Emergence and initial growth of *Copernicia prunifera (*Arecaceae) as a function of fruit maturation[1]

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ABSTRACT – The aim of this study was to analyze the effect of fruit maturation on the physiological quality of seeds and on the initial growth of carnauba palm (*Copernicia prunifera*). Propagules were collected from specimens of urban tree growth in Fortaleza, CE, Brazil. The treatments were set up with four replications in a 2x3+1 factorial arrangement; the factors consisted of two color tones of fruit (yellowish-green and dark colored fruit), three types of propagules (whole fruit, pulped fruit and seeds) and an additional control (pre-germinated seed extracted from dark colored fruits) in a completely randomized design. The variables assessed were: percentage of emergence, plant height, stem diameter, dry weight of the shoots and of the root system, and the Dickson quality index. The yellowish-green fruits may be used in carnauba palm propagation if the pulp and the pellicle around the seed are removed. Plants derived from dark colored fruits exhibit greater values for height, stem diameter, dry weight of the above ground part and of the roots. From the Dickson quality index, plants derived from dark colored fruits have a better standard of quality than those from yellowish-green fruits.

Index terms: carnauba, physiological maturation, imbibition.

Emergência e crescimento inicial de *Copernicia prunifera (*Arecaceae) em função da maturação dos frutos

RESUMO – Objetivou-se analisar o efeito da maturação dos frutos na qualidade fisiológica das sementes e no crescimento inicial de *Copernicia prunifera.* Os propágulos foram coletados de exemplares da arborização urbana de Fortaleza, CE, Brasil. Os tratamentos foram arranjados com quatro repetições em um fatorial 2x3+1; os fatores foram constituídos por duas colorações de frutos (verde-amarelados e escuros), três tipos de propágulos (fruto íntegro, fruto despolpado e semente) e uma testemunha adicional (semente pré-germinada extraída de frutos de coloração escura) dispostos em delineamento inteiramente casualizado. As variáveis avalidas foram: porcentagem de emergência, altura da planta, diâmetro do coleto, massa seca da parte aérea e do sistema radicular, e o índice de qualidade de Dickson. Os frutos verde-amarelados podem ser usados na propagação da carnaúba desde que se proceda à retirada da polpa e da película que envolve a semente. As plantas provenientes dos frutos escuros apresentam maiores valores de altura, diâmetro do coleto, massa seca da parte aérea e das raízes. Pelo índice de qualidade de Dickson plantas provenientes de frutos de coloração escura possuem melhor padrão de qualidade do que as dos frutos verde amarelados.

Termos para indexação: carnaúba, maturação fisiológica, embebição.

Introduction

Carnauba palm [*Copernicia prunifera* (Miller) H.E. Moore] grows in the Northeast of Brazil, more specifically in the states of Ceara, Piaui, and Rio Grande do Norte. It is popularly known as the "tree of life" due to its multiple applications, whether in civil construction, in craftwork or in industry. Its wax, obtained from wax powder which covers the carnauba leaves, has broad application in the pharmaceutical industry, and the fruit is commonly used for animal feed (D'Alva, 2004; Lorenzi, 2004; Silva et al., 2009; Reis et al., 2011). Because of its multiple uses and the expansion of shrimp farming and of irrigated fruit growing in the Northeast region of Brazil, there has been a reduction in the carnauba palm

[1]Submitted on 04/26/2013. Accepted for publication on 01/24/2014.
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population, and development of seedling production programs, encouragement of tree planting and preservation of these areas have become important. Nevertheless, there has been no encouragement for utilization of this species nor programs for planting native carnauba in the semiarid Northeast.

One of the reasons for low encouragement of its utilization is the lack of studies related to propagation and breeding of palm species present in the region. According to Broschat (1994), palm propagation is carried out through seeds, which has limitations, such as slow and irregular germination, frequently at a low percentage, for most Arecaceae species.

Physiological maturation of the seed was defined by Hartmann (1997) as a series of morphological, physiological and functional changes that occur from the fertilization period up to the phase at which the seeds become physiologically independent from the mother plant, culminating in maximum dry weight. Modifications in seed germination and vigor during this stage depend on the species, cultivar and environmental conditions. Therefore, the ideal harvest time should be when the seed reaches physiological maturity, but this becomes difficult when the species has indeterminate growth or exhibits dormancy.

In this context, studies on the Arecaceae family are being developed in different lines of research, such as morphology, germination and ecophysiological aspects, highlighting the studies with *Archontophoenix cunninghamii* H. Wendl. and Drude (Luz et al., 2011), *Oenocarpus minor* Mart. (Oliveira et al., 2010), *Phoenix canariensis* Hort. ex Chabaud (Pimenta et al., 2010), *Butia capitata* (Mart.) Becc. (Neves et al., 2010), *Copernicia prunifera* (Miller) H. E. Moore (Silva et al., 2009; Reis et al., 2010; Reis et al., 2011), *Copernicia hospita* Martius (Oliveira et al., 2009), *Oenocarpus bacaba* MART. (Queiroz and Bianco, 2009), *Rhapis excelsa* (Thunberg) Henry ex. Rehder (Luz et al., 2008), *Syagrus romanzoffiana* (Cham.) Glassman (Bernacci et al., 2008), *Phoenix roebelenii* O'Brien (Iossi et al., 2007), *Euterpe edulis* MART. (Martins-Corder and Saldanha, 2006), *Astrocaryum aculeatum* Meyer (Ferreira and Gentil, 2006; Nazário and Ferreira, 2010) and *Thrinax parviflora* Swartz. (Pivetta et al., 2005).

For seedling production of palm species, complete removal of the parts of the fruit that surround the seeds is recommended, with a view toward accelerating the germination process and making it more uniform. Another procedure adopted is immersion of the seeds in water, as indicated for *Copernicia prunifera* (Silva et al., 2009; Reis et al., 2011). In light of these considerations, the aim of this study was to analyze the effect of fruit maturation on the physiological quality of the seeds and on the initial growth of *Copernicia prunifera.*

Materials and Methods

The carnauba fruits used in this study were collected from specimens of urban tree growth in the city of Fortaleza, CE, Brazil. After homogenization of the collected samples, 400 yellowish-green fruits and 400 dark colored fruits were selected in order to obtain the propagules. The pulp (epicarp and mesocarp) was removed through use of a knife. For removal of the endocarp, a small surface cut was made with a utility knife and then it was easily removed, obtaining the seed.

The treatments were set up in a 2x3+1 factorial arrangement with four replications of 50 propagules; the factors consisted of two fruit colors (yellowish-green and dark colored fruit), three types of propagules (normal or whole fruit, pulped fruit, and seeds) and an additional control represented by seeds of the dark colored fruits pre-soaked in water for 12 days, as proposed by Reis et al. (2010), constituting an additional control.

Sowing was carried out in sandy loam soil (Table 1) in a surface seedbed (1.0 m x 10.0 m) in full sun conditions. A spacing of 20.0 cm was maintained between rows and approximately 3.0 cm between propagules, at a depth of 3.0 cm (Reis et al., 2010; Reis et al., 2011). Water was supplied by daily irrigation, in the morning and in the afternoon, by a microsprinkler system. Garden trowels were used for plant extraction from the soil.

The experiment was carried out from January to April 2011, with a mean temperature of 27.8 ºC and mean humidity of 78.6% (RH). At 120 days after sowing, percentage of emergence (PE) was assessed by counting the number of plants that emerged, with the results expressed in percentage. After removing the soil and washing the plants in running water to clean the roots, the following determinations were made: plant height (HEI) and root length (RL) with a ruler, in mm; stem diameter (SD), measured with the aid of a digital caliper rule with resolution of 0.001 mm; dry weight of the above ground part (DWAG) and dry weight of the roots (DWR), obtained by dividing the weight by the number of plants ($g.plant^{-1}$) after drying the respective organs in an air circulation laboratory oven at 80 ºC for 24 h; and the Dickson quality index (DQI), according to Fonseca et al. (2002).

The emergence data and the morphological parameters, without transformation, were subjected to analysis of variance (ANOVA), and the mean values were compared by the Tukey test ($p<0.05$) when there was interaction between the factors or in an isolated manner. In comparison of the factorial group with the additional control, the Dunnett test was applied at 5% probability, using the computational application ASSISTAT 7.6®.

Table 1. Physicochemical characteristics of the soil used for emergence and initial growth of *Copernicia prunifera* seedlings.

Particle size composition (g/kg)			pH		
Sand	Silt	Clay	Water	KCl	CaCl
667	207.8	126.2	7.8	6.55	6.58
Sorption complex ($cmol_c/kg$)					
Ca^{2+}	Mg^{2+}	K^+	H^+	S	T
3.80	4.40	0.53	3.2	9.43	12.83
OC (g/kg)	OM (g/kg)	V (%)	Assimilable P (mg/kg)	Textural classification	
16.11	27.71	73.49	10.57	Loamy sand	

(pH) power of hydrogen, (S) sum of bases, (T) total cation exchange capacity at pH 7.0, (V) base saturation, (OC) organic carbon, (OM) organic matter.

Results and Discussion

From the results of analysis of variance (Table 2), it may be seen that there was an interaction between color and type of propagule only for emergence, while for the other characteristics, only the main effect of fruit color affected them in a significant way. The factorial vs. control contrast was significant only for height and stem diameter.

The mean values of percent of emergence exhibited in Table 3 show that whole fruit exhibited lower values than pulped fruit and seeds, for both dark colored and yellowish-green fruits.

The study of fruit color in each type of propagule shows a difference only in the whole fruit, with fruits of dark color presented better quality than those of yellowish-green color. Pulped fruit and seeds showed better quality than whole fruit.

Table 2. Summary of analysis of variance and coefficient of variation (CV) of the data of percentage of emergence (PE), height (HEI), stem diameter (SD), dry weight of the above ground part (DWAG), dry weight of the root (DWR) and Dickson quality index (DQI) of carnauba seedlings produced by the combination of two colors of fruits with three types of propagules and one additional control at 120 days after sowing.

Sources of Variation	DF	Mean squares					
		PE	HEI	SD	DWAG	DWR	DQI
Color (C)	1	22.04^{**}	56.00^{**}	13.47^{**}	10.4^{**}	47.68^{**}	26.55^{**}
Propagule (P)	2	33.66^{**}	2.28^{ns}	1.13^{ns}	1.4^{ns}	1.12^{ns}	0.18^{ns}
CxP Interaction	2	15.60^{**}	0.40^{ns}	0.75^{ns}	0.25^{ns}	0.27^{ns}	1.22^{ns}
Fact. vs. Control	1	1.03^{ns}	9.61^{**}	5.34^{*}	0.13^{ns}	3.64^{ns}	1.03^{ns}
Residue	21	-	-	-	-	-	-
CV(%)	-	14.2	4.38	5.94	13.38	11.15	14.29

*; ** Value significant at 5% and 1% of probability. ^{ns} Non-significant value.

Table 3. Mean values of the percentage of emergence of *Copernicia prunifera* in the combination of the factors of fruit color (yellowish-green and dark colored), type of propagule (whole fruit, pulped fruit, seed) and additional control (AC) represented by the pre-germinated seed.

Color	Propagule			Mean
	Whole	Pulped	Seed	
Yellowish green	22 bB	85 aA	73 aA	60
Dark colored	72 aA	86 aA	78 aA	79
Mean	47	86	76	69
AC				64

Mean values followed by the same upper case letter in the column and lower case letter in the lines do not differ from each other by the Tukey test (5%).

In general, emergence of seedlings derived from dark colored fruits was greater than that observed for those of yellowish-green color. The mean of the treatments and the additional control exhibited the same behavior in regard to emergence at 120 days after sowing.

The emergence data in Table 3 show that for carnauba palm, yellowish-green fruits may be used in propagation as long as the pulp and the pellicle around the seed are removed. Dark colored fruits considered to be mature may be used for propagation without any treatment (whole) or after pulping and removal of the pellicle, producing the same or better results than the result of pre-germinated seeds.

The beneficial effect of pre-soaking for making seedling emergence more uniform was also observed by Silva et al. (2009)

for this species, with mean values ranging from 82 to 91%. In the same way, Ferreira and Gentil (2006) observed that for *Astrocaryum aculeatum* Meyer, removal of the endocarp, followed by imbibition, led to greater germination when compared to seeds with the endocarp, and they characterized this structure as a partial physical barrier to imbibition of the seeds, causing uneven germination and seedling emergence.

These emergence data are compatible with those observed by Oliveira et al. (2009), who observed a variation in the mean values of seedling emergence from 64 to 81% for the species *Copernicia hospita* when seeds collected in the final stage of maturation were used, i.e., from dark colored fruits. Variability is common among *Copernicia* species.

The greatest emergence percentages were obtained from seeds extracted from dark colored fruits since they are at the end of the maturation process, which was also observed by Pimenta et al. (2010) in *Phoenix canariensis* Hort. ex Chabaude seeds, and by Iossi et al. (2007) in *Phoenix roebelenii* O'Brien seeds. These authors observed greater physiological quality when the fruits had a brown and purplish-black color, in the more advanced stage of maturity, associated with physiological maturity of the seeds.

The growth variables showed similar behavioral patterns, differences being detected only for fruit color, except for root length. Growth of the above ground part and the root system of the plants derived from dark colored fruits were greater than the values obtained from the plants derived from yellowish-green fruits (Table 4).

It may be seen that in the period of 120 days, the roots grew around four times more than the above ground part. The same pattern was observed in relation to stem diameter, in which plants derived from seeds of dark colored fruits exhibited greater values than plants from fruits of a yellowish-green color (Table 4).

In relation to biomass concentration in the above ground and root portion of plants at 120 days, represented by the dry weight values (Table 5), it was observed that the use of dark colored fruits results in more vigorous plants in relation to those derived from yellowish-green fruits.

By the Dickson quality index (DQI), it may be seen that the type of propagule does not affect plant quality (Table 6). Nevertheless, it may be observed that plants originated from dark colored fruits exhibited greater numerical values than those obtained for plants derived from fruits of a yellowish-green color.

Carnauba palm initially exhibits differentiated growth in comparing the above ground portion and root portion; i.e., the roots grow nearly four times more than the above ground part in the first 120 days. This differentiated growth of plants as a function of fruit color had a direct effect on seedling quality, where the DQI of plants obtained from seeds extracted from dark colored fruits was greater than that of fruits with a yellowish-green color.

Table 4. Mean values of the variables of height, root length and stem diameter in the combination of the factors of fruit color (YG-yellowish-green, DC-dark colored), type of propagule (W-whole fruit, P-pulped fruit, S-seed) and additional control (AC).

Color	Propagule			Mean
	W	P	S	
Height (cm)				
YG	20.11	20.67	21.23	20.67 B
DC	22.99	24.06	23.77	23.61 A
Mean	21.55	22.36	22.50	22.14 X
AC	-	-	-	20.53 Y
Root length (cm)				
YG	87.35	88.65	87.46	87.82
DC	89.06	108.62	104.96	100.88
Mean	88.20	98.63	96.21	94.35
AC	-	-	-	96.35
Stem diameter (mm)				
YG	5.15	5.37	5.40	5.31 B
DC	5.78	5.64	6.00	5.81 A
Mean	5.46	5.50	5.7	6.24 X
AC	-	-	-	5.97 Y

Mean values followed by the same upper case letters (A, B) and (X, Y) in the column do not differ from each other by the Tukey test (5%) and Dunnett test (5%).

Table 5. Mean values of the variables of dry weight of the above ground part and of the roots in the combination of the factors of fruit color (YG-yellowish-green, DC-dark colored), type of propagule (W-whole fruit, P-pulped fruit, S-seed) and additional control (AC) represented by the pre-germinated seed.

Color	Propagule			Mean
	W	P	S	
Dry weight of the above ground part (g)				
YG	0.570	0.605	0.645	0.607 B
DC	0.675	0.757	0.737	0.723 A
Mean	0.622	0.681	0.691	0.665
AC	-	-	-	0.647
Dry weight of the root (g)				
YG	0.932	0.967	0.902	0.934 B
DC	1.225	1.347	1.255	1.276 A
Mean	1.078	1.157	1.078	1.087
AC	-	-	-	0.98

Mean values followed by the same upper case letters in the column do not differ from each other by the Tukey test (5%).

Table 6. Dickson quality index of carnauba plants in the combination of types of propagules (W-whole fruit, P-pulped fruit, S-seeds), color of fruits (YG-yellowish-green, DC-dark colored) and of the additional control (AC).

Color	Propagule			Mean
	W	P	S	
YG	0.33	0.36	0.30	0.33B
DC	0.43	0.44	0.47	0.45A
Mean	0.38	0.40	0.38	0.39
AC	-	-	-	0.42

Mean values followed by the same letter in the column do not differ from each other by the Tukey test at 5% probability.

Concerning plant vigor, the data are similar to those observed for *Copernicia prunifera* (Mill.) H.E. Moore (Silva et al., 2009 and Reis et al., 2011), for *Copernicia hospita* Mart. (Oliveira et al., 2009), for *Astrocaryum aculeatum* Meyer (Ferreira and Gentil, 2006; Nazário and Ferreira, 2010) and for *Archontophoenix cunninghamii* H. Wendl. and Drude (Luz et al., 2011). These authors observed that plant vigor was positively affected by the use of seeds coming from fruit in the final maturation stage, corroborating the results obtained in this study.

Although the dark colored fruits obtained at the end of the maturation process lead to greater values for the characteristics assessed than the fruits of yellowish-green color, the latter may be used in production of carnauba seedlings as long as the pulp and the pellicle around the seeds is removed, as was clear from the percentage of emerged seedlings 120 days after sowing.

Pre-soaking of seeds, characterized by the additional control, did not have an effect on the emergence and quality of carnauba seedlings. In contrast, Silva et al. (2009) report that pre-soaking of carnauba seeds accelerated germination, but did not affect final emergence and the quality of the seedlings produced, corroborating the results obtained.

Conclusions

Yellowish-green fruits may be used in propagation of carnauba as long as the pulp and pellicle around the seed are removed.

Plants derived from dark colored fruits exhibit greater height, stem diameter and dry weight of the above ground part and the roots than those derived from fruits of a yellowish-green color.

From the Dickson quality index, it may be seen that plants derived from dark colored fruits have a higher standard of quality than those from yellowish-green fruits.

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