The hyphae of these fungi are attached to the root cells of the cycad and form a fine, dense net in the soil, sharing their absorptive surface with the cycad. This increases the ability of the cycad to take up water and nutrients, especially phosphorus. In exchange the cycad provides food in the form of sugars to the fungi in a mutually beneficial relationship. VA mycorrhizae have very large spores that are not easily dispersed. To be infected by these beneficial fungi a cycad must be growing close to another plant that can serve as a source of innoculum. In a pot, in sterilized soil such a beneficial cooperation is usually denied to a cycad unless an innoculum is introduced. The last root type are coralloid roots. These are roots which grow up toward the light instead of down. When they reach near the soil surface, they branch profusely to form a coral-like mass, hence their name (**Fig. 9**). These specialized roots form yet another symbiotic relationship, not with fungi but with nitrogen-fixing blue-green bacteria. Coralloid roots are analogous to the root nodules found in legumes, which also harbor nitrogen-fixing bacteria, and give the cycad plant the ability to take up nitrogen from the air. They are delicate and the soil around cycads should not be raked or dug up or these roots will be damaged.

Soil

The first step for promoting good growth of cycads is providing proper soil conditions. Planting without careful consideration of the soil may lead to many growth problems later that will not be easily solved, so it is wise to lavish care and effort in planting.

Cycads require soil with excellent drainage. This is absolutely essential whether grown in pots or in the ground. In the wild cycads are most often found in situations where water drains away quickly, such as on limestone, sandy soils and mountain slopes. If your soil is heavy clay or if drainage at or below the surface is poor your cycad should be planted on a mound.

For potted cycads I recommend a soil mix simplified from one developed by Loran Whitelock in California over some 30 years of cycad growing:

1 part sharp sand, as coarse as possible
1 part small orchid bark
1 part Canadian peat moss (coarse)
1 part pumice (1/8 - 1/4 inch).

The grower may substitute components with comparable ingredients that are more readily available. For instance, perlite may be substituted for pumice. Under no condition, however, should muck be added to the potting mix as this will interfere with soil aeration. Poor drainage causes root rot which may eventually kill the plant. In a potted cycad, water should be able to drain out as fast as it is poured in. If water puddles and drains slowly it has failed the test as a cycad soil mix.

Cycads that have evolved on unusual soils may require special soil conditions. Many New World cycads occur naturally on limestone-derived soils and often do best in cultivation when planted in limestone soils. This appears true for many species of *Zamia*, *Ceratozamia* and *Dioon*. Others, such as many *Macrozamia* species, occur naturally in acidic soils and tend to be difficult to grow in limestone and other alkaline soils. Some species have very specialized soil needs. For instance, two South African species, *Encephalartos lanatus* and *E. middelburgensis* are difficult to grow on soils outside of their natural range. If your soils prove unsuitable for particular species, it is recommended that you create beds with special soils. Mixing sand into your soil will improve drainage. Adding organic matter or applying a mulch will improve soils with low nutrient levels. The more stressed a cycad is, the more sensitive it will be to soil conditions.

Watering

Cycads are often treated as desert succulents. This is a mistake. Cycads should never be denied water for long periods. In the wild a cycad living under seemingly arid conditions is tapping into underground moisture. In cultivation during the growing season they should be given constant adequate moisture while allowing for good root aeration. If your area experiences a winter or cool season, less watering is required during this period. Tropical species growing under greenhouse conditions will require adequate moisture year round. Rainforest zamias are especially sensitive to periods of water shortage and extra care should be given to ensure that they receive regular irrigation and constant warmth if they are to flourish. If your cycads are potted in a soil mixture with poor aeration and you absolutely cannot find another soil mix, then care must be taken not to overwater. Allow the soil to nearly dry out between watering or root rot may ensue, especially if the plants are grown under cool conditions (average temperature approximately 65°F or below). Under cool conditions plants may enter periods of inactivity during which they are particularly susceptible to root rot if kept too wet.

Fertilizers

Just before and during the growing season, when cycads undergo rapid flushes of growth, regular doses of a well-balanced fertilizer with minor elements are required, especially if optimum growth is desired. Regular mineral nutrition is also a good way to prevent health problems in cycads, especially for plants grown outside of their climatic range or in soils which they are not well-suited for.

Nutrient deficiencies often appear first in the emerging leaves. For instance, if the new leaves become brown and shrivel up (**Fig. 21**) it may be a sign of manganese deficiency, a problem occurring frequently in *Cycas revoluta* in limestone soils. If the new leaves emerge yellow or white it is probably a sign of a deficiency in the micronutrient zinc (**Fig. 22**). Applying zinc (in the form of zinc sulfate) to the soil may correct the problem, but it may take months. Often times the best solution to such mineral deficiencies is to repot the cycad in a different soil mix. If emerging leaves are pale green it may be a sign of iron deficiency. In severe cases the leaves will be yellow while the veins remain green. Lower leaves on a cycad crown will yellow as they age, however, premature yellowing may be a sign of nitrogen deficiency. If yellowing on lower leaves is not uniform or spotty it may be due to a deficiency of magnesium.

Cycads are not easily burned by fertilizer applications, although granular fertilizers accidentally sprinkled into the crown of an *Encephalartos* have been reported to cause the meristem to die. Any fertilizer that falls on the stem apex should be washed out.

Some species of cycads that have evolved on unusual soils have special fertilizer requirements. The *Cycas* species native to northern Australia (see **Table 2**), cannot tolerate high concentrations of phosphorus around their roots. These plants have evolved on ancient soils that are very poor in this element and are adapted to growing conditions with very low levels of phosphorus. Even applying a fertilizer with moderate levels of phosphorus will burn them - killing them outright or causing leaf death and setting growth back for some time. Only a fertilizer with very low levels of phosphorus should be applied to these species.

Roots and Herbicides

Cycads may be sensitive to certain herbicides. Hormone weed killers with an oil base should not be used near a cycad plant. The effect of other herbicides, such as roundup, is poorly understood and it is recommended that they be used sparingly around cycads or not at all. There is a report of a large healthy *Lepidozamia* at Foster Botanic Garden in Hawaii which died suddenly after herbicides were applied in its vicinity.

STEMS

Cycads have thick fleshy stems. There is a narrow ring of woody tissue inside, but otherwise the stem is composed primarily of a watery, starch-filled tissue (see **Fig. 10**). In most genera, the stem has a protective layer of leaf bases on the outer surface. The stem of a cycad may be an underground tuber or a trunk that may reach 30 ft or more in a few species. The aerial trunk with its intricate covering of leaf bases is one of the most ornamental parts of the cycad plant (**Figs. 3,4,6**).

Care of the Stem

The stem, whether an aerial trunk or a tuber, is the heart of the cycad. It is the single most important organ of a cycad. If you can keep the stem healthy you can ensure the survival of a cycad. Stem tissue will give rise to new leaves and roots (**Fig. 13,1 5**) and can renew itself indefinitely, if given the opportunity. Leaves on the other hand are short-lived and cannot, except under special conditions, be a point of future growth. In most of the species examined so far root tissue will not give rise to leaf and stem tissue and also cannot serve as an organ from which a plant can regenerate itself. The one exception is *Stangeria eriopus.* Healthy cycads will recover from damage to roots or leaves; however, injury to the stem, even if slight, may prove fatal.

Treating Stem Injuries

In most genera, except *Bowenia*, *Stangeria* and *Zamia* the stem is covered by a layer of old scale leaves and leaf bases. This layer is alive and helps protect the stem. Below the leaf base armor the cycad stem is very delicate and is easily wounded. Because it is full of starch and water, the stem is a tempting target for burrowing insects and pathogens, like fungi and bacteria. If the outer protective jacket of a cycad stem is breached, it may be subject to a combination attack of the two and quickly succumb. Burrowing insects open up tissue for fungi and bacteria to infect, and infected tissue is an ideal site for insects to attack further. So a viscous cycle may begin with a single cut or bruise of the stem leading to the rapid rot and collapse of the entire organ.

If given a chance a cycad stem can halt infection and heal its wounds. The cycad stem is filled with canals containing a gummy substance called mucilage. If the stem or leaf or root is cut mucilage will ooze out to seal the wound, much as a clot seals a cut on your finger (**Fig. 11**). Mucilage, as well as other cycad tissues, contain compounds that are toxic to insects and other animals (Care must be taken to avoid ingesting any part of the cycad) and may help inhibit bacterial and fungal growth.

To enable a cycad stem to heal itself, the wound, whether a cut or a bruise, should be cut out and cleaned so that only a smooth surface is left

exposed. This will minimize infection. A ragged cut or broken surface, on the other hand, can provide a convenient place for a pathogen or insect to lodge itself and begin to do damage. A combination of insecticide and fungicide should be applied to the cleaned wound. If in spite of cleaning and the application of chemicals the wound continues to rot, the treatment must be repeated until successful. During such time, as with any patient in a hospital, the wound should be inspected regularly and the plant be given adequate water and nutrition until new tissue grows over the wounded surface. This may take only a few weeks. A healthy stem will feel firm if squeezed gently; if it is soft and the inner tissue has a brownish color, that part of the stem is beyond recovery.

If the injured stem is bare root, it is best (after it is cleaned and treated) to place it inside a sterile plastic bag. This will further isolate the stem from insects and pathogens and increase the chance of recovery.

Growth Rate

Increases in stem height in cycads coincide with production of leaves and scale leaves, which usually occur on a yearly cycle. Stem growth rate, when compared to woody trees, is relatively slow, but is similar to some of the slower growing palms (**Table 1**).

Table 1. Yearly growth of cycad trunks deduced from distance between leaf flushes.

	DISTANCE BETWEEN LEAF FLUSHES	
SPECIES	Centimeters	Inches
Ceratozamia robusta (Belize form)	5	2
Cycas media	14	5.5
C. rumphii	14	5.5
C. seemannii	12	4.7
C. taitungensis (formerly *C. taiwaniana*)*	38	15
Dioon edule (var. *edule*)*	8	3.1
D. spinulosum	14	5.5
Encephalartos altensteinii	5	2
E. gratus	8	3.1
E. hildebrandtii	8	3.1
E. inopinus	6	2.4
E. sp. (Lake George, Uganda)	11	4.3
E. longifolius	4	1.6
E. manikensis	4.5	1.8
E. munchii	7	2.7
E. paucidentatus	5.5	2.2
E. septentrionalis	7	2.7
E. tegulaneus	10	4
Lepidozamia hopei	12	4.7
Macrozamia moorei	3	1.3
Microcycas calocoma	17	6.7
Zamia lindenii	8	3.1
Z. neurophyllidia	5	2
Z. tuerckheimii	6	2.4

* This species may skip a year between leaf flushes; this may represent 2 years of growth.

Insect Pests

Some beetles burrow into the stems of cycads. The most notorious of these is the weevil *Tranes internatus*, which is found naturally in parts of Australia and has been introduced into southern California. These weevils will burrow past the protective leaf-base layer of the trunk into the cortex and pith and eventually kill the trunk. A plant infested with these beetles cannot be easily diagnosed until its trunk begins to die and collapse. There is no easy cure for an infestation. One treatment which has been used with some success is to drill a sloping hole into an infested trunk using a 1/4-1/2 inch bit and pour a strong systemic insecticide into the hole. The best treatment against the tranes weevil is prevention. Avoid bringing a suspect plant, particularly wild-collected trunks, into your collection. The infestation will spread and is difficult to control and can do great damage.

Transplanting

Repotting is best accomplished in the growing season, namely spring and summer. New roots will grow into the fresh soil within a matter of weeks if there has been little disturbance to the root ball during replanting. Transplanting specimens already established in the ground is another matter. A large portion of the roots will be severed when they are moved. The best time to transplant will depend on the species of cycad involved and the type of climate in your area. Edgar Wohlberg of Natal, South Africa, which has a subtropical climate, has transplanted many large *Encephalartos*. In his experience it is best to transplant specimens of this genus in the mild, winter dormant period. Those plants transplanted during the growing season, particularly when flushing leaves or cones have a lower rate of recovery and often die. *Lepidozamia*, a tropical to subtropical Australian genus, is said to be very sensitive to transplanting, especially in the winter dormant season. They have a much higher chance of recovery if transplanted just prior to the growing season, perhaps because the root system is more able to grow new roots and reestablish the plant. In general I would recommend transplanting in spring, when the plants are in a period of active growth, but have not commenced production of leaves or cones. The flushing of leaves appears to stimulate vigorous root growth. A plant dug out of the ground should be replanted as soon as possible. The longer you wait, the greater the chance that it will not recover. A fungicide drench or paste should be applied to any wounds on the trunk or tap root. Also a large portion of the leaves should be removed and the plant be given shade to prevent too much water stress during recovery.

Transplanting very large plants is not recommended. A plant with a trunk above 2 meters may be prone to stem damage if an attempt is made to move it. According to Aston Vice and Edgar Wohlberg of South Africa, who have transplanted many large *Encephalartos* to prevent their

destruction during construction projects, the trunks of large plants are prone to flexing during lifting and transport. This can lead to internal stem damage that is not readily apparent until it is at an advanced stage of rotting by which time it may be too late to treat.

If transplantation of a large-trunked cycad cannot be avoided, it is suggested that the stem (or stems if it is multi-trunked) be supported with slings of burlap cloth when being lifted to minimize flexing of the stem. Extreme care must be taken to ensure that the stem does not bump objects or the ground. Even slight bumps may lead to severe and fatal bruises. The plant should be moved with a ball of soil and with roots intact. The size of the root ball will vary with the size of the plant. A large *Encephalartos* with a half-foot thick trunk needs a root ball extending one foot beyond the trunk. A cycad transplanted without an intact root system cannot supply its leaves with water and the stress from transplantation may be fatal.

Bonsai

Cycads make ideal pot plants if provided with the proper soil mix. For most species, growth will be limited by the size of the container they are grown in. A plant may be maintained at a certain size for long periods. They are thus ideal bonsai plants (see **Cover**). Indeed, *Cycas revoluta* has been used by the Japanese as bonsai for centuries.

LEAVES

Cycads have two types of leaves: (1) Scale leaves are small and rudimentary and have a protective function; they emerge at the stem apex in a flush (**Fig. 7**) and cover the delicate growing point, and (2) Large photosynthetic leaves which act as "solar panels" to gather sunlight and produce food. In most species these are feather-shaped and form a crown. They may be various shades of green or blue and are usually leathery and spiny. Cycad leaves tend to be very durable and if removed from the plant they may remain fresh and green for weeks. Because of this they are used in many parts of the world in floral decorations and funeral wreaths. In most genera except *Bowenia*, *Stangeria* and *Zamia* both the scale leaves and the bases of the regular leaves remain intact on the trunk to form a protective armor. This layer of trunk armor remains alive and has some capacity to heal itself and seal wounds on the trunk.

When leaves are emerging on a potted cycad it is important that the plant not be moved as the young leaves will twist in the new direction of light. This is important because cycads more than a few years old usually produce only one crown of leaves a year and unsightly, twisted leaves will not be replaced for a year or longer. In the wild cycad leaves have been

recorded to last between 1 1/2 to 2 years in some species. In the rainforest species *Zamia neurophyllidia* leaves typically last 4-5 years under natural conditions and some remain alive for nearly 10 years! One cause for leaf mortality in forest species appears to be the growth of algae and lichens on the leaflets. These will eventually coat the surface until the leaflets can no longer photosynthesize effectively. In cultivation, if cycads are prevented from enduring drought stress and excessive exposure to full sun and its damaging UV light, leaves may last considerably longer than they normally would in the wild. I have seen 6-7 year old leaves on *Dioon spinulosum* and *Cycas seemannii* that were protected from full afternoon sun. Some *Encephalartos*, however, prefer full sun, especially the blue-leafed species. Another cause of leaf damage is sunburn. Leaves that formed in shade but are suddenly exposed to harsh midday sun may burn. If plants are watered with overhead sprinklers in the late morning or afternoon the beads of water that remain may burn the leaflets as they are heated by the afternoon sun. Overhead watering is best limited to the early morning, so that accumulated beads of water may evaporate before doing harm.

Leaf Ailments and Their Treatment

Cycads are subject to a number of cultural problems that usually manifest themselves in the leaves. Common symptoms include leaves that emerge yellow (**Fig. 22**) or that soon brown and shrivel (**Fig. 21**). These can be traced back to mineral deficiencies due to poor soil conditions (see Fertilizers) or to unhealthy roots due to waterlogged soils.

Cycads tend to be susceptible to infestations of mealybugs and scale insects. These will congregate in crevices and nooks of the leaves and stem apex where their natural predators, such as lady beetles (Coccinelidae), have difficulty finding them. Indoor and greenhouse plants are especially susceptible. Oil base insecticides are effective in dealing with the problem.

In regions where cycads are native, there may be moths or butterflies whose larvae feed on cycad leaves. In Florida and Central America, larvae of the butterfly *Eumaeus* do extensive damage to new crowns of cycad leaves. Similarly in South Africa the leopard moth, *Zerenopsis leopardina*, are destructive to new foliage of *Encephalartos*. If there is an outbreak of these insects in your garden, remove the egg clumps and larvae by hand, if possible, or apply an insecticide consisting of *Bacillus thuringiensis* (trade names: Dipel and Thuricide) that kills only lepidoptera.

As a general rule insecticides should be applied sparingly and only when required. In the wild beneficial insects and spiders may live on cycad leaves, stems and in the soil around their roots. Insects suspected of being important pollinators of cycads are known to hide on cycad stems, in the soil below them or under the bark of nearby trees.

Table 2: Landscaping Guide

This table is organized into 6 categories, allowing the landscaper to quickly determine the suitability of a cycad for a particular landscape:1) **Climate** - is the species in question suitable for tropical, subtropical or warm temperate climates? (In this table southern California, southern Florida and Brownsville, Texas are considered subtropical and the San Francisco Bay area, New Orleans, southern Texas and north Florida are considered warm temperate.) 2) **Leaf Length** - how wide and tall is the foliage? 3) **Stem Height** - will the plant outgrow its location? 4) **Leaflet Texture** - does it produce the desired effect? Are the leaflets too spiny to be along a walkway? Are the leaflets wide (greater than 4 cm wide), medium width (between 1 and 4 cm) or narrow (less than 1 cm). 5) **Microclimate** - will the plant tolerate full sun or deep shade? Is it frost tolerant? 6) **Cone** color and texture - does the species produce a beautiful cone. The **Remarks** column indicates additional horticultural features of each species. Species recommended because of their adaptability to a wide range of conditions are indicated by a star at the far left.

		CLIMATE			LEAF LENGTH		STEM HEIGHT			LEAFLET SHAPE			MICRO-CLIMATE					
	SPECIES	Tropical	Subtrop.	W. Temp.	< 6 ft	> 6 ft	< 3 ft	> 1.5 ft	< 1.5 ft	Spiny	Wide	Medium	Narrow	Sun	Shade	Frost	Cone Color	Remark
	Bowenia serrulata	•	•		< 6 ft	•			•				•	•	•	•	green	rachis branches, fern-like
	B. spectabilis	•	•			•			•				•	•	•	•	green	rachis branches, fern-like
	Ceratozamia euryphyllidia	•	•		•	•			•		•				•			large oval leaflets
*	*C. hildae*	•	•	•	•				•			•		•	•	•	brown-green	leaflets clumped, foliage bamboo-like
	C. kuesteriana	•	•	•		•			•			•		•	•	•	brown-green	Subtrop forest
	C. matudae	•	•	•		•			•			•		•	•			petiole and rachis yellow
*	*C. mexicana*	•	•	•		•			•			•		•	•	•	brown-green	petioles spiny
	C. microstrobila	•	•	•		•			•			•		•	•		brown-green	dwarf
	C. miqueliana	•	•	•		•			•		•				•		green	light green oval leaflets
	C. norstogii	•	•	•		•			•				•	•	•		brown-green	includes C. "plumosa" with spiral leaves
*	*C. robusta*	•	•	•	•	•		•				•		•	•		brown-green	petioles spiny
	C. sabatoi	•	•	•			•		•			•		•	•		green to brown	
	C. zaragozae	•	•	•		•			•				•	•	•			spiral leaf

	CLIMATE			LEAF LENGTH			STEM HEIGHT		LEAFLET SHAPE			MICRO-CLIMATE					
SPECIES	Tropical	Subtrop.	W. Temp.	> 6 ft	< 6 ft	< 3 ft	> 1.5 ft	< 1.5 ft	Spiny	Wide	Medium	Narrow	Sun	Shade	Frost	Cone Color	Remark
Chigua bernalii	•				•			•			•			•			rainforest, leaflets paper-like
C. restrepoi	•				•			•			•			•		F-Dark red	rainforest, leaflets paper-like
Cycas angulata	•	•			•		•					•	•			M-yellow-brown	leaf blue
C. arenicola	•	•			•		•					•	•				No phosphorus fertilizer
C. armstrongii	•	•			•		•					•	•			M-rust-felt	No phosphorus fertilizer
C. armhemica	•	•			•		•					•	•			M-yellow-brown-felt	No phosphorus fertilizer
C. balansae	•	•			•		•					•	•				poorly known species from Vietnam
C. basaltica	•	•			•		•					•	•		•	M-brown-felt	No phosphorus fertilizer
C. beddomei	•	•			•			•				•	•			M-brown-felt	
C. bougainvilleana	•	•					•					•	•				
C. brunnea	•	•			•		•		•			•	•			M-brown-felt	No phosphorus fertilizer
C. caimsiana		•				•	•		•			•	•		•	seed and leaf blue	= 'Mt. Surprise', prefers low humidity
C. calcicola	•	•			•		•		•			•	•			M-grey-felt	leaf hairy, no phosphorus
C. canalis	•	•			•		•					•	•			M-yellow-brown-felt	No phosphorus fertilizer
C. chamberlainii	•	•			•		•					•	•			M-brown-felt	leaves wide, fast grower
C. chevalieri	•	•		•	•	•	•	•			•		•				includes C. simplicipinna
C. circinalis	•	•			•		•					•	•				
C. conferta	•	•			•		•					•	•			M-brown-felt	leaflets overlap, no phosphorus
C. couttsiana	•	•			•		•		•			•	•		•		leaf blue, prefers low humidity
C. furfuracea	•	•				•	•		•			•	•		•	seeds yellow	leaf blue, hairy beneath, no phosphorus
C. guizhouensis	•	•			•		•					•	•		•	seed yellow	
C. hainanensis	•	•			•		•				•		•			seed yellow	
C. hongheensis	•	•				•	•		•			•	•				
C. macrocarpa	•	•			•		•				•		•			M-rusty-felt	
C. media	•	•			•		•					•	•		•	M-brown-felt	leaves glossy

	CLIMATE			LEAF LENGTH			STEM HEIGHT		LEAFLET SHAPE			MICRO-CLIMATE					
SPECIES	Tropical	Subtrop.	W. Temp.	> 6 ft	< 6 ft	< 3 ft	> 1.5 ft	< 1.5 ft	Spiny	Wide	Medium	Narrow	Sun	Shade	Frost	Cone Color	Remark
Cycas megacarpa	•	•			•	•	•		•			•	•		•	M-brown-felt	= 'C. kennedyana'
C. micholitzii																	
var. micholitzii	•	•		•				•			•		•	•		M-cream-felt	foliage bamboo-like, leaflets branch
var. "stenosis"	•	•		•				•			•		•				foliage bamboo-like, leaflets branch
C. micronesica	•	•		•			•				•		•				
C. multipinnata	•	•			•			•			•		•				leaflets branch, a var. of C. micholitzii
C. ophiolitica	•	•	•		•		•		•			•	•			seeds & leaf blue	='Marlborough Blue', low humidity
C. orientis	•	•			•		•					•	•			M-yellow-brown-felt	No phosphorus fertilizer
C. panzhihuaensis		•	•		•		•					•			•	M-brown-yellow	green & blue-leaf varieties
C. papuana	•	•			•		•					•				M-yellow-brown	
C. parvulus	•	•			•			•			•		•				
C. pectinata	•	•			•		•					•	•			M-brown-felt, seed-orange to yellow	
C. platyphylla	•	•	•		•	•	•		•			•	•			M-brown, seed blue	dry eucalypt forest
C. pruinosa	•	•			•		•					•				M-tan-felt	seed & leaf blue, no phosphorus
* *C. revoluta*	•	•	•				•		•			•	•		•	M-yellow, seed-orange	
* *C. rumphii*	•	•		•			•				•		•			M-tan-felt	includes C. apoa & C. micronesica
C. seemannii	•	•		•			•				•		•			orange-brown-felt	leaf glossy
C. scratchleyana	•	•		•			•				•		•				
C. schumanniana	•	•		•			•				•	•	•			M-cream-felt	
C. siamensis	•	•			•			•				•	•			brown-felt	needs excellent drainage
C. sylvestris	•	•			•		•				•		•	•			
C. szechuanensis	•	•	•	•	•		•				•		•				
* *C. taitungensis*	•	•			•		•		•			•	•			seed-orange-red	formerly called C. taiwaniana
C. thouarsii	•	•		•	•		•				•		•			orange-brown	
C. wadei	•	•				•	•					•	•			orange-brown-felt	trunk with distinct rings

	SPECIES	CLIMATE			LEAF LENGTH		STEM HEIGHT		LEAFLET SHAPE			MICRO-CLIMATE			Cone Color	Remark
		Tropical	Subtrop.	W. Temp.	> 6 ft	< 6 ft	< 3 ft	> 1.5 ft	< 1.5 ft	Spiny	Wide	Medium	Narrow	Sun	Shade	Frost		
	Dioon califanoi	●	●				●	●		●			●	●			gray-hairy	
	D. caputoi		●				●		●	●			●	●			gray-hairy	
	D. edule																gray-hairy	
*	*var. angustifolium*	●	●	●			●		●	●			●	●		●	gray-hairy	
*	*var. edule*	●	●	●		●		●		●			●	●		●	gray-hairy	
	D. holmgrenii	●	●			●		●		●			●	●			gray-hairy	
	D. mejiae	●	●			●		●		●		●		●			gray-hairy	
	D. merolae	●	●	●		●		●		●		●		●			gray-hairy	lealfets in venetian blind pattern
	D. purpusii	●	●	●		●				●			●	●			gray-hairy	
	D. rzedowskii	●	●	●		●		●		●		●		●			gray-hairy	F-cone pendent
*	*D. spinulosum*	●	●	●		●		●		●		●		●	●		gray-hairy	F-cone pendent
	D. tomasellii																	
	var. tomasellii		●	●		●			●			●	●	●			gray-hairy	
	var. sonorense		●	●			●		●	●			●	●			gray-hairy	arid habitat
	Encephalartos aemulans	●	●			●		●		●		●		●			brown-felt	
*	*E. altensteinii*	●	●			●		●		●		●		●			yellow	
	E. arenarius	●	●			●		●		●		●		●			green	coastal dunes, fast grower
	E. barteri																	
	subsp. barteri	●	●			●			●	●		●		●			dark-green	lowland form
	subsp. allochrous	●	●			●		●		●		●		●			dark-green	highland form
	E. bubalinus	●	●			●		●		●		●		●			dark green	leaflets in venetian blind pattern
	E. caffer	●	●				●		●	●			●	●			green	dwarf & medium size varieties
	E. cerinus	●	●			●			●	●			●	●			blue-green, yellow	waxy blue leaf
	E. chimanimaniensis	●	●			●		●		●		●		●			greenish-blue	

	SPECIES	CLIMATE			LEAF LENGTH		STEM HEIGHT		LEAFLET SHAPE			MICRO-CLIMATE			Cone Color	Remark
		Tropical	Subtrop.	W. Temp.	> 6 ft	< 6 ft	< 3 ft	> 1.5 ft	< 1.5 ft	Spiny	Wide	Medium	Narrow	Sun	Shade	Frost		
	Encephalartos concinnus	●	●			●		●		●		●		●			green	
	E. cupidus	●	●			●			●	●		●		●			green	leaf blue
	E. cycadifolius			●		●		●		●			●	●		●	gray wool	high altitude species, tolerates snow
	E. delucanus	●	●				●		●	●		●		●				
	E. dolomiticus		●			●		●		●		●		●			glaucous green	leaf blue
	E. dyerianus		●			●		●		●		●		●			blue-green, yellow	
	E. eugene-maraisii	●	●			●		●		●		●		●			green-brown	leaf blue
	E. ferox	●	●			●			●	●	●			●			orange (yellow)	coastal dunes
	E. friderici-guilielmi		●	●		●		●		●			●	●		●	cream-wool	wooly crown
	E. ghellinckii			●		●		●		●			●	●		●	yellow-wool	montane, lowland forms
*	*E. gratus*	●	●			●		●		●		●		●			dark orange	
	E. heenanii		●			●		●		●		●		●			brown wool-green	
*	*E. hildebrandtii*	●	●		●			●		●		●		●			green, yellow	
	E. horridus		●	●			●		●	●		●		●			bluish-green	blue leaf
	E. humilis			●			●		●	●			●	●		●	yellow	nearly deciduous
	E. inopinus	●	●			●		●		●		●		●			light green	blue leaf
	E. ituriensis	●	●		●			●		●		●		●			green, yellow	M-cone with long stalk
	E. kisambo	●	●		●			●		●		●		●			golden yellow	
	E. laevifolius			●			●	●		●			●	●		●	light green	nearly deciduous
	E. lanatus		●	●			●	●		●			●	●		●	yellow	
	E. latifrons		●	●		●		●		●		●		●			bluish to olive green	
	E. laurentianus	●	●		●		●			●		●		●			green	
	E. lebomboensis	●	●			●		●		●		●		●			yellow	
	E. lehmannii		●	●		●		●		●		●		●			green	blue leaf
	E. longifolius		●			●		●				●		●			olive-green, large	leaf not spiny

	SPECIES	CLIMATE: Tropical	CLIMATE: Subtrop.	CLIMATE: W. Temp.	LEAF LENGTH: >6 ft	LEAF LENGTH: <6 ft	LEAF LENGTH: <3 ft	STEM HEIGHT: >1.5 ft	STEM HEIGHT: <1.5 ft	LEAFLET SHAPE: Spiny	LEAFLET SHAPE: Wide	LEAFLET SHAPE: Medium	LEAFLET SHAPE: Narrow	MICRO-CLIMATE: Sun	MICRO-CLIMATE: Shade	MICRO-CLIMATE: Frost	Cone Color	Remark
*	*Encephalartos manikensis*	•	•			•		•		•		•		•			green	
	E. marunguensis	•	•				•		•	•		•		•			green	
	E. middelburgensis		•			•		•		•		•		•		•	green	leaf blue
	E. munchii	•	•			•		•		•		•		•			bright-gluacous-green	
	E. natalensis	•	•			•		•		•		•		•			orange-yellow	
	E. ngoyanus		•				•		•	•			•	•			light green	semi-deciduous
	E. paucidentatus		•			•		•		•		•		•			tan-felt	
	E. poggei	•	•			•			•	•		•		•			peach, yellow	
	E. princeps	•	•			•		•		•		•		•			green	occurs with succulents in wild
	E. pterogonus	•	•			•		•		•		•		•			bright-green	
	E. schaijesii	•	•			•			•	•		•		•			F-green	
	E. schmitzii	•	•				•		•	•			•	•			green	
	E. sclavoi	•	•			•			•			•		•			yellow	leaflets in venetian blind pattern
	E. septentrionalis	•	•			•		•		•		•		•			green	M&F-cone pendant
	E. tegulaneus	•	•			•		•		•		•		•			green, yellow	M-cone with long stalk
	E. transvenosus		•		•			•		•		•		•			golden yellow	
	E. trispinosus		•			•	•	•		•		•		•			bluish-green	blue leaf
	E. turneri	•	•			•		•		•		•		•			green, pink-yellow	
	E. umbeluziensis	•	•			•			•	•			•	•	•		green	
*	*E. villosus*	•	•		•	•			•	•	•	•		•	•		green, yellow	
	E. woodii.	•	•		•			•		•	•			•			orange-yellow	fast grower
*	*Lepidozamia hopei*	•	•		•			•				•		•	•	•	F-grey-green	rainforest, no spines
*	*L. peroffskyana*	•	•	•	•			•				•		•	•	•	M-green, F-brown	no spines
*	*Macrozamia communis*		•	•		•		•	•	•			•	•	•	•	green	
	M. conferta		•	•			•		•				•	•				

	SPECIES	CLIMATE: Tropical	CLIMATE: Subtrop.	CLIMATE: W. Temp.	LEAF LENGTH: >6 ft	LEAF LENGTH: <6 ft	LEAF LENGTH: <3 ft	STEM HEIGHT: >1.5 ft	STEM HEIGHT: <1.5 ft	LEAFLET SHAPE: Spiny	LEAFLET SHAPE: Wide	LEAFLET SHAPE: Medium	LEAFLET SHAPE: Narrow	MICRO-CLIMATE: Sun	MICRO-CLIMATE: Shade	MICRO-CLIMATE: Frost	Cone Color	Remark
	Macrozamia cranei		•	•			•		•				•	•			F-green	spiral leaf
	M. crassifolia		•	•			•		•				•	•			F-green	spiral leaf
	M. diplomera		•	•		•	•		•				•	•		•	green	leaflets branch
	M. douglasii		•	•		•		•	•	•		•		•	•		green	
	M. dyeri		•	•		•		•				•		•		•	M-straw, F-green	Mediterranean climate
	M. fawcettii		•	•			•		•			•	•	•	•	•	green	spiral leaf
	M. fearnsidei		•	•		•	•		•				•	•		•	green	spiral leaf
	M. flexuosa		•	•			•		•				•	•		•	green	
	M. heteromera		•	•			•		•				•	•		•	green	leaflet branch
	M. johnsonii		•	•	•	•		•		•			•	•	•	•	green	
	M. lomandroides		•	•			•		•			•		•		•	green	spiral leaf
*	*M. lucida*		•	•		•			•				•	•	•		green, yellow	easily cultivated
	M. macdonnellii		•	•		•		•		•			•	•		•	bluish, seed large	blue leaf
	M. machinii		•	•			•		•				•	•			F-green	spiral leaf
	M. miquelii	•	•	•		•			•	•			•	•		•	green	
	M. moorei	•	•	•	•	•		•		•			•	•		•	green, yellow	
	M. mountperriensis		•	•			•		•	•			•	•		•	green	
	M. occidua		•	•			•		•				•	•				spiral leaf
	M. parcifolia		•	•			•		•				•	•				spiral leaf
	M. riedlei			•		•			•	•			•	•		•	green	Mediterranean climate
	M. pauli-guilielmi		•	•			•		•				•	•			green	spiral leaf
	M. platyrachis		•	•			•		•			•		•				
	M. plurinervia		•	•			•		•				•	•			cone & leaf bluish	spiral leaf
	M. secunda		•	•			•		•				•	•		•	green	
	M. spiralis		•	•			•		•				•	•		•		

	SPECIES	CLIMATE: Tropical	CLIMATE: Subtrop.	CLIMATE: W. Temp.	LEAF LENGTH: >6 ft	LEAF LENGTH: <6 ft	LEAF LENGTH: <3 ft	STEM HEIGHT: >1.5 ft	STEM HEIGHT: <1.5 ft	LEAFLET SHAPE: Spiny	LEAFLET SHAPE: Wide	LEAFLET SHAPE: Medium	LEAFLET SHAPE: Narrow	MICRO-CLIMATE: Sun	MICRO-CLIMATE: Shade	MICRO-CLIMATE: Frost	Cone Color	Remark
	Macrozamia stenomera		•	•			•		•				•	•			green	Leaflets branch
	M. viridis		•	•			•		•				•	•				spiral leaf
	Microcycas calocoma	•	•				•	•					•	•			cream-felt	
	Stangeria eriopus	•	•			•	•		•			•		•	•		silver-felt	fern-like
	Zamia acuminata	•	•				•		•			•			•		tan	
	Z. amazonica	•					•		•			•			•			rainforest
	Z. amblyphyllidia	•	•			•	•		•			•		•	•		grey to black-felt	
	Z. amplifolia	•	•			•	•		•		•				•		tan	rainforest
	Z. angustifolia	•	•				•		•				•	•			grey tp black	spiral leaf
	Z. boliviana	•	•				•		•			•			•		red-brown-felt	rainforest
	Z. chigua	•				•	•	•					•		•		tan-felt	rainforest
	Z. cremnophila	•	•			•			•			•			•		brown-felt	cliff dweller, leaves pendant
	Z. cunaria	•	•			•	•		•		•				•		M-tan, F-dark red	rainforest
	Z. dressleri	•				•	•		•		•				•		M-tan, F-dark red	rainforest, corrugated leaflet
	Z. fairchildiana	•	•			•		•				•			•		M-cream, F-yellow-green to light brown	
	Z. fischeri	•	•				•		•			•			•		M-gray, F-green	dwarf
*	*Z. furfuracea*	•	•				•		•		•	•		•			tan-felt	coastal dunes, fast grower
	Z. herrerae	•	•				•		•			•	•	•			M-tan	
	Z. inermis	•	•				•		•				•	•			brown-felt	
*	*Z. integrifolia*	•	•			•	•		•				•	•		•	red-brown-felt	only N. Florida form frost-tolerant
	Z. ipetiensis	•				•	•		•		•				•		M-tan, F-dark red	rainforest
	Z. lacondonis	•	•			•			•		•				•			new leaf pink
	Z. lecointei	•	•			•			•			•			•		M-tan, F-dark red	= Z. jirijirimensis(?), rainforest
	Z. lindleyi		•				•		•				•		•			montane forest, dislikes too much heat
	Z. loddigesii	•	•				•		•			•		•			tan to brown-felt	highly variable species

	SPECIES	CLIMATE: Tropical	CLIMATE: Subtrop.	CLIMATE: W. Temp.	LEAF LENGTH: >6 ft	LEAF LENGTH: <6 ft	LEAF LENGTH: <3 ft.	STEM HEIGHT: >1.5 ft	STEM HEIGHT: <1.5 ft	LEAFLET SHAPE: Spiny	LEAFLET SHAPE: Wide	LEAFLET SHAPE: Medium	LEAFLET SHAPE: Narrow	MICRO-CLIMATE: Sun	MICRO-CLIMATE: Shade	MICRO-CLIMATE: Frost	Cone Color	Remark
	Zamia manicata	•	•			•			•		•				•		M-tan, F-dark red	rainforest, collar on leaflet
	Z. montana	•	•			•		•			•				•		brown-felt	montane forest
	Z. muricata	•	•			•			•		•			•	•		brown-felt	
	Z. neurophyllidia	•	•				•	•			•				•		M-tan, F-brown	rainforest, corrugated leaflet
	Z. obliqua	•				•		•			•				•		Mtan-felt	rainforest
	Z. paucijuga	•	•				•		•			•		•			brown-felt	
	Z. poeppigiana	•	•		•			•				•			•		brown-felt	rainforest
	Z. polymorpha	•	•				•		•			•		•				
	Z. portoricensis	•	•				•		•				•	•			reddish-felt	serpentine soils
	Z. pseudomonticola	•	•				•		•		•				•		F-brown-felt	
	Z. pseudoparasitica	•	•		•	•			•			•			•		tan-felt	epiphyte, leaves pendent
	Z. pumila	•	•				•		•			•		•			red-brown-felt	no spines
	Z. purpurea	•	•				•		•		•	•			•		M-tan, F-purplish-brown-felt	
	Z. pygmaea	•	•				•		•				•				grey to black-felt	smallest of all cycads, serpentine soils
	Z. roezlii	•	•		•			•				•			•		tan-felt	rainforest, corrugated leaflet
	Z. skinneri	•	•			•		•			•				•		M-tan, F-brown	rainforest, corrugated leaflet
	Z. soconuscensis	•	•			•			•			•	•		•		deep brown-felt	
	Z. spartea	•	•				•		•				•	•			brown-felt	
	Z. splendens	•	•				•		•		•	•			•		light pink-felt	new leaf pink
	Z. standleyi	•	•				•		•			•		•			brown-felt	
*	*Z. tuerckheimii*	•	•			•		•				•			•		cream-felt	rainforest
	Z. ulei	•	•				•		•			•			•		brown-felt	rainforest
	Z. variegata	•	•			•			•		•	•			•		brown	rainforest
	Z. vazquezii	•	•				•		•			•		•			F-grey-green	dwarf
	Z. wallisii	•			•				•		•				•		cream-felt	rainforest, corrugated leaflet

LANDSCAPING WITH CYCADS

Cycads have been used for a variety of ornamental and landscaping purposes. In Japan and China *Cycas revoluta* has been cherished for centuries as specimen plants in gardens and entrance ways. Cycads come in a variety of sizes, shapes and textures - from dwarf species that can be used as ground cover to those that can be used as specimen trees. They can be grown to produce a bushy appearance or be tall and palm-like. They have attractive trunks, but their most striking features are their foliage and cones. There is enough variety in leaf and cone shapes, colors and textures to fulfill a myriad of landscaping needs.

Cycad leaves, almost without exception, have a rich tropical appearance. Their thick, often shiny leaflets have distinct shapes and are usually arranged in tidy, symmetrical crowns that are striking. They almost always give the viewer the impression of something of value, like a piece of art. Thus cycads make excellent specimen plants for entryways and patios and as centerpieces for landscape beds. Their cones, when they occur, are often impressive in their symmetry and texture and are often augmented by bright colors ranging from light green and bright yellows to orange and reds. In many species the cones are covered with felt or hair. Male cones may be produced in a sequence and enjoyed for many months, while female cones may persist on the plant for more than a year (**Table 4**). Foliage growth occurs in flushes and is an event that makes one take notice. New leaves, which sometimes have a pink to dark red color, will emerge in a spectacular whorl or in an orderly sequence. Thus cycads have an entertaining visual appeal that plays itself out over the seasons.

Cycads are especially striking and attractive when placed on sloping ground and among large rocks (see **Cover** and **Back cover**). Like palms they are best planted as solitary specimens or in groups of 3 or 5. They should be planted with their adult width in mind to prevent them from becoming overcrowded. Cycads need room to develop a symmetrical crown of leaves, their most ornamental feature, and to properly display their attractive trunks. Besides their suitability in the home garden they are excellent around public grounds and buildings. Their symmetrical, richly textured foliage blends in well with the straight lines usually found in modern architecture and monumental buildings. They look especially attractive against polished dark marble and concrete and other stonework. They are at home in nooks and corners as well as in plazas and open areas and around fountains and flowing water (see **Back cover**). Cycads are mostly small to medium sized plants and they are best used where they will not be overwhelmed by other plants or structures. Their visual appeal will be lost or overlooked if they can only be viewed from a long distance or if they are overcrowded by large plants.

An added benefit to the use of cycads as landscape plants is that they are low in maintenance. To those who have little time for yard work this is a real blessing. Cycad foliage needs no pruning since their leaves and crowns grow to a specific size and no more. They do not shed messy leaves and their trunks branch infrequently and rarely need to be trimmed back. All they need is to have their older leaves removed, but even this is not necessary, since the dead leaves may hang from the plant in an interesting manner. Cycads are not demanding in their fertilizing needs, although regular fertilizing will ensure their health and prevent many problems. Except for scale or mealybug infestations in enclosed areas, they are surprisingly free of insect pests in most urban settings.

Choosing the Planting Site

As a general rule cycads like a stable microclimate with gradual and minimal fluctuations in temperature, humidity and moisture. Periods of intense heat, water stress and low humidity during the day will nullify the benefits of favorable conditions during the rest of the day.

Temperature and Humidity

Cycads like warmth and humidity. There are some exceptions to this general rule among the species native to more temperate regions, deserts or high altitudes that prefer cooler nights and lower humidity. Also many of the more temperate species require cooler winters. These may not do well and may not cone when planted in tropical and subtropical zones. If you are located in a humid tropical zone, some of these limitations can be overcome if the plants are planted in an open area with a gravel ground cover. Such a planting site may cool quicker in the evenings. The openness and exposure allows more air flow and thus quicker drying and lower humidity. This condition is not unlike the cliff habitats of many species. At Fairchild Tropical Garden in Miami, Florida, with hot humid summers, arid land species such as *Encephalartos horridus* and *E. trispinosus* planted on gravel-covered beds grow better and are less susceptible to fungal infections than those in more moister situations.

Cold Tolerance

Most cycads are native to regions where freezing temperatures do not occur, hence provisions must be made to protect them from freeze damage. In periods of brief freezing temperatures their leaves may be burned on the edges and senesce prematurely. Freezing temperatures of greater intensity and duration may kill the leaves and stems completely. The best protection for the stem during such weather is a mound of mulch. Leaves can be protected during mild frosts by covering them with a box or cloth sheet. Potted plants are especially susceptible to cold and should be brought indoors.

In general, if a cycad does not suffer stem damage during a severe cold,

it will produce a new set of leaves in the warmth of the next growing season. Some cycad species are adapted to endure long periods of cold. This is true for some of the South African *Encephalartos*, Australian *Macrozamia* and Mexican *Dioon* and *Ceratozamia*, particularly those growing in high altitudes (see **Table 2**). Some of these are suitable for growing in more temperate climates, such as northern California.

Shading

Except for those species from semi-desert climates, most cycads grow best if given some afternoon shade. Intense mid-day sun may burn leaves or cause their premature aging and subject plants to drought stress and possible heat damage. Loran Whitelock reports that during a heat wave in southern California, temperatures at the soil surface became so intense that the stem/root tissue of a specimen of *Encephalartos horridus* burned at the level of the soil surface and the stem died. This is a species of the desert margin! If high temperatures are experienced in your area and your plants are exposed to full afternoon sun, it is recommended that a layer of mulch be applied to the base of the plant to prevent such heat damage.

Many species grow naturally in the understory of forests and prefer filtered light and protection from hot sun. This is especially true of the rainforest *Zamia* and *Ceratozamia*.

Greenhouse

If the required microhabitat cannot be found or created in the garden it will be necessary to grow these plants in a greenhouse. Cycads usually do very well in greenhouses, especially with climate control. They may be kept in pots for decades and even centuries. The oldest known potted plant is a cycad cultivated at Kew Gardens in England since 1776. Pot culture, however, may stunt a cycad's growth and prevent it from reaching a size where it can begin to cone.

PROPAGATION

Stem Suckers

Plants can be propagated vegetatively from stem bulbs or "suckers". These are usually produced at the base of the stem (**Fig. 13**), but may occur along the entire length of the trunk. They tend to be more abundant in particular species and in those specimens whose main trunks are tilting. Suckers can be removed during the growing season after they reach a width of more than 2 inches. After surrounding debris and soil are cleared away they can be cut from the parent with a sharp knife. It is best to remove suckers just prior to a surge of leaf production, which is usually in spring after a recent flush of scale leaves on the sucker. Leaf production will stimulate root growth. If the sucker has existing leaves, all but one or

two should be removed. The wound on both the parent and the sucker should be clean and smooth and treated with a fungicide/insecticide and allowed to heal for a few days before covering with soil. When first removed it is essential that the suckers be stored in nondesiccating conditions, such as a plastic bag, until they are planted. Desiccation will weaken the sucker and reduce its chances of rooting. If the cut surface is allowed to dry this will lead to tissue death, which promotes rot. Some suckers at ground level may already have roots and are ideal for transplanting.

Leaf Bases

Sometimes cycads can be propagated from the leaf bases that form the "armor" of the trunk. If removed from the stem, especially with a portion of the leaf still intact, the leaf base may form roots if planted in warm moist medium such as sharp sand. This is a slow and poorly understood method of propagation.

Tissue Culture

Tissue culture is a technique of vegetative propagation, much like propagation from suckers and leaf bases, although under sterile, controlled conditions. This propagation technique has been commercially successful for some plants (e.g. orchids), however, for cycads is still in an experimental stage. Leaf tissue has been successfully used to produce new plants, but two years may be required to produce a seedling-sized plant. Root tissue of *Stangeria* has been successfully used to propagate new plants, however, it does not appear promising in other genera. Because of these limitations propagation by seeds is presently more effective and efficient. In those species where one sex of the species is extinct (*Encephalartos woodii*), or those species that have been reduced to critically low numbers or that do not produce viable seeds in cultivation, this technique holds great promise. Once perfected, tissue culture may allow mass production of desired species and cultivars.

Table 3. Maturation rates for cycads grown under near ideal conditions.

SPECIES	SEX	AGE AT MATURITY
Bowenia spectabilis	M	3 years
Ceratozamia hildae	M,F	5
C. robusta (Belize form)	M,F	5
Cycas taitungensis	M,F	5,6
C. thouarsii	F	4
Encephalartos hildebrandtii	F	8
Lepidozamia peroffskyana	F	7
Macrozamia communis	M	8
Stangeria eriopus	M	4
Zamia fischeri	M,F	2
Z. integrifolia (Florida form)	M,F	2,3

Sexual Maturity

Cycads have a reputation of being slow growing. This reputation is based in part on cultivation practices in unsuitable temperate climates where they are usually potbound and receive inadequate warmth, light and nutrition. Under such conditions it is surprising that cycads survive at all. That they do is a testament to their ability to endure abuse. Modern knowledge of soils, fertilizers and growing conditions discussed in this book have shown that many cycads can be grown quickly from seed and mature in as little as 2-8 years. **Table 3** above lists maturation times from seed for representative species grown under near ideal conditions.

Pollination

In most of the older literature on cycads these plants are assumed, like conifers, to be wind-pollinated. More recent observations and experiments show that insects are much more important for pollination than wind. In fact, cycads in cultivation, that have lost their insect pollinators, usually produce no viable seeds. This is strong evidence that these plants are exclusively insect-pollinated. In the species so far examined, beetles, particularly weevils, appear to be the major pollinators of cycads in the wild. In cultivation where pollinators are absent, it is necessary to hand-pollinate cycad cones.

Distinguishing Male and Female Cones

Male cones usually have an elongated cylindrical shape with rounded ends and are attached to stalks. Female cones are larger, more broadly cylindrical or conical in shape and have larger and less numerous scales than male cones (**Figs. 2,5,6,7,14,16,17**). In a few species of *Encephalartos*, namely *E. heenanii* and *E. manikensis*, male and female cones will appear almost indistinguishable until they begin to shed pollen or become receptive to pollination.

Collecting and Storing Cycad Pollen

When the male cone reaches maturity it will begin elongating. This is rapid in most species with the cone increasing in length by 10-20% a day. You will notice a change literally overnight. Often the cone will change hue or the lighter-colored interior will be exposed as the cone lengthens and opens. Pollen will be shed over a week or more. In most species with multiple male cones, cones will shed their pollen in sequence. Often the cone can be tipped and the pollen shaken onto a piece of paper. Or the cone may be cut off at an early stage of pollen shedding and brought indoors and placed on a smooth piece of paper. It will continue to shed its pollen over several days. The pollen should be dried either in an air-conditioned atmosphere or with a desiccant and then frozen in dry conditions in a jar. The pollen can retain its viability for a year or longer under these conditions. If frozen with liquid nitrogen they can be stored for even longer periods.

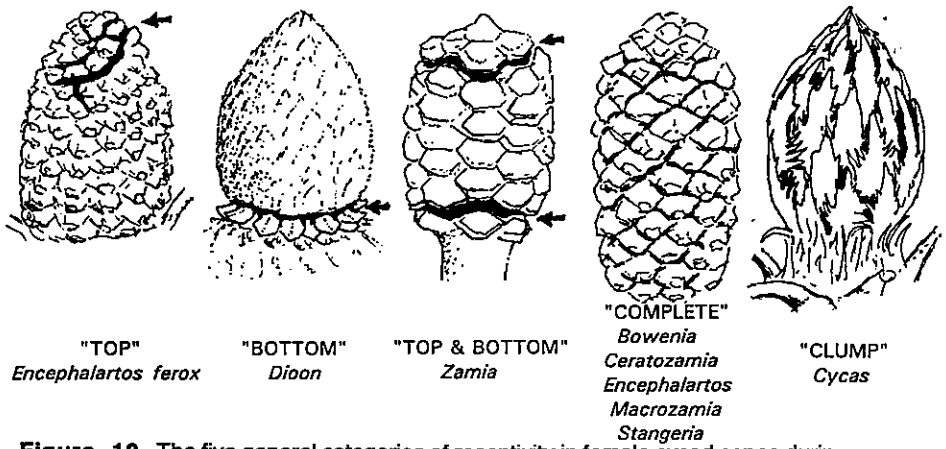

Figure 12. The five general categories of receptivity in female cycad cones during pollination and the genera that display them.

Recognizing when to Pollinate the Female Cone

Female cycad cones are closed structures with seeds covered over with scales. When they become receptive to pollination cracks will appear for brief periods from a few days to two weeks. These cracks form in a particular pattern depending on the genus and species (**Fig. 12**)

Pollinating Female Cones

There are three techniques to hand-pollinating cycad cones. (1) "Bang" method: in species where the female cone opens widely during receptivity, successful pollination can be achieved merely by banging a shedding male cone against the female. This technique is very effective for *Zamia fischeri* and *Ceratozamia robusta* (Belize form) in cultivation in south Florida. Because of the closed structure of the female cone in most species much greater pollination success is achieved by injecting pollen into the receptive female. (2) "Dry" method: dry pollen is injected into the female cone using a small pump, such as an eyedropper with a large bulb. If pollen is seen exiting other crevices, this is a sign that pollen was successfully spread through the cone. Injecting pollen over several days will increase pollination success. (3) "Wet" method: pollen mixed with a small amount of water can be placed in a syringe and squirted into the female cone crevices (**Fig. 16**). In the blue-leafed *Encephalartos* pollen should not be mixed with water before injection as this may cause the cone to rot and the seeds to abort.

Collecting and Cleaning Seeds

After pollination cycad seeds will remain in the cone to develop. In all genera except *Encephalartos* the seed will grow substantially and the

Table 4. Time elapsed from pollination to release of seeds from the cone for 17 species of cycad growing in south Florida.

SPECIES	PERIOD FROM POLLINATION TO SEED RELEASE
Ceratozamia hildae	7-8 Months
C. robusta (from Belize)	7
Dioon edule	12-13
D. spinulosum	15-16
Encephalartos ferox	5-6
E. gratus	5-6
E. hildebrandtii	4-6
E. manikensis	5-6
Macrozamia lucida	7-8
M. moorei	6-7
Microcycas calocoma	10
Stangeria eriopus	10-11
Zamia fischeri	11-12
Z. furfuracea	7-9
Z. pseudoparasitica	11
Z. splendens	9-10
Z. tuerckheimii	24

cone will swell. This period of "pregnancy" may last as little as 4 months in some *Encephalartos* and over a year in *Dioon* (**Table 4**). In *Zamia tuerckheimii* more than two years may elapse after pollination before the seeds are shed. When the cone begins breaking apart (**Fig. 17**) the seeds should be collected immediately and their fleshy outer coat (**Fig. 18**) removed. Seeds lying on the ground are subject to attack by insects and rodents. The fleshy coat may begin to decay and the rot may spread to the kernel and kill the embryo.

The fleshy coat can be removed with a small knife to expose the hard inner shell (**Fig. 19**). If there is a large quantity of seed (*Encephalartos* cones may have over 500 seeds and *Cycas* may have over 1000) a mechanical cleaning method, using a cement mixer, may be employed. Wait until the fleshy coat becomes soft and place the seeds in the mixer with coarse gravel. After 1/2 hour of mixing, with periodic flushing with water, the seeds will be scoured clean. The small seeds of *Zamia* are too delicate for this method. Bijan Dehgan has developed a technique with a wire brush attached to a drill. The brush is applied to a mixture of *Zamia* seed and sand and the fleshy coat is scoured off.

Germinating Seeds

Seedling emergence occurs through a star-shaped hatch in the seed in 10 of the 11 genera. The exception is *Cycas* whose seeds open like a clam during emergence of the seedling.

The seed of some species have fully matured embryos when they are released from the cone and will begin germinating immediately. This is particularly true with the more tropical New World species including *Dioon*

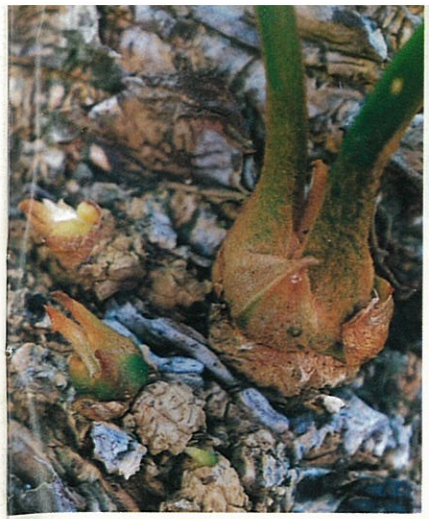

Figure 13. (Upper left) Suckers forming on the trunk base of *Cycas seemannii* (New Caledonia form).
Figure 14. (Upper right) Female cone of *Macrozamia communis* receptive to pollination. Note the cracks between the scales exposing the pink interior.
Figure 15. (Below) The cut end of a *Dioon spinulosum* trunk. The tissue is firm indicating that there is no decay. Its dark slimy appearance indicates that it is properly healing. New roots are emerging from its vascular ring.

Figure 16. (Above) Receptive female cone of *Encephalartos ferox* being hand-pollinated using the "wet method": pollen is injected as a slurry with water. Note that in this species cones only open at the top and for a brief one week period.

Figure 17. (Left) *Encephalartos arenarius* with ripe female cone at Huntington Garden, California.

Figure 18. (Below) Fresh cycad seeds with fleshy coat intact (left to right): *Zamia integrifolia* (Florida form), *Encephalartos ferox*, *E. gratus*, *E. hildebrandtii*, *E. manikensis* (2 seeds), *Dioon spinulosum* and *Cycas rumphii*. 3/5 natural size.

spinulosum and many *Zamia*. Upon being shed from the cone these can be immediately placed on germination beds where there is constant warmth and humidity. Those cycads originating from more temperate and seasonal climates may have seeds that are released from the female cone when the embryos are still quite small and undeveloped. South African *Encephalartos* fall into this category. These seeds need to be stored in cool (55°F) non-desiccating conditions for about four months before planting. If placed under constant high temperatures and humidity before they are ready, these seeds will suffer high mortality.

Various methods have been devised to germinate cycad seeds. In general temperatures between 80-110°F are ideal. In a greenhouse or tropical climate the seeds can be lightly covered with coarse pumice, or some similar volcanically derived medium with lots of pore space, and kept moist. This will provide the seed with conditions of constant high humidity and temperature while allowing for good aeration. Artificial germination media like pumice and perlite have the benefit of being sterile, thus lowering the likelihood of infestation by pathogens - a main cause of seed and seedling mortality. If you live in a temperate area or wish to watch your seeds germinate in your home you can build a germination box using a styrofoam ice chest with a low Watt bulb attached to the inside of the lid to generate heat. The seeds may be placed, but not buried, on a sterile moisture retaining medium like vermiculite. Once a plant begins to emerge from the seed it should be placed in a soil mix so that it may begin forming a root system and extract nutrients from the soil.

Other germination methods have been successful. In greenhouses seeds may be placed on sand, covered with burlap and periodically misted (**Fig. 20**). Many South African species appear to benefit from special germination conditions. Koos Oosthuyzen of South Africa has obtained high germination of seeds of the native *Encephalartos* by placing them in a cold frame, where they receive very high temperatures during the day, but cool and sometimes nearly freezing temperatures at night. This method is only suitable for the warm temperate species of that country and are not recommended for other species and genera.

Cycad seeds can be placed in communal pots with sterile potting soil and allowed to root. Commercial cycad growers have noted that young seedlings germinating and rooting together in one pot appear to grow more vigorously than when potted alone. The combined demand on water from many seedlings may prevent the soil from becoming waterlogged and keep the soil well aerated and thus maintain a more favorable soil for rooting. The reason for this effect, however, is not totally clear.

Germination of seeds of some *Zamia* have been sped up by scarifying the germinating end of the seed with a file. Scarification has also been

successfully done with concentrated sulfuric acid, however, this is an elaborate and potentially hazardous technique that may kill the seeds if not properly applied. Scarification apparently allows moisture to enter the seed more quickly. Moisture uptake appears to be a major factor in speeding germination.

Care of Seedlings

For several months cycad seedlings can rely solely on seed reserves for their nutrition. In those species with large seeds, a large well established seedling will result without much effort from the grower (e.g. *Dioon spinulosum* (**Fig. 1 8**), *Lepidozamia peroffskyana* and *Macrozamia macdonnellii*). For smaller-seeded species care from the grower is important for the establishment of the seedling. Seed size can be be used as an indicator of the care required to raise a species from seed.

For the first two years I recommend that young cycads be grown in deep narrow pots. This will allow them to form a long, healthy taproot, while avoiding the waterlogged soils that result from being overpotted. Warmth, constant adequate moisture, but excellent drainage is essential for the growth of the young plant. They are much less tolerant of drought and extremes in temperature and humidity than older plants and should be given partial shade (about 33% sun) and shelter from drying winds and cold temperatures. Given the proper conditions the seedling will grow rapidly and may double its size several times a year for several years. This is the stage of the most rapid growth for cycads. If your seedling doesn't show good growth it is probably under stress. I had a young *Encephalartos gratus* that increased its stem width from 2 to 7 inches in three years and a *Ceratozamia robusta* (Belize form) that increased its stem width from 2 to 6 1/2 inches in 2 1/2 years. Because of their more rapid pace of growth young plants should be fertilized more often. As a general rule a young plant should not be planted out in the garden until their stems are at least 3 inches wide and its leaves are more than 2 feet long. The larger the better! Spring is the best time, at the beginning of the growing season, and the plant should be watered regularly until it has produced deeper roots and adjusted to its new conditions.

Acknowledgements

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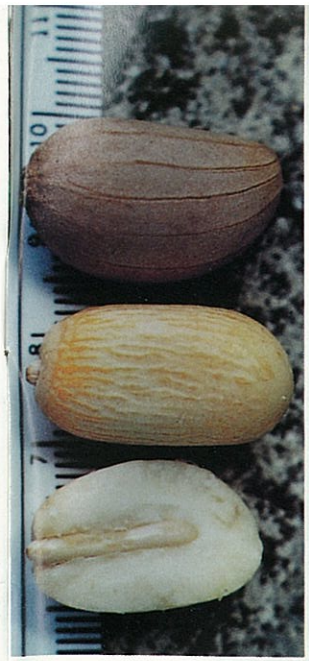

Figure 19. (Upper left) *Encephalartos ferox* seeds:(top to bottom) fleshy layer removed exposing hard shell, hard shell removed showing kernel and kernal cut open to reveal fully developed embryo. 1.5x natural size. **Figure 20.** (Lower left) Germination bed for cycad seeds at The University of Pretoria Botanical Garden. The seeds are covered with burlap and periodically misted. **Figure 21.** (Upper right) *Cycas revoluta* with new leaves brown and shriveled, indicating a deficiency in manganese. **Figure 22.** (Lower right) Pale emerging leaf of *Zamia fairchildiana*, indicating a deficiency in zinc.