Our soil tests conducted in 1995 corroborate those of a 1977 USDA Soil Conservation Service survey of Murville soils in New Hanover, North Carolina (Anonymous, 1977). The fine black sand soils where these plants grow in North Carolina have a pH between 4.3 and 4.5 with an E.C. of 0.1. Organic to mineral (sand) ratios run 1 lb to 7 lb on a dry weight basis. Bulk densities run about half of that of a loam soil, based on dry matter per cubic yard. Iron runs 1.8 lb cu yd^{-1} and nitrogen runs 1.6 lb cu yd^{-1} of dry matter.

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Propagating Palms from Seeds

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Optimal germination of palm seeds is attained by using mature, fresh, clean seeds; a disease-free, moist but well aerated medium; clean containers and benches; and maintaining temperatures of 30 to 35C and relative humidity of 90% to 100%.

INTRODUCTION

Although some palms can be propagated vegetatively, such as those with clumping stems, or through tissue culture, nearly all palms can be propagated by seeds. Commercial seed propagation of palms is relatively inexpensive and easy, and germination is usually rapid and high if one adheres to several principles. These principles include using only mature, fresh, clean seeds; planting in a disease-free, moist but well aerated medium; using clean containers and benches and keeping them clean; and maintaining appropriate temperature and moisture levels.

SOURCES AND HANDLING OF SEEDS

Plant only clean, fresh seeds from mature fruits. Obtain seeds from reliable, reputable suppliers or collect them yourself. Collect seeds from forms or strains of individuals with desirable characteristics, such as color, vigor, conformation, etc. Check a representative sample of seeds of unknown origin by a visual examination of the embryo. Healthy, viable embryos will mostly be moist, firm, white to yellow, and full, not shrunken from the endosperm. A float test is sometimes also used for assessing viability, but it is not always reliable.

Palm seeds, sprouted seeds, and germinated seedlings are highly susceptible to damping-off diseases. Thus, it is preferable to collect seeds from the tree since those collected from the ground are more likely to be contaminated with diseases and/or insects or other pests. Seeds should be kept clean until planting and then planted in disease-free media and clean containers. Containers of planted seeds should be kept off the ground on clean benches and growers should follow the simple rules of general nursery sanitation to prevent contamination.

Plant only seeds from completely mature or nearly so, soft-ripe fruits. Depending on the species, fruits at maturation are usually black, red, yellow, orange, purple, or brown. Full-sized, but green or undercolored, hard fruits have seeds which might germinate at a reduced percentage and rate (Rauch and Crivellon, 1989b), or not at all (Broschat and Donselman, 1988; Carpenter, 1988b). Removing the fruit pulp prior to planting usually improves germination (Yoshii and Rauch, 1989b) although seeds of some species, such as *Dypsis lutescens* (areca palm), do not have to be cleaned if planted immediately (Broschat and Donselman, 1988). Pulp of soft, juicy fruits, often thought to contain germination inhibitors (Rauch and Crivellone, 1989a), is easily removed by mashing in a bucket or other container and then using water to decant the pulp. Some palm fruits are fibrous and are not easily removed by mashing and decanting. In such cases a commercially available, mechanical seed cleaner might be useful. Wear waterproof gloves when cleaning palm seeds since the juice of some fruits can be highly irritating to tender skin.

Most palm seeds lose viability quickly so plant them as soon as possible after collection for best results. Without proper storage palm seeds will have much reduced germination percentages and rates, even after as little time as 2 to 4 weeks. Even with proper storage, though, expect reduced germination percentages and rates with many species. Some notable exceptions and their maximum seed storage times under ideal conditions include *Dypsis lutescens* - 12 months, *Phoenix roebelenii* (pygmy date palm) — 8 months, *Roystonea regia* (royal palm) — 9 months, and *Syagrus romanzoffiana* (queen palm) — 4 months. Seeds not planted immediately should be cleaned, air dried at 80%-90% relative humidity, and stored in air-tight plastic bags at 20 to 23C (Broschat and Donselman, 1988; Carpenter and Gilman, 1988; Carpenter and Ostmark, 1989). In a few rare cases, seed storage at cooler temperatures, -10C and -20C, actually enhanced seed germination of some species, such as *Sabal causiarum* (Puerto Rican hat palm) (Carpenter, 1989). Moisture content of seeds also plays a critical role in successful storage. Depending on the species, seeds store best if moisture content is at least 7% to 14% (Carpenter, 1989; Carpenter and Gilman, 1988; Carpenter and Ostmark, 1989; Carpenter et al., 1993a).

Presoaking seeds in gibberellic acid accelerates germination of some species (Nagao et al, 1980; Nagao and Sakai, 1979; Schmidt and Rauch, 1982), but is not recommended since it can also cause excessive elongation of resulting seedlings (Broschat and Donselman, 1988). Soaking seeds for 2 to 7 days in plain water alone (changing water daily), sometimes maintained at 35 to 45C (Carpenter, 1986; 1987), is preferable and often improves germination (Broschat and Donselman, 1988; Carpenter et al., 1993a; 1993b; Schmidt and Rauch, 1982; Yoshii and Rauch, 1989a; Yoshii et al., 1989). Scarifying seeds by filing just deep enough to break the seed coat at the micropylar end enhances germination of some species (Doughty et al., 1986; Nagao et al., 1980) while removal of the embryo cap stimulates rapid germination

of *Rhapidophyllum hystrix* (needle palm) (Carpenter et al., 1993a; 1993b); however, both methods can be labor intensive and expensive. Pre-plant treatment of palm seeds with fungicides is not recommended. In most cases, fungicidal treatment is unnecessary and, in a few instances might even be detrimental. More is gained by using clean seed, media, and containers, and following the rules of sanitation.

Seeds of some palm species fail to germinate if planted immediately after harvest. Freshly harvested seeds of these species contain germination inhibitors which gradually decline after several months at low relative humidity and lower temperatures than needed for germination. This process, called after-ripening, is probably a mechanism to ensure that seeds pass through lengthy, generally unfavorable conditions without germinating until conditions favorable to germination and seedling establishment occur. For example, clean, air-dried seeds of *Butia capitata* (pindo palm) germinate best when stored at 5 to 25C for 90 to 150 days and then planted and held at 40C for 3 weeks and 30C thereafter (Carpenter, 1988b). Other palms with similar requirements include some *Attalea* spp. and *Syagrus* spp.

PLANTING MEDIA AND PLANTING

Any clean, disease-free, moist but well aerated medium is suitable for palm seed germination. Equal parts of fine peat moss and perlite have given good results although there are as many successful germination media as there are growers. Position seeds on top of a premoistened medium with their long axis horizontally aligned. Depress seeds slightly into the medium so that about half the seed is above and the other half is below the surface. Water gently but thoroughly and allow to drain for 10 to 24 h, then cover the container with a clear plastic film or other air-tight covering. Seeds planted in this manner are visible for periodic observation, have less risk of remaining too wet yet high humidity (90% to 100% R.H.) is still maintained, and need to be watered much less frequently. Seeds planted without an air-tight cover should be positioned at a depth equal to about one-half the diameter of the seed, but not to exceed 1 cm, and the medium then closely monitored for moisture. Clearly label and date all seed containers.

Temperature is probably the most critical factor affecting germination. Generally, planted seeds of most species should be maintained at 30 to 35C for optimal germination (Broschat and Donselman, 1988; Carpenter, 1988a; Yoshii and Rauch, 1989a; Yoshii et al., 1991) although seeds of a few species germinate better at slightly lower or higher temperatures. Too low or high temperatures will delay, decrease, or inhibit germination. Bottom heat systems employing a thermostat and electric cables, heating pads, hot water or steam are available for maintaining temperatures in the correct range are recommended. Alternating rather than constant temperatures sometime enhance germination (Carpenter, 1998a; 1988b; 1989; Carpenter and Gilman, 1988; Carpenter and Ostmark, 1989; Carpenter et al., 1993a). Seeds of *Coccothrinax argentata* (silver thatch palm), *Pseudophoenix sargentii*, *Rhapidophyllum hystrix*, and *Thrinax morrisii* (key thatch palm) germinate best when temperatures are alternated from 25 to 35C or 30 to 40C at 6- to 12-h intervals while seeds of *Butia capitata* germinate best when initially held at 40C for 3 weeks and 30C thereafter.

Light levels should be similar to that provided by commercial shade cloth in the 40% to 60% shade range. Growers in cooler areas might consider higher light for additional heat. Too low light will result in excessively elongated and weakened

seedlings unless sprouted seeds are removed promptly, potted up into individual containers, and placed in a growing structure with appropriate light.

GERMINATION

Fresh, clean seeds of most palm species will germinate in 1 to 12 months. Historically imprecise and highly variable germination percentage and rate are dependent on several factors, including freshness and quality of seeds, temperature, moisture, and simple natural variation within and among species. Species with seeds which normally germinate within 1 to 6 months include *Archontophoenix* spp. (king and Alexander palms), *Chamaedorea* spp. (bamboo palms), *Chamaerops humilis* (Mediterranean fan palm), *Dypsis decaryi* (triangle palm) and *D. lutescens*, *Livistona* spp. (fountain palms), *Phoenix* spp. (date palms), *Rhopalostylis* spp. (shaving brush palms), *Washingtonia* spp. (California and Mexican fan palms), *Wodyetia bifurcata* (fox tail palm), and many other wet lowland tropical genera.

Some species with seeds which normally germinate within 6 to 12 months include *Butia* spp., *Chamaedorea* spp., *Howea* spp. (kentia and sentry palms), *Syagrus* spp., *Trachycarpus* spp. (windmill palms),and other tropical genera. Species with seeds which normally germinate in 12 to 24 months included *Brahea* spp., *Ceroxylon* spp. (wax palms),and *Jubaea chilensis* (wine palm).

Seeds of many species will germinate uniformly in a single flush while others will germinate sporadically or in multiple flushes over a lengthy period, sometimes as long as a year or more. Such delayed or sporadic germination might be a mechanism to enhance survival in areas with periodically less favorable germination conditions such as irregular rainfall or a long and pronounced dry season. Long and/or long-sporadic germination is possibly associated with the after-ripening process mentioned earlier.

Seeds of most palm species germinate with the new shoot developing adjacent to the seed. However, seeds of several species, such as *Bismarckia nobilis* (Bismarck palm), *Livistona* spp., *Phoenix* spp., and *Sabal* spp. (palmetto palms), germinate with the new shoot initiating remotely from the seed along an elongated cotyledonary petiole or "sinker". In this remote germination the "sinker", from which the new shoot arises, has usually grown downward, sometimes as deep as 60 cm. Seedlings which germinate remotely on "sinkers" are especially sensitive to disturbance. Care should be taken to ensure containers are of sufficient depth to accommodate easily the downward-growing "sinker". Especially large seeds with deep "sinkers", particularly those of rare or unusually valuable species, are best planted singly in a deep container. Although this method is more expensive and requires more bench space, young seedlings have sufficient space and time to develop an extensive root system without disturbance.

HANDLING GERMINATED SEEDS AND SEEDLINGS

Sprouted seeds may be transplanted into individual pots at the one-leaf stage. Most seedlings at this stage will have either deeply bifid, v-shaped leaf blades ("rabbit ears") or elongated, undivided blades. They are more difficult to handle when smaller and their roots might be entangled if transplanting is delayed beyond the two-leaf stage.

Sprouted seeds and seedlings are especially sensitive to root disturbance and drying out during transplanting. Carefully remove seedlings from the community

container, taking care not to damage their roots or the attached seed. The seed might still be supplying nutrients to the seedling so it is best to leave it attached. Plant immediately in a clean, porous, fertile potting medium. Remove only as many seedlings from a community container as can be planted within a few minutes. Cover exposed roots of removed seedlings with potting soil or damp newspaper until planting. Work in a wind- and sun-protected location.

Planting depth is critical when transplanting into individual containers. Position seedlings so the attached seed is at the soil line or, if the seed is absent, so the root/stem junction is at the soil line. Water thoroughly and place in a growing structure where light, temperature, and relative humidity are identical or similar to that during germination. Protect from sun and wind.

Planted seedlings should be monitored carefully for water during establishment. Seedling roots need abundant oxygen for optimal growth; over-watering is one of the leading causes of seedling failure. Once established, weather conditions permitting, seedlings should be moved without delay into growing structures or open beds where light levels are optimal for that particular species as adult plants. Too low light will cause excessive stretching and elongation, resulting in weakened plants susceptible to sun burn; too high light will yellow or burn seedling leaves, resulting in stunted growth.

SUMMARY

The following general principles will give the best results when germinating palm seeds:

- Use only mature, fresh, clean seeds;
- Plant them properly in a disease-free, moist but well aerated medium;
- Use clean containers and benches and keep them clean; and
- Maintain appropriate temperatures and moisture levels.

Unfortunately, specific, optimal germination conditions have yet to be determined for most palms. Experiment and try different methods employing some of the principles discussed. Don't get discouraged, and remember there is little more satisfying than to have excellent germination on a batch of palm seeds.

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