Principes, 32(1), 1988, pp. 3–12

Palm Seed Storage and Germination Studies

TIMOTHY K. BROSCHAT AND HENRY DONSELMAN
University of Florida, Research and Education Center, 3205 College Avenue, Ft. Lauderdale, FL 33314

ABSTRACT

A series of experiments was performed to evaluate the effects of seed maturity, seed cleaning, and gibberellic acid (GA_3) or water presoaking on the percentage and speed of germination of *Chrysalidocarpus lutescens*, *Syagrus romanzoffiana*, *Phoenix roebelenii*, and *Roystonea regia* seed. Effects of temperature, cleaning, and storage container on the viability of stored *C. lutescens* seed were determined in another set of experiments. Most palm seed germinated rapidly and consistently when half-ripe to ripe seed was maintained at temperatures between 30° and 35° C. Cleaning seed is not essential if planting is done immediately for *C. lutescens*, but cleaning seed of the other 3 species enhanced germination. Presoaking seeds in 1,000 ppm GA_3 for 48 hr slightly accelerated germination speed, but caused excessive elongation of the resulting seedlings and was therefore not recommended. The best method for long term storage of palm seed was to clean half-ripe or ripe seed, air dry at 80 to 90% relative humidity, treat with a seed protectant fungicide, and store at 23° C in tightly sealed polyethylene containers. Optimum planting depth was dependent on the drying potential of the germination site.

The primary method of propagating most palms is by seed, although tissue culture techniques have made it possible to propagate asexually a few important palm species (Tisserat 1979, Startisky 1970). Germination of palm seeds can require from several weeks to over a year (McCurrach 1960, Basu and Mukherjee 1972) and methods of accelerating palm seed germination are being sought. Presoaking seeds in gibberellic acid (GA_3) has been shown to accelerate germination of *Ptychosperma macarthuri* (H. A. Wendl.) Nichols, *Archontophoenix alexandrae* (F. J. Muell.) H. A. Wendl. and Drude, and *Chrysalidocarpus lutescens* H. A. Wendl. (Nagao and Sakai 1979, Nagao et al. 1980, Schmidt and Rauch 1982), but preliminary studies by the authors indicated that GA_3 presoaking can cause excessive elongation of seedlings.

Maintaining relatively high germination temperatures (e.g. 27° C) is known to promote seed germination of *Chamaedorea elegans* Mart., *Elaeis guineensis* Jacq. and *P. macarthurii* (Poole et al. 1975, Nagao et al. 1980). Other factors such as seed maturity, pericarp removal (cleaning), and planting depth have not been critically investigated, however.

Palm seed is generally considered to be short-lived and often loses its viability after 2 weeks to 3 months of storage (DeLeon 1958). Effective seed storage methods have been determined for *E. guineensis*, but little is known about the storage of other palm species (Rees 1963). The purpose of this study was to determine the effects of various factors on seed storability and germination in several species of ornamental palms.

Materials and Methods

Freshly harvested fruit of *C. lutescens*, *Syagrus romanzoffiana* (Cham.) Becc., *Roystonea regia* (Kunth) O. F. Cook, and *Phoenix roebelenii* O'Brien was sorted into green, half-ripe, and ripe categories for determination of fruit maturity effects as well as interactive effects of seed cleaning and presoaking on speed of germination and germination percentage. Green fruit was hard, full-sized, and was collected from infructescences containing some ripening fruits. Half-ripe fruits were semi-hard and slightly green in color, while ripe fruits

were soft and had the normal ripe fruit color for each species. Half the fruit in each ripeness category were cleaned by manually removing the pericarp from the seed and half were left uncleaned. A 3 × 2 × 2 factorial experiment involving 3 ripeness categories, cleaned vs. uncleaned seed, and water vs. GA_3 presoaks was set up using 3 replicate lots of 50 seeds each per treatment. Seeds were soaked in GA_3 at 1,000 ppm or deionized water for 48 hr. Following presoaking, seed was sown in 10 cm square containers filled with a Canadian peat and perlite (1:1, by vol.) medium. The containers were placed in a seed germination room in which temperatures of 30–35° C were maintained. Green *P. roebelenii* seeds were not cleaned due to the difficulty of this operation and no *R. regia* seeds were water-soaked due to a shortage of seed. Number of emerging shoots per container was recorded weekly and final germination percentage and time required for 50% of final germination percentage rate were determined from this. Data from this experiment was subjected to analysis of variance.

Optimum germination temperature for *C. lutescens* seed was determined by planting fresh cleaned seed as above and placing the containers in growth chambers set at constant temperatures of 15, 20, 25, 30, 35, or 40° C. Presoak treatments consisting of 1,000 ppm GA_3 for 48 hr, deionized water for 48 hr, or no presoak were applied to 3 replicate lots of 50 seeds each for each temperature. Emerging seedlings were counted weekly and the data used to calculate final germination and time required for 50% of final germination percentage.

Effects of storage temperature on germination of *C. lutescens* seed were determined by storing lots of 50 seeds each in sealed polyethylene bags placed in chambers maintained at 0, 5, 10, 15, and 23° C. Fresh cleaned ripe seed was air-dried at 80–90% relative humidity and dusted with thiram (a seed protectant fungicide) prior to storage. Three replicate lots of 50 seeds each were removed monthly (hourly for 0° C and every 8 hr for 5° C stored seed) from each storage chamber and planted as in the seed maturity experiment. Number of seeds germinating each week was counted for each treatment and storage was continued for a maximum of 600 days. Seed storage was discontinued for a given temperature 4 months after such seed ceased germinating. Similar lots of *P. roebelenii*, *R. regia*, and *S. romanzoffiana* seed were stored only at 23° C since preliminary studies showed this to be the optimum temperature for these species.

Cleaned and uncleaned *C. lutescens* seeds were air-dried at 80–90% relative humidity and treated with thiram prior to storage to determine if dry or humid storage was best. Seeds were stored in lots of 50 in either paper bags (permeable to moisture) or sealed polyethylene bags (impervious to water) at 23° C. Three replicate lots of 50 seeds each were removed from each storage treatment every month and planted as in the seed maturity experiment. Number of seeds germinating weekly was recorded and final germination percentage was calculated. Data from germination temperature and seed storage experiments were analyzed by analysis of covariance.

Interaction of planting depth and germination environment on germination time and percentage was determined by performing an additional experiment involving direct seeding of cleaned *C. lutescens* seed in 3-liter containers. One hundred fresh cleaned seeds were planted in each of 10 replicate containers per treatment using a well drained potting medium. Treatments consisted of factorial combinations of various planting depths (surface planting, barely covered, or 1, 2, 4, or 6 cm deep) and germination environments (full sun, full sun but containers covered with 2 layers of cheesecloth, or shadehouse having 63% shade). Number of seedlings was counted weekly for each container and from this, germination rate and time were calculated.

Table 1. Effects of seed maturity, seed cleaning, and GA_3 presoaking on Chrysalidocarpus *seed germination percentage and time.*

Fruit Maturity	Cleaned	Presoak	Final Germ. %	Germination Time (Days)
Green	yes	H_2O	28.0	61.3
Green	no	H_2O	74.7	58.0
Green	yes	GA_3	4.7	45.3
Green	no	GA_3	64.7	53.0
Half-ripe	yes	H_2O	86.7	43.0
Half-ripe	no	H_2O	88.7	57.0
Half-ripe	yes	GA_3	84.0	33.7
Half-ripe	no	GA_3	72.0	46.3
Ripe	yes	H_2O	86.0	40.0
Ripe	no	H_2O	82.7	53.0
Ripe	yes	GA_3	83.3	30.3
Ripe	no	GA_3	76.0	50.3
Significant Effects				
Fruit maturity			**[z]	***
Cleaning			***	***
Presoak			**	***
Maturity × Presoak			NS	NS
Maturity × Cleaning			***	***
Presoak × Cleaning			NS	*
Maturity × Presoak × Cleaning			NS	NS

[z] NS, * , **, and *** indicate not significant, or significant at 5%, 1%, or 0.1% levels, respectively.

Results and Discussion

Fruit Maturity. Fruit maturity, cleaning, and presoaking effects were highly significant in improving final germination percentage of *C. lutescens* seed (Table 1). Poorest germination occurred when seed from green fruit was cleaned and presoaked in GA_3, although germination was somewhat better if this seed was presoaked in water. The best germination occurred when half-ripe or fully ripe seed was used, but cleaning and presoaking showed no systematic effects within the half-ripe and fully ripe seed treatments.

Seed maturity, presoaking, and cleaning, as well as the seed maturity and cleaning interaction, all had highly significant effects on time required for germination.

Table 2. Effects of fruit maturity, seed cleaning, and presoaking on Syagrus romanzoffiana *seed germination.*

Fruit Maturity	Presoak	Cleaned	Germination Time (Days)	Final Germ. (%)
Green	None	no	78.3	14.0
Green	None	yes	41.7	45.3
Green	H_2O	no	77.5	5.3
Green	H_2O	yes	33.7	57.3
Green	GA_3	no	87.7	2.7
Green	GA_3	yes	48.0	27.3
Half-ripe	None	no	81.3	4.7
Half-ripe	None	yes	75.3	38.7
Half-ripe	H_2O	no	—	0.0
Half-ripe	H_2O	yes	77.7	73.3
Half-ripe	GA_3	no	81.5	6.0
Half-ripe	GA_3	yes	99.0	10.0
Ripe	None	no	78.0	4.7
Ripe	None	yes	86.5	20.0
Ripe	H_2O	no	85.0	1.3
Ripe	H_2O	yes	99.3	23.3
Ripe	GA_3	no	—	0.0
Ripe	GA_3	yes	102.7	27.3
Significant Effects				
Fruit Maturity			***[z]	NS
Presoak			NS	NS
Cleaning			NS	***
Maturity × Presoak			NS	NS
Maturity × Cleaning			***	NS
Presoak × Cleaning			NS	NS
Maturity × Presoak × Cleaning			NS	NS

[z] NS, and *** indicate not significant, or significant at 0.1% level, respectively.

The presoak interaction was less effective, although still significant. Fastest germination occurred with cleaned fully ripe or half-ripe seed. GA_3 presoaking slightly accelerated germination within these treatments. With the exception of the green, water-soaked, cleaned treatment, the slowest germination occurred when seed was not cleaned.

Fruit maturity had a significant effect on time required for germination of *S. romanzoffiana* seeds, but did not affect final germination percentage (Table 2). Cleaned green seeds germinated more rap-

Table 3. Effects of fruit maturity, seed cleaning, and presoaking on Phoenix roebelenii *seed germination.*

Fruit Maturity	Presoak	Cleaned	Germination Time (Days)	Final Germ. (%)
Green	None	no	79.5	9.0
Green	H_2O	no	79.5	6.0
Green	GA_3	no	101.5	4.0
Half-ripe	None	no	82.0	48.0
Half-ripe	None	yes	50.5	59.0
Half-ripe	H_2O	no	66.0	58.0
Half-ripe	H_2O	yes	37.0	49.0
Half-ripe	GA_3	no	72.5	40.0
Half-ripe	GA_3	yes	55.0	59.0
Ripe	None	no	63.0	51.3
Ripe	None	yes	54.0	74.0
Ripe	H_2O	no	74.0	65.0
Ripe	H_2O	yes	43.7	77.3
Ripe	GA_3	no	67.3	67.3
Ripe	GA_3	yes	56.0	87.0
Significant Effects				
Fruit Maturity			***[z]	***
Presoak			*	NS
Cleaning			***	**
Maturity × Presoak			NS	NS
Maturity × Cleaning			NS	NS
Presoak × Cleaning			NS	NS
Maturity × Presoak × Cleaning			NS	NS

[z] *, **, and ***, and NS indicate significance at 5%, 1%, and 0.1% levels, or not significant, respectively.

Table 4. Effects of fruit maturity, seed cleaning, and presoaking on Roystonea regia *seed germination.*

Fruit Maturity	Presoak	Cleaned	Germination Time (Days)	Final Germ. (%)
Green	None	no	287.7	24.0
Green	None	yes	259.3	24.0
Green	GA_3	no	262.3	24.0
Green	GA_3	yes	276.7	20.7
Half-ripe	None	no	281.3	18.7
Half-ripe	None	yes	261.7	37.5
Half-ripe	GA_3	no	281.0	18.7
Half-ripe	GA_3	yes	263.7	46.7
Ripe	None	no	301.7	18.0
Ripe	None	yes	331.0	52.0
Ripe	GA_3	no	306.3	11.3
Ripe	GA_3	yes	297.7	28.7
Significant Effects				
Fruit Maturity			**[z]	**
Presoak			NS	**
Cleaning			NS	***
Maturity × Presoak			NS	***
Maturity × Cleaning			NS	***
Presoak × Cleaning			NS	NS
Maturity × Presoak × Cleaning			NS	**

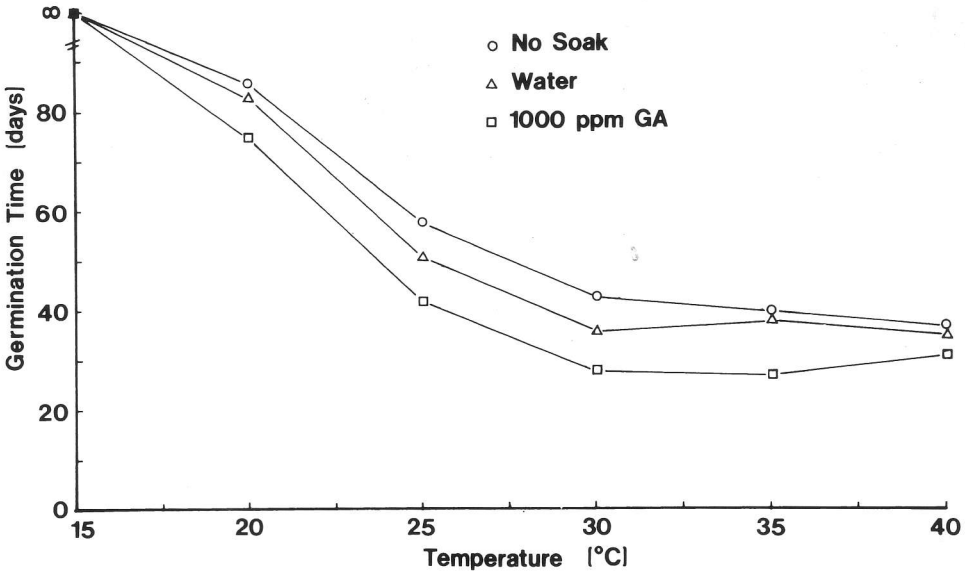
[z] NS, **, and *** indicate not significant or significance at 1%, and 0.1% levels, respectively.

idly than did half-ripe or ripe seeds, or uncleaned green seeds. Seed presoaking had no effect on germination or final germination percentage, but cleaning *S. romanzoffiana* seed greatly improved final germination percentage. The highest germination percentage was obtained when cleaned green or half-ripe seeds were used. The fact that ripe *S. romanzoffiana* seeds germinated more slowly and that very few uncleaned seeds germinated suggests the presence of a germination inhibitor in the pericarp of ripe fruit.

Fruit maturity, presoaking, and cleaning all had significant effects on time required for germination of *P. roebelenii* seeds, with cleaned ripe or half-ripe seed germinating the fastest (Table 3). Final germination percentage was also affected by fruit maturity, with cleaned ripe seeds germinating best.

Germination time was affected only by fruit maturity for *R. regia* (Table 4). Ripe seed generally germinated more slowly than half-ripe or green seed, but differences were slight. Final germination percentage was greatest for cleaned ripe seed which was not presoaked or cleaned half-ripe seed presoaked in GA_3. Poorest germination occurred in green or uncleaned ripe or half-ripe seed.

Acceleration of palm seed germination by GA_3 presoaks has been noted for *C. lutescens*, as well as *P. macarthurii* and *A. alexandrae* (Schmidt and Rauch 1982,

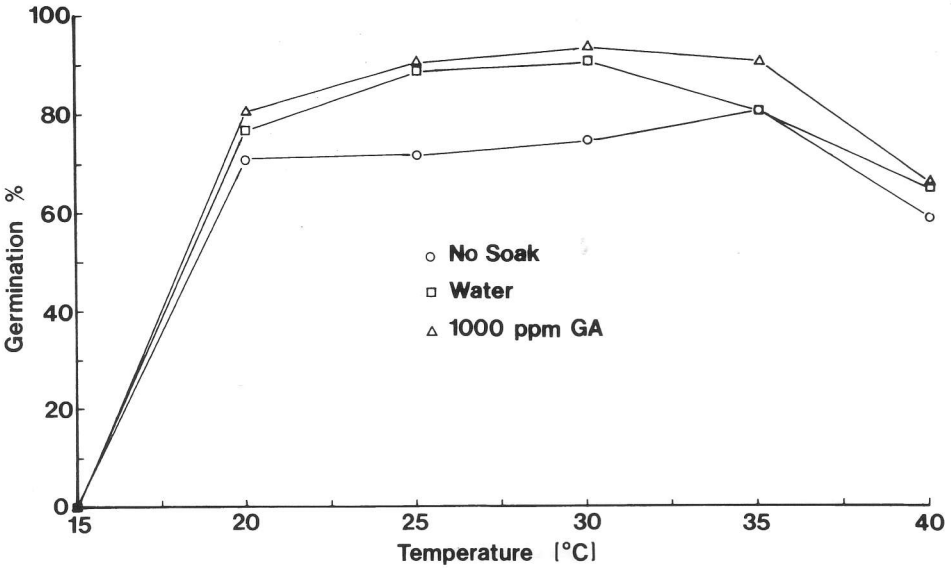


1. Effects of germination temperatures and presoaking seed on germination time for *Chrysalidocarpus lutescens* seed. Points represent means for treatments.

Nagao and Sakai 1979, Nagao et al. 1980) however, the effects GA_3 seed presoaking had on seedling morphology were not mentioned. Seedlings of *C. lutescens*, *S. romanzoffiana*, and *R. regia* from GA_3-soaked seeds elongated much more rapidly than palms from water-soaked seeds, resulting in tall, weak, unattractive plants. Seedlings of *P. roebelenii* from GA_3-soaked seeds were twisted and assumed a corkscrew-like appearance. Seedlings from these experiments were grown for a year after germination and GA_3 effects on shoot elongation were still apparent at that time. Since compact plants are usually stronger and more attractive, the slight decrease in germination time for GA_3 treated seeds would be more than offset by the inferior quality of the resulting plants.

Germination Temperature. Germination temperature had a highly significant effect on germination time of *C. lutescens*. Time decreased as temperature increased from 20 to 40° C, although differences between 30, 35, and 40° C were less than at lower temperatures (Fig. 1). Presoaking seeds in GA_3 decreased germination time significantly over water-presoaked and non-soaked seeds, and water-presoaked seed germinated faster than non-soaked seed. This is consistent with previous results obtained in other experiments (Schmidt and Rauch 1982, Nagao and Sakai 1979, Nagao et al. 1980). There was no significant interaction between germination temperature and presoak treatment.

Final germination percentage of *C. lutescens* increased significantly as germination temperature was increased from 20 to 25° C, but percent germination at 40° C was less than at slightly lower temperatures (Fig. 2). This could have been caused by desiccation of some of the barely covered seed at this higher temperature since those that did germinate did so more rapidly than at lower temperatures. No seed germinated at 15° C. Final germination percentage was not enhanced by GA_3 presoaking, but both water and GA_3 presoaking resulted in greater final germination percentages than non-presoaked seeds at temperatures of 25 to 30° C.

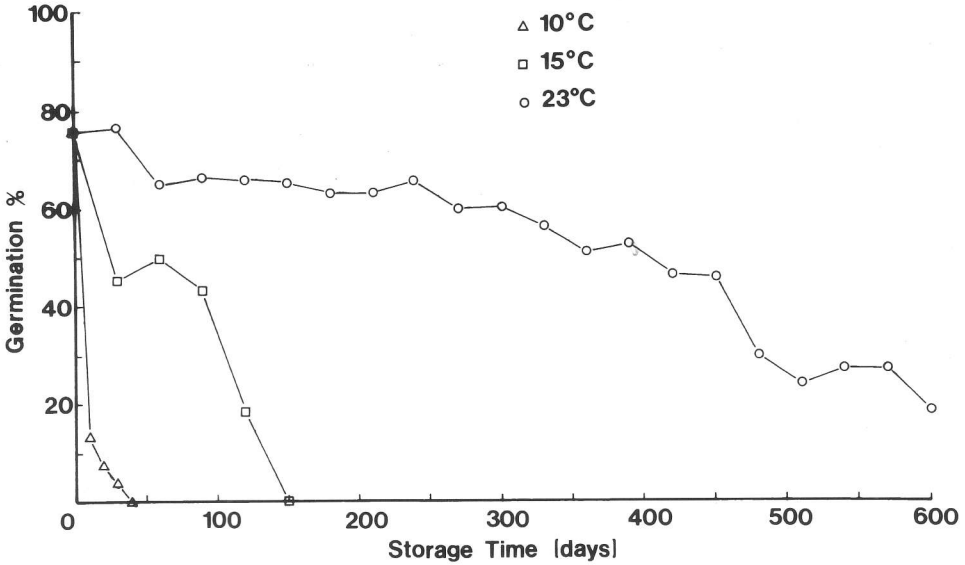


2. Effects of germination temperatures and presoaking seed on germination percentage of *Chrysalidocarpus lutescens* seed. Points represent means for treatments.

Seed Storage. Germination of cleaned *C. lutescens* seed stored in polyethylene bags was strongly influenced by storage temperature (Fig. 3). None of the seed stored at 0° C survived one hr, but seed stored at 5° C survived 8 hr with only a slight loss of germination (data not shown). No seed stored at 5° C germinated after 10 days and germination of seed stored at 10° C decreased from 13% at 10 days to 0% after 40 days (Fig. 3). Germination of seed stored at 15° C was reduced from nearly 50% at 30 days to 0% at 150 days, but germination percentage remained above 50% for 420 days with seed stored at 23° C. Nearly 20% of the seed germinated even after 600 days of storage at 23° C.

Germination percentage of *S. romanzoffiana* seed declined rapidly after 4 months of storage at 23° C (Fig. 4). *P. roebelenii* seed rapidly lost its viability after 8 months of storage, but germination of *R. regia* seeds stored for 9 months or less exceeded that of freshly planted seed. Approximately 1% of *R. regia* seeds planted immediately germinated within 6 weeks, but no additional germination occurred until about 8 months after harvest when most of the seeds germinated. Seed which had been stored in sealed polyethylene bags germinated 8 months after harvest, regardless of the storage time. This may be due to immature embryos in these seeds at harvest time (Hartmann and Kester 1983). Stored royal palm seed probably germinated better than seed planted immediately because seed stored in sealed polyethylene bags is less subject to desiccation than that which is planted and subjected to periodic partial drying.

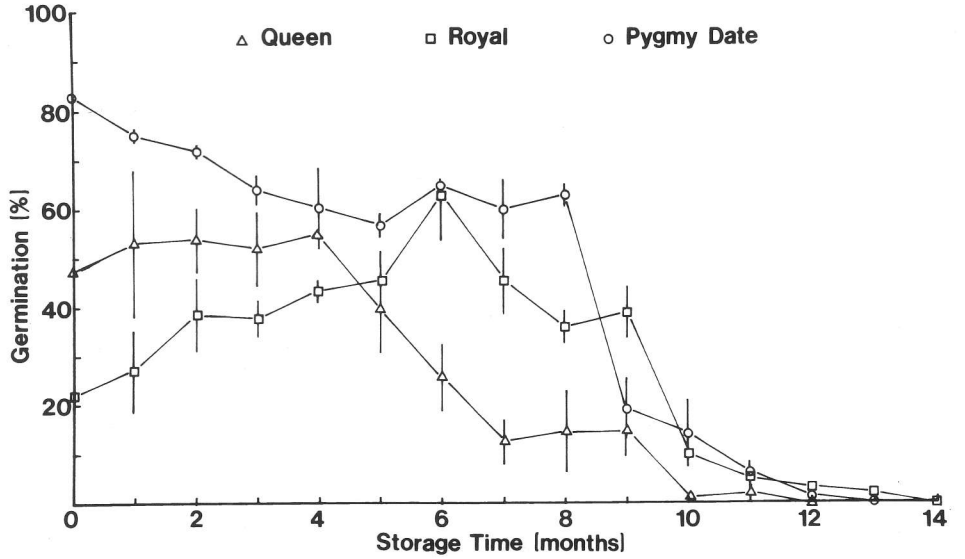
The method and preparation of seeds for storage also had a major influence on the germination of stored *C. lutescens* seed (Fig. 5). Less than 10% of the uncleaned ripe seed stored for 30 days at 23° C in polyethylene bags germinated, whereas nearly 80% of such seed germinated prior to storage. Germination of cleaned *C. lutescens* seed declined rapidly from 70% to almost 0% after 120 days when stored in porous paper bags, but cleaned seed



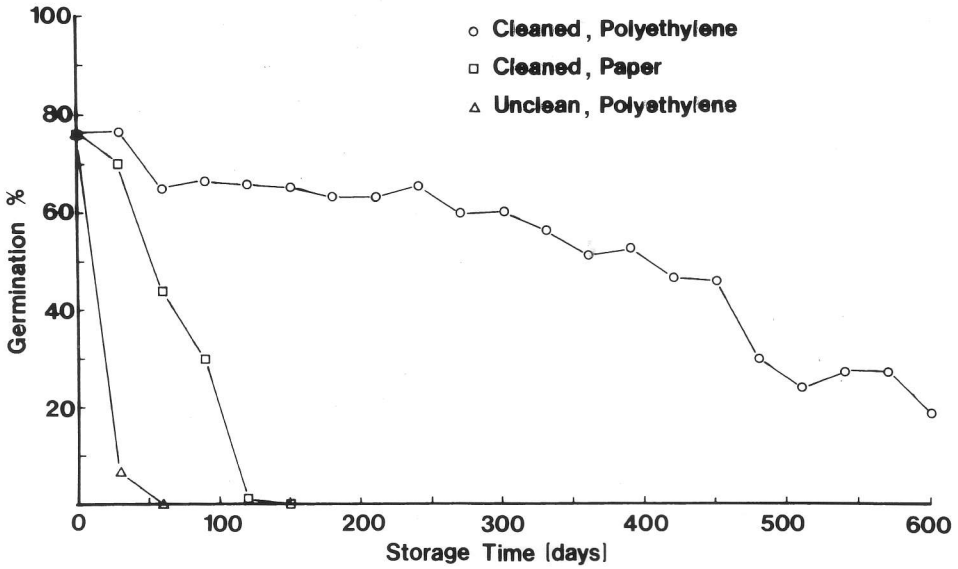
3. Effects of storage temperature and storage time on germination of stored cleaned *Chrysalidocarpus lutescens* seed. Points represent means for treatments.

stored in sealed polyethylene bags remained viable for over 600 days. Dissection of seed from known viable and non-viable lots showed that embryo desiccation was the main reason for non-viability among palm seeds.

The reason uncleaned seed stored so poorly is not known, but could involve the

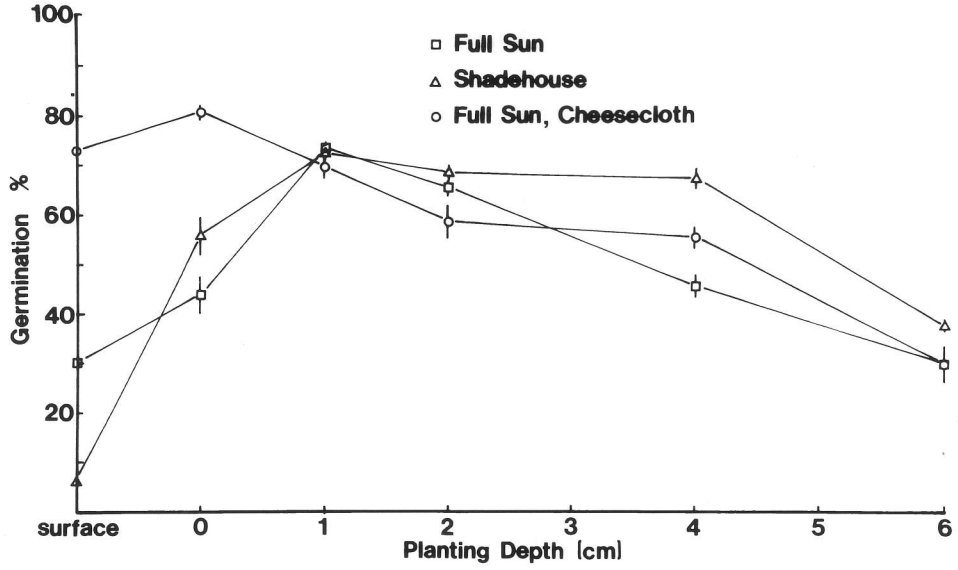


4. Effects of storage on germination of *Syagrus romanzoffiana*, *Phoenix roebelenii*, and *Roystonea regia*. Points represent means for treatments.

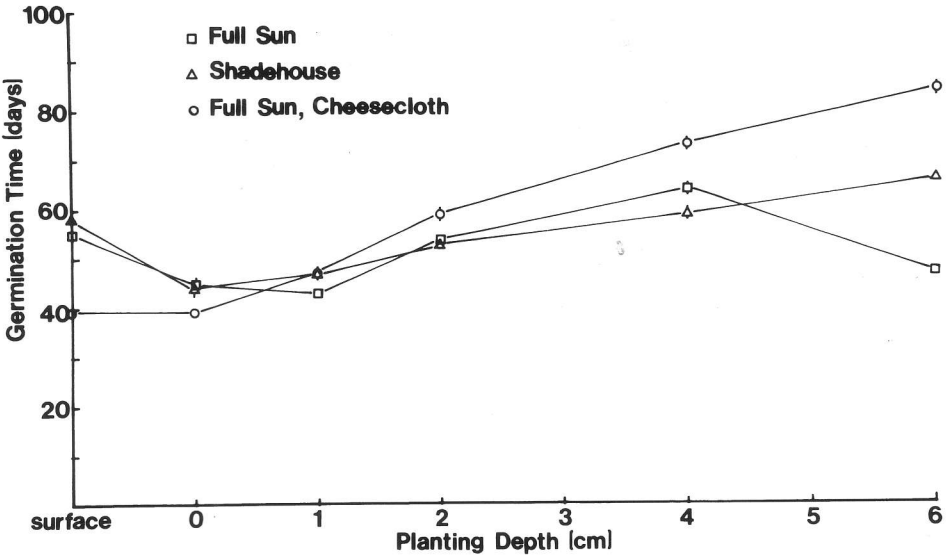


5. Effects of storage method and storage time on germination of stored *Chrysalidocarpus lutescens* seed stored at 23° C. Points represent means for treatments.

formation or release of germination inhibitors in overripe fruit. Anaerobic decomposition in sealed polyethylene bags is probably not involved since similar uncleaned seed stored in paper bags in preliminary studies (data not shown) germinated as poorly as those sealed in the polyethylene bags.



6. Effects of planting depth and germination environment on germination percentage of *Chrysalidocarpus lutescens* seed. Points represent means for treatments.



7. Effects of planting depth and germination environment on germination time of *Chrysalidocarpus lutescens* seed. Points represent means for treatments.

Planting Depth. Germination percentage and germination time were greatly affected by planting depth (Figs. 6,7). Final germination percentage for *C. lutescens* seeds germinated in full sun ranged from nearly 74% for seeds planted 1 cm deep to about 30% for seeds planted on the surface or 6 cm deep. Similarly, germination time in full sun decreased from 67 days for the seeds planted 6 cm deep to about 44 days for those covered with only 1 cm of medium. However, palms from seed covered with 2 cm or more of medium were more susceptible to iron deficiency symptoms when grown for 1 yr than those planted less than 2 cm deep (1). Optimum planting depth for *C. lutescens* seeds germinated in full sun but covered with cheesecloth occurred when seeds were barely covered, both with respect to final germination percentage and speed of germination. Excellent germination percentage under shadehouse conditions occurred with seeds covered with 1, 2, or 4 cm of medium, but seeds barely covered germinated faster. Thus, as the drying potential of the germination site increases from that of cheesecloth-covered containers through shadehouse conditions, and finally to exposed full sun conditions, optimum planting depth increases accordingly from barely covered for sites with low drying potential to 1 cm deep for sunny drier sites.

Conclusions. These studies show that many factors can affect palm seed storability and germination. Best *C. lutescens* seed germination occurs if half-ripe or fully ripe seed is used. Removal of the fleshy pericarp is not essential if the seed is planted immediately, but if it is to be stored for more than a few days, removal is essential. Optimum germination percentage for *S. romanzoffiana* seed occurred when cleaned green or half-ripe seed is used. Cleaned ripe or half-ripe seeds germinated best for *P. roebelenii* and *R. regia.*

Presoaking seed in 1,000 ppm GA_3 for 48 hr slightly decreased germination time, but also caused excessive and undesirable elongation of the seedlings. Presoaking for 48 hr in water alone had a lesser but still

significant effect on germination time and is preferable to GA_3 presoaking, since water did not cause distortion in the growth of the seedlings. If green *C. lutescens* seed must be used, it should not be cleaned.

Optimum germination temperatures for *C. lutescens* seed were determined to be between 30 and 35° C. Since embryo desiccation is a major cause for seeds not germinating, seed germinated in full sun or similar drying conditions should be covered with 1 cm of medium, while optimum planting depth for *C. lutescens* seed under less drying conditions is barely covered.

C. lutescens seed can be successfully stored for a year or more if fresh ripe seed is cleaned, air-dried at 80–90% relative humidity, treated with a seed protectant fungicide, sealed in polyethylene bags, and stored at temperatures of approximately 23° C. Using similar procedures, seed of *S. romanzoffiana* can be stored for up to 4 months, *P. roebelenii* for up to 8 months, and *R. regia* for about 9 months.

LITERATURE CITED

BASU, S. K. AND D. P. MUKHERJEE. 1972. Studies on the germination of palm seeds. Principes 16: 136–137.

DELEON, N. 1958. Viability of palm seed. Principes 2: 96–98.

HARTMANN, H. T. AND D. E. KESTER. 1983. Plant propagation principles and practices. 4th edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

MCCURRACH, J. C. 1960. Palms of the world. Harper and Brothers. New York.

NAGAO, M. A. AND W. S. SAKAI. 1979. Effects of growth regulators on seed germination of *Archontophoenix alexandrae*. HortScience 14: 182–183.

——— K. KANEGAWA, AND W. S. SAKAI. 1980. Accelerating palm seed germination with GA, scarification, and bottom heat. HortScience 15: 200–201.

POOLE, R. T., C. A. CONOVER, AND R. W. HENLEY. 1975. Parlor palm germination. Flor. Rev. 157(4067): 89, 106.

REES, A. R. 1963. Germination of palm seeds using a method developed for the oil palm. Principes 7: 27–29.

SCHMIDT, L. AND F. D. RAUCH. 1982. Effects of presoaking seed of *Chrysalidocarpus lutescens* in water and gibberellic acid. Foliage Digest 5(12): 4–5.

STARTISKY, G. 1970. Tissue culture of the oil palm (*Elaeis guineensis* Jacq.) as a tool for its vegetative propagation. Euphytica 19: 288–292.

TISSERAT, B. 1979. Propagation of date palm (*Phoenix dactylifera* L.) in vitro. J. Expt. Bot. 30: 1275–1283.
