EFFECTS OF HARVESTING ON LEAF PRODUCTION AND REPRODUCTIVE PERFORMANCE OF *Copernicia prunifera* (Mill.) H.E. Moore[1]

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ABSTRACT – This work aimed to evaluate the consequences of the monthly extraction of immature leaves in survival, leaf production and reproductive performance of *Copernicia prunifera* H. E. Moore palm, popularly known as carnaúba. One hundred sixty reproductive adult palms were monitored for 17 months in four extractive communities located at the coast of the state of Piauí. As a result, it was observed that leaves, flowers, fruits and seeds production were reduced in the palm submitted to 50% or 75% monthly extraction. Higher levels of extraction were followed by smaller levels in seed germination. No deaths were observed even in the group subjected to 75% monthly leaves exploration. In order not to produce damage to palm trees development it is suggested that leaf extraction rate should not exceed 25% monthly as well as pausing of extractive activity preferentially during fruit maturation.

Keywords: Traditional management; Environmental sustainability; Carnaúba.

EFEITOS DO EXTRATIVISMO DE FOLHAS IMATURAS NA PERFORMANCE FOLIAR E REPRODUTIVA DE Copernicia prunifera (Mill.) H.E. Moore

RESUMO – Este trabalho objetivou avaliar as consequências da extração mensal de folhas imaturas sobre a sobrevivência, produção de folhas e desempenho reprodutivo da palmeira ***Copernicia prunifera*** *H. E. Moore, popularmente conhecida como carnaúba. Cento e sessenta palmeiras reprodutivas adultas foram monitoradas por 17 meses em quatro comunidades extrativistas localizadas no litoral do Estado do Piauí. O resultado foi que a produção de folhas, flores, frutos e sementes diminuiu 50% e 75% em palmeiras submetidas à extração mensal das folhas imaturas. Elevados níveis de extração foram acompanhados por menores níveis de germinação de sementes. Não foram observadas mortes, mesmo no grupo submetido à extração mensal de folhas de 75%. Para não causar danos ao desenvolvimento das palmeiras, sugere-se um pousio, preferencialmente durante o período de maturação dos frutos, e que a taxa de extração mensal das folhas não exceda a 25%.*

Palavras-chave: Manejo tradicional; Sustentabilidade ambiental; Carnaúba.

1. INTRODUCTION

Forest products are source of income for extractive communities (TICKTIN, 2004). The traditional extraction is usually sustainable and is based on popular knowledge about the ecology of exploited species (TICKTIN; JOHNS, 2002). However, this knowledge does not ensure that the extraction is performed in a sustainable manner. When forest products obtain economic valorization, there is often an intensification of extraction and consequently damage occurs to the exploited species (PERES et al., 2003; BOTHA et al., 2004).

One of the widely exploited forest products are the leaves of palm trees. Both expanded leaves (mature) and unexpanded (immature) are obtained for various uses (JOYAL, 1996; TICKTIN, 2004). Studies have reported that the extraction of mature leaves adult reproductive palms can adversely affect the production of their leaves and the reproductive performance, influencing the number of inflorescences of the plant and its fruits production (ENDRESS et al., 2004). However, there is a lack of information on the consequences of removing immature leaves palms (SAMPAIO et al., 2008). The extraction of immature leaves may have more severe consequences than the extraction of mature leaves in palm trees. In a study developed by Joyal (1996) in the *Sabal uresana* Trel palm, it was found that the rate of leaf production was decreased after the immature palm leaves were extracted, while the removal of mature leaves did not affect the palm development.

The immature leaves are extracted when fully formed, but not expanded. Consequently, these palms present deprived their photosynthetic capacity. Thus, removing immature leaves represents a subtraction of a structure that consume energy during it formation, without repair the photosynthetic cost of it production. On the contrary, the mature leaves enable the photosynthesis to happen and replaced to the palm tree the cost of carbon invested (JOYAL, 1996).

In the Northeastern of Brazil it is observed an expressive extraction of immature leaves of carnaúba palm (*Copernicia prunifera* H.E. Moore). During the dried months, the immature leaves are extracted to obtain carnauba wax and during the whole year the immature leaves are harvested for the handicrafts production (CARVALHO, 2008; IBGE, 2011).

The valorization of sustainable and ethnic products, the expansion of tourism, government support and the requalification of artisans promoted the expansion of commercial craft in Northeastern from Brazil, especially in state of Piauí (LAND INSTITUTE, 2011; SEBRAE, 2011). This increment lead to an intensification of the monthly extraction of immature leaves, which may have negative consequences on the development of vegetative and reproductive structures that are essential to reproduction and maintenance of species in the community (RATSIRARSON et al., 1996).

The present work aimed to understand the effects of the different extraction rate of immature leaves from *Copernicia prunifera* H. E. Moore upon plant survival, vegetative and reproductive structures production and seed germination.

2. MATERIALAND METHODS

2.1 Study area and specie description

The study was conducted in four distinct sites located in extractive communities of Parnaíba city located on the coast of the state of Piauí, Brazil (2° 54’14.17 “S, 41° 46’35.57" W). This city has its history, economy and culture related to the extraction of carnaúba (DOMINGOS NETO, 2010). The climate is semi-arid, with average of annual rainfall and temperature of 965 mm and 27.9 °C, respectively (BASTOS et al., 2000). The types of vegetation found are mangroves, salt marshes, savannas and forest formations with presence of the carnaúba palm (ICMBIO, 2010).

The sites evaluated are located in the communities of Paraíso, Fazendinha, Alto do Pirão and Vazantinha (Table 1). These areas have similar abiotic factors of soil, moisture, temperature and light (JACOMINE et al., 1986; ANDRADE JÚNIOR et al., 2004). Each site was submitted to a specific regime of monthly extraction imposed by owners of areas (Table 1).

The *Copernicia prunifera* is a palm tree native from Brazil, living in alluvial clay soils of vegetation at semi-arid region of the Brazil (LORENZI, 1992; LEITMAN, 2012). It has a single stipe growing up to 15 meters tall and leaves are deeply divided halfway into segments, and are about one meter wide. Between leaves, numerous flowers are produced in inflorescences (LORENZI, 1992). Fruits present ovoid appearance, containing a single seed (LORENZI et al., 2004; BORÉM;

Table 1 – Location of evaluated extractive communities and intensity of monthly extraction of immature leaves of carnaúba.
Tabela 1 – *Localização das comunidades extrativistas avaliadas e intensidade de extração mensal de folhas imaturas de carnaúba.*

Extractive communities	Coordinates	Intensity of extraction (%)
Vazantinha	2º53'42.99"S 41º46'49.17"O	0
Paraíso	2º53'40.92"S 41º46'57.59"O	25
Fazendinha	2º53'23.59"S41º47'2.33"O	50
Alto do Pirão	2º53'2.31"S 41º46'54.91"O	75

MIRANDA, 2009).The plant plays an important social role and is locally titled "tree of life" because it has different uses. The leaves are source of wax, immature leaves are used to make crafts, fruits are used as meal, trunk are used to building houses and the roots in the folk medicine (D'ALVA, 2004).

2.2 Experimental designs

All the experimental design was performed from June 2011 to November 2012. One hundred sixty reproductive adult palms with an average 12 meters tall were selected in four extractive communities (Alto do Pirão, Fazendinha, Vazantinha, and Paraíso). Immature leaves were extracted monthly and the intensity of extraction (75% Alto do Pirão, 50% Fazendinha, 25% Vazantinha and 0% Paraíso) was the same as traditionally performed by harvesters in each community. Palms from each of four areas (40 individuals per area) were evaluated by direct countingle af production, availability of mature leaves, number of inflorescences and number of floral branches containing immature, mature and aborted fruits. The palm flowers and fruits production per branch were estimated by counting 15inflorescences and 15 floral branches containing immature fruits chosen randomly per area. The total seeds per branch were estimated taking into consideration that each fruit produces a single seed. The seeds were evaluated for length, width and biomass. Each half year, 15 inflorescences were collected per area and evaluated for length, number of rachilles and biomass. At the last month of the experiment, 50 mature leaves were collected from each site and evaluated for length, number of leaf segments and biomass.

2.3 Seed germination

Two hundred visually healthy seeds were collected in each studied area. These were placed in plastic tubes containing 500 ml of water and incubated in BOD germination chamber with a 12 h light-dark cycle and at 27 °C. After 40 days, the number of germinated seeds was registered. The seed germination was considered positive when protrusion of the cotyledon petiole was seen (PINHEIRO, 1986).

2.4 Data analysis

In order to evaluate the production, length, number of leaf segments and biomass of leaves among different intensity of extraction, it was used the ANOVA followed by Kruskal-Wallis ($p < 0.05$). The intensity extraction was correlated to production of inflorescences, biomass, number of rachilles and number of flowers per inflorescence through Spearman correlation (rs). The length of floral branches was performed through Pearson correlation (r). In addition, the average of rs and r were evaluated through ANOVA followed by Kruskal-Wallis ($p < 0.05$). Fruit production was verified through ANOVA followed by Kruskal-Wallis ($p < 0.05$) and seed germination thought ANOVA followed by Tukey test ($p < 0.01$).

The influence of seasonality in the reproductive and vegetative structures production were analyzed using the correlation between the average monthly production and the corresponding month precipitation (data provided by the National Institute of Meteorology), using Pearson (r).

3. RESULTS

In the present study, it was observed that the monthly leaves production showed strongly influenced by the intensity of extraction ($rs = -0.7142$, $p < 0.0001$). The palms that were not exploited (0%) or exploited at 25% monthly intensity produced more leaves than those submitted to 50% or 75% of extraction (Table 2). Leaf structures were also affected by extractive activity. Palm subjected to intensity of 50% or 75% month extraction showed leaves with shorter length and biomass compared to control and 25% of extraction. Moreover, plants subjected to an extraction of 75% also showed a significant reduction in the number of leaf segments per leaf (Table 2).

The intensity of extraction was negatively correlated to the production of inflorescences ($r = -0.6215$, $p < 0.0001$), length of the floral branches ($r = -0.4660$, $p = 0.0002$), the floral branches biomass ($rs = -0.8552$, $p < 0.0001$), number of rachilles of floral branches ($rs = -0.7126$,

Table 2 – Production and structural alterations of leaves of palms submitted to different intensities of monthly extraction of immature leaves.
Tabela 2 *– Produção e alterações estruturais de folhas de palmeiras submetidas a diferentes intensidades de extração mensal de folhas imaturas.*

Intensity of extraction	Leaf production	Leaf segments	Length (cm)	Biomass (g)
0%	5.30 ± 0.58	58.97 ± 3.08	82.82 ± 6.2	184.85 ± 34.24
25%	4.56 ± 1.44	59.14 ± 3.70	82.62 ± 5.82	193.71 ± 30.80
50%	3.27 ± 0.84^{b,c}	57.71 ± 4.52	78.97 ± 6.92^{c,d}	177.31 ± 34.08^{d}
75%	3.015 ±1.35^{a,b,c}	56.62 ± 1.80^{a,b}	69.74 ± 4.90^{a,b}	136.91 ± 29.b29^{a,b,e}

Values are expressed as mean ± SDof 40 plants, as analyzed by ANOVA followed by Kruskal-Wallis test (p<0.05). [a]Compared with 0% group; [b]Compared with 25% group; [c]Compared with 0% group; [d]Compared with 25% group and; and [e]Compared with 50% group.

p <0.0001), and the number of flowers per inflorescence (rs = -0.8066, p <0.0001). The number and length of inflorescences of unexploited palms were higher than those submitted to leaves extraction of 50% or 75% per month, but did not differ statistically from those that had 25% of leaves monthly exploited (Table 3). However, palm submitted to 25% exploration produced floral branches with less biomass when compared to control. This event was also observed at 50% or 75% intensity of extraction. The production of rachilles and flowers were also affected by extraction. Control palms (0%) produced more rachilles and flowers than explored plants and no significant differences were observed in the production of these structures among harvested palms.

The number of floral branches containing immature and mature fruits was higher in control plants, however no statistical difference was observed compared to harvested groups (Table 4). On the other hand, fruits and seeds production reduced significantly at 25% extraction per month and it was not observed difference among plants subjected to 50% or 75% of exploration. Seeds from palms submitted to 75% extractive activity presented significant reduction on size and biomass (Table 4). In addition, the increment on intensity of exploration induced high rates of fruits abortions. It was also observed that the intensity of exploration influenced the percentage of germination of the seeds (Figure 1). At 75% of exploration seed germination reduced

Table 3 – Floral structure production of palms submitted to different intensities of monthly extraction of immature leaves.
Tabela 3 *– Produção de estruturas florais de palmeiras submetidas a diferentes intensidades de extração mensal de folhas imaturas.*

Intensity of extraction	Number of inflorescences	Floral branches length (cm)	Floral branches biomass (g)	Number of rachilles	Number of flowers per inflorescence ($x10^3$)
0%	1.18 ± 0.73	2.50 ± 0.40	0.59 ± 0.23	1170.00 ± 866.00	82.80 ± 37.57
25%	0.83 ± 0.47	2.27 ± 0.29^{f}	0.30 ± 0.08^{f}	319.00 ± 133.00^{f}	21.81 ± 10.85^{f}
50%	0.70 ± 0.65^{d,e}	2.06 ± 0.45^{d}	0.17 ± 0.09^{d,e}	149.00 ± 45.00^{d}	9.81 ± 4.89^{d}
75%	0.22 ± 0.32^{a,b,c}	1.98 ± 0.40^{b}	0.12 ± 0.03^{f,g}	155.00 ± 74.00^{a}	8.14 ± 4.80^{a}

Values are expressed as mean ± SD of 40 plants, as analyzed by ANOVA followed by Kruskal-Wallis test (p<0.05). [a]Compared with 0% group; [b]Compared with 25% group; [c]Compared with 50% group; [d]Compared with 0% group; [e]Compared with 25% group; and [f]Compared with 0% group.

Table 4 – Fruiting of palms submitted to different intensities of monthly extraction of immature leaves.
Tabela 4 *– Frutificação de palmeiras submetidas a diferentes intensidades de extração mensal de folhas imaturas.*

Intensity of extraction	Floral branches containing immature fruits	Floral branches containing mature fruits	Mature fruits per cluster	Seed size (cm)	Seed biomass (g)	Aborted fruits (%)
0%	64.46 ± 53.60	40.41 ± 47.00	150.00 ± 24.50	4.29 ± 0.41	3.40 ± 1.08	42.12
25%	29.92 ± 23.30	8.30 ± 12.33	54.50 ± 29.10^{f}	4.40 ± 0.50^{f}	3.35 ± 0.65	71.47^{f}
50%	54.46 ± 42.50	15.53 ± 18.83	25.20 ± 25.00^{d,e}	4.70 ± 0.44^{d}	2.49 ± 0.64^{e}	72.24^{d,e}
75%	20.30 ± 25.80^{a}	1.53 ± 2.47^{b}	8.08 ± 5.50^{a,c}	4.00 ±0.50^{a,b,c}	2.98 ± 0.70^{a,b,c}	92.42^{a,b,c}

Values are expressed as mean ± SD of 40 plants, as analyzed by ANOVA followed by Kruskal-Wallis test (p<0.05). [a]Compared with 0% group; [b]Compared with 50% group; [c]Compared with 25% group; [d]Compared with 0% group; [e]Compared with 25% group; and [f]Compared with 0% group.

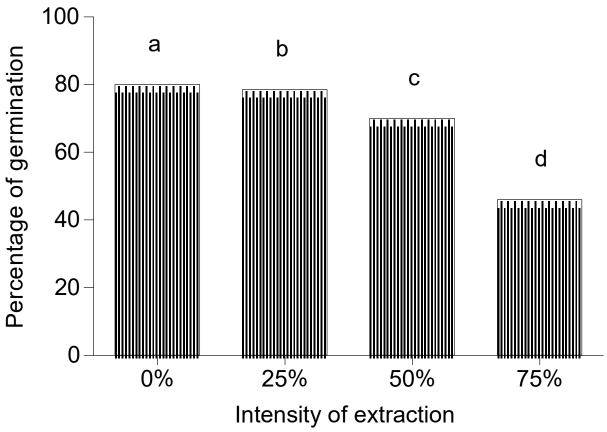

Figure 1 – Seed germination of carnaúba palms submitted to increasing intensities of monthly immature leaves extraction. Letters indicate significant differences among evaluated groups. ANOVA followed by Tukey test ($p < 0.01$).

Figura 1 *– Germinação de sementes de carnaúbas submetidas a crescentes intensidades de extração mensal de folhas imaturas. As letras indicam diferenças significativas entre os grupos. ANOVA seguido pelo teste de Tukey (p <0.01).*

at about 42%. In the present study, deaths were not reported among studied groups and none of evaluated parameter presented correlation to monthly precipitation ($rs < 0.00$, $p > 0.05$).

4. DISCUSSION

The obtained data indicated that leaf production was impaired by extractive activity, except in palms exposed to 25% monthly exploration. The palms invest energy in the leaf production that will be refilled by photosynthesis process performed in the leaf. In the case of extraction of immature leaves, the process of photosynthesis should be compromised and the initial investment is not recovered. This event weaken palm and consequently reducing leaves production (JOYAL, 1996).

Besides of leaves production, the monthly extraction of leaves at a rate exceeding 50% affected negatively the length and biomass of leaves. These data corroborate to the effects observed in palms that had their mature leaves removed (RATSIRARSON et al., 1996; MCKEAN, 2003). The authors observed that the sizes of leaves were diminished significantly.

According to Obeso (1993), the ability of plants to compensate the loss of a structure depends on the resources available for replacement. In the present work, it was observed that plants submitted to extraction of 75% monthly showed insufficient amounts of leaves to keep the energetic demands of the palm. This observation was supported by reduction of leaf segments count per leaves and biomass of carnaúbas subject to this system of extraction (75%). This event should occur because of low energy availability, as reflect of the intense exploitation.

The production of inflorescences, flowers and fruits in carnaúbas were also affected by extractive activity higher than 25% per month. When plants are submitted to energy shortage, as promoted by leaves extraction, it is common to observe reduction or reallocation of energy to produce some plant structures, such as flowers and fruits (KIGOMO et al., 1994; RATSIRASON et al., 1996; ENDRESS et al., 2004; HE et al., 2005). Similar observations were previously reported. Plant adjustments were observed in palms submitted to extraction of mature and immature leaves (FLOWERS; ASHTON, 2000; ENDRESS et al., 2004). Herein, we suggested that the strategies of reallocation of energy displayed by carnaúba changed according to the intensity of extraction. This hypothesis is reinforced by the observation that plants with extracted leaves at 25% per month maintained the total production and length of floral branches similar to control group (0% of extraction), although they had invested less energy in floral branches biomass, production of flowers and fruits. Moreover, at intensities of leaves extraction of 50% or 75%, plants produced less flowers and fruits per cluster, generated shorter inflorescences concerning on length and biomass when compared to control.

The extraction of immature leaves induced significant reduction in total production and morphology of fruits. These effects may be associated to the fact of maintenance and development of fruits requires a high energy cost to the plant (KOZLOWSKY, 1971). Reducing the size of the fruit should be a mechanism to produce healthy fruits. However, this alteration may affect the percentage of seed germination. In the present work, it was observed that plants submitted to extractive activity produced lower seeds in size and biomass as well as less successful in germination. The increasing in seed fail germination may be related to malformed embryos commonly found in plants submitted to energy shortage (GRAY et al., 1986; CARVALHO; NAKAGAWA, 2012). These seeds present lower availability of nutritional reserves to embryo, making them potentially less vigorous.

5. CONCLUSIONS

Negative results were found in the extractive activity of reproductive adult palms leaves. It was observed that extraction of immature leaves at 50% or 75% per month promoted intense depletion of energy reserves observed by reduction of count, size and biomass of reproductive and vegetative structures of the carnaúba palm. In view of this, we suggest that a monthly leaves of extraction near to 25% should be respected in order to allow the palms refill their energy storage. It is suggested that pausing extractive activity should occurs preferentially during fruits maturation. This pausing period will help to conciliate environmental conservation and extraction activities.

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