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Phenology, biometric parameters and productivity of fruits of the palm *Butia capitata* (Mart.) Beccari in the Brazilian *cerrado* in the north of the state of Minas Gerais

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ABSTRACT

The fruits of the palm *Butia capitata* are harvested from wild populations. A lack of knowledge of their ecology has hindered the establishment of sustainable management practices. We investigated fruit biometric parameters, yield and phenology in two populations of *B. capitata* in the *cerrado* (savanna) in the north of the state of Minas Gerais, Brazil, at two study sites: in the communities of Mirabela (Fazenda Baixa site, studied from December 2006 through December 2007) and Campos (studied throughout 2007). Overall, adult palms produced an annual average of 7.6 leaves. At the Fazenda Baixa site, the mean annual number of infructescences was 4.9, compared with only 1.6 at the Campos site, and the annual yield was 197-373 and 145-468 fruits per tree (in 2006 and 2007, respectively), compared with 67-247 at the Campos site. Reproductive events were seasonal and influenced by rainfall distribution. Typically, inflorescences and immature infructescences appeared in the dry season, mature infructescences appearing in the rainy season. Inflorescence production and fruit biometric parameters differed between the two populations. Fruit yield correlated with height and leaf biomass. We found that *B. capitata* fruits, which are highly perishable, should be harvested when nearly-ripe and remain attached to the infructescence during transport. Our findings have important implications for the development of strategies for sustainable management and *in situ* conservation of populations of this species.

Key words: Extractivism, fruiting, management, coquinho-azedo, post-harvest ripening

Introduction

Palms play a fundamental role in the structure and composition of the vegetation in the tropics (Scariot *et al.* 1995; Scariot 1999). Along with grasses and legumes, palms are commonly employed by rural and indigenous populations in the tropics (Balick 1984; Johnson 2010). Palms are widely used as food and in construction, as well as in the fabrication of domestic tools and ornaments (Balick 1984; Sullivan *et al.* 1995; Johnson 1988, 2010), making them one of the leading non-timber forest products (NTFPs).

Well-managed plant populations can provide income and contribute to the conservation of natural resources. However, sustainable management has been greatly affected by the lack of basic ecological knowledge of the harvested species. The harvest of NTFPs is important for local economies and for the conservation of tropical ecosystems, because the commercialization of these products has a direct impact on the sustainable development of the communities that engage in such activities. The ecological and economic aspects of the of native fruits harvesting and processing in tropical forests have received little attention, despite their importance in the evaluation of the sustainability of extractive activities and of the commercial viability of these products (Anderson & Putz 2002, Miller 2002, Kathriarachchi *et al.* 2004, Plowden 2004, Rai & Uhl 2004, Ticktin 2004).

Among the necessary basic ecological knowledge, an understanding of the phenological behavior of a plant species is critical to understanding the dynamics of a community, because the regulation of, duration of and synchrony among the various phases of the biological cycle have great implications for the structure, functioning and regeneration of a community, as well as for the quantity and quality of the resources available to consumers (Williams *et al.* 1999). The phenology, reproductive patterns and productivity of a population are of fundamental importance in the planning of management strategies for harvested species. Examples of the use of such knowledge to support management and conservation recommendations exist for *Oenocarpus bataua* var. *bataua* Balick in the equatorial Amazon of Ecuador (Miller 2002); *Astrocaryum tucuma* Mart. in the central Amazon of Brazil (Schroth *et al.* 2004);

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Euterpe edulis Mart. in the Atlantic Forest of Brazil (Reis *et al.* 2000); and *Mauritia flexuosa* L. (Sampaio *et al.* 2008) and *Acrocomia aculeata* (Jacq.) Lodd. ex Mart (Scariot *et al.* 1995) in the Brazilian *cerrado* (savanna). Knowledge of the temporal and interpopulational variation in the production and biometric parameters of fruits of a species can foster the harvest of fruits and seeds for consumption and commercialization, as well as their *ex situ* conservation. For most NTFPs, the information available is insufficient to allow reasoned decision-making regarding sustainable management and harvesting.

In this study, we examined the biometric parameters, phenology and productivity of the fruits of two populations of *Butia capitata* (Mart.) Beccari in an area of *cerrado*. Our objective was to identify temporal and interpopulational variations in the biometric parameters of *B. capitata* fruit, as well as to estimate the fruit production and quantify the phenology.

Material and methods

Study site and populations

This study was conducted in two areas of *cerrado sensu stricto* (a savanna formation that constitutes the principal vegetation formation in the *cerrado*), in the north of the state of Minas Gerais, Brazil, where populations of *B. capitata*, locally known as *coquinho-azedo*, occur in dense patches that dot the landscape.

The first study site was in the rural community of Campos (15°89'13"S; 42°82'13"W), in the municipality of Serranópolis de Minas, in the Southern Espinhaço mountain range, where the *B. capitata* population grows on rocky soil among rock outcrops. The *cerrado* vegetation is in a zone of transition between the *cerrado* biome and the *caatinga* (shrublands) biome, at 910 m of elevation. The climate of the region is semi-humid hot tropical—four to five months of high temperatures (mean, 24.5°C) with no rain (IBGE 2012). Some of the plant species (with their local common names) that are found in this area and are characteristic of *cerrado sensu stricto* and of rocky *cerrado*: *Lychnophora* sp. ("*arnica*"); *Dalbergia miscolobium* Benth. ("*caviúna*"); *Attalea geraensis* Barb. Rodr. ("*coco catulé*"); *Hancornia speciosa* Gomes ("*mangaba*"); *Xylopia aromatica* (Lam.) Mart. ("*pimenta-de-macaco*"); *Roupala montana* Aubl. ("*carne-de-vaca*"); *Qualea grandiflora* Mart. ("*pau-terra-folha-larga*"); and *Qualea parviflora* Mart. ("*pau-terra-folha-miúda*"). For more than ten years, there has been sporadic harvest of *B. capitata* fruits in this area. However, fruit harvest has increased since 2002, because the members of a community that seeks to be recognized by the Brazilian federal government as a *quilombo* (a community established by descendants of escaped or freed slaves), have been extracting *B. capitata* fruit on a regular basis. The fruits are provided to the Grande Sertão cooperative for the production of juice pulp. The Campos site was studied throughout 2007.

The second study site was located on a privately owned farm called Fazenda Baixa (16°26'64"S; 44°19'34"W), near the municipality of Mirabela, at an elevation of 789 m. The palms grow along the vegetation of *cerrado sensu stricto*, which is disturbed by common activities in this region such as cattle raising and extraction of firewood. Some of the plant species (with their local common names) include *Caryocar brasiliense* Camb. ("*pequi*"); *Peritassa campestris* (Cambess.) A.C.Sm. ("*rufão*"); *Annona crassiflora* Mart. ("*panã*"); *Stryphnodendron adstringens* (Mart.) Coville ("*barbatimão*"); *Curatella americana* L. ("*lixeira*"); *Copaifera langsdorffii* Desf. ("*copaíba*"); *Hymenea stignocarpa* Mart. ex Hayne. ("*jatobá*"); *Magonia pubescens* St.-Hil. ("*tingui*"); *Lafoensia pacari* St. Hil. ("*pacari*"); *Solanum lycocarpum* St. Hil. ("*lobeira*"); and *Bromelia* sp ("*macambira*"). This site was studied during 2006 and 2007, a period encompassing two harvests. Since December 2006, the beginning of the study period, the landowner had been collecting *B. capitata* fruit as a cash crop.

Butia capitata (Mart.) Beccari belongs to family Arecaceae (Palmae), subfamily Arecoideae, tribe Cocoeae, subtribe Butiinae (Jones 1995). It is monoecious, with a single stem; petioles with coarse spines along the margins; leaflets glaucous and rigid, regularly arranged, forming a "V" (Henderson *et al.* 1995). The species has yellow staminate flowers, spirally arranged in triads and mostly in pairs or single at the distal portion of the rachis, with approximately 7.5 mm in length and 6 mm in width, valvate sepals and petals, with six stamens; yellow pistillate flowers with 4.8-5.6 mm in length and 3.6-3.9 mm in width (Marcato & Pirani 2006).

Butia capitata is distributed throughout Brazil (Henderson *et al.* 1995; Lorenzi *et al.* 2010), occurring on sandy soils in areas of open *cerrado* in the states of Bahia (northeastern part of the state), Goiás (eastern part of the state) and Minas Gerais (northern and northwestern parts of the state). It was previously thought to occur in the states of Rio Grande do Sul (west of the Patos lagoon) and Santa Catarina (coastal region of the state). However, those two populations have now been classified, respectively, as *B. odorata* (Barb. Rodr.) Noblick & Lorenzi and *B. catarinenses* Noblick & Lorenzi (Lorenzi *et al.* 2010). The fruits of *B. capitata* are much appreciated in the north of Minas Gerais. The unprocessed fruits are sold at street markets, and the pulp, which is used for making juice, ice cream and popsicles, is sold either to cooperatives or directly to restaurants, hotels and supermarkets.

Biometric parameters and fruit production

To describe the biometric parameters of the fruits of *Butia capitata*, we collected six infructescences in each sampling site. We weighed the infructescences, counted the number of fruits and measured the total length from the insertion of the first rachis to the extremity. Of each infructescence, a sample of ten fruits was selected. Each fruit was evaluated regarding color and stage of maturation, the longitudinal and equatorial diameters of the fruit were measured with a digital caliper and the total weight of the entire fruit and of the pyrene (endocarp with seeds, without the pulp) was obtained with a scale (accuracy, 0.01 g). The fresh weight of the pulp was obtained by calculating the difference between the fresh weight of the entire fruit and the fresh weight of the pyrene. The endocarp was broken with the aid of a vise, and the seeds were counted. In 40 adult individuals with signs of prior reproduction, randomly selected in each area, productivity was estimated by counting the infructescences produced and multiplying that number by the mean number of fruits per infructescence.

To determine whether fruit production differed between the two populations, as well as whether that production was affected by the environmental history and characteristics of each area, we used Student's t-tests (Zar 1999) to compare the biometric characteristics and the productivity of both areas. Associations between the biometric parameters were quantified with Spearman's rank correlation coefficient (rs) analysis, because the data did not have a normal distribution even after transformation.

Phenology

In the 40 reproductive individuals selected for the Campos site, reproductive phenology and leaf flushing were evaluated monthly during the first six months of 2007. In the last six months of the year, during which there is intense flowering and fruiting, observations were made every 15 days.

The individuals were marked and numbered. The reproductive structures were categorized, by stage of development, as follows: spathe (closed fibrous involucral bract enveloping the condensed inflorescence); inflorescence (elongation and emergence of the inflorescence from inside the bract, representing the onset of flowering); immature infructescence (appearance and development of green fruits); and mature infructescence (ripening of the fruits, which are then yellow, fleshy and ready to be dispersed and consumed). It was not possible to perform monthly monitoring at the Fazenda Baixa. Therefore, for the 40 adult individuals selected at that site, we counted their infructescences only at end of the study, disregarding their temporal distribution. For these individuals, we measured the total height and the width of the three youngest, fully expanded leaves. We also counted the total number of leaves. To determine the number of leaves produced annually, the spear leaf (the closed and developing leaf, with an apical position) was identified with an aluminum tag, and new leaf flushing was monitored along the year. The concentration of the production of leaves and reproductive structures was investigated with circular statistics by means of the Z value on the Rayleigh test (Zar 1999), which determines the concentration of frequencies of phenological events, within the distribution, over the course of the year. To evaluate whether reproductive and vegetative structures were related to the height of adult individuals or to the climatic variables along the year, we performed Spearman's rank correlation coefficient analysis. We also investigated the relationships among number of leaves, leaf length, leaf width, and leaf width/leaf length ratio—for adult and juvenile individuals.

In all analyses, the distributions of the variables were evaluated with the Shapiro-Wilk test, to comply with the premises of homoscedasticity and normality (Zar 1999). When the variables did not have a normal distribution even after transformation, non-parametric analyses were used. For all analyses, the level of significance was set at ≤ 5%.

Post-harvest maturation and quality of the fruits

To evaluate the effect of the stage of maturation and the time, in days, in which the *B. capitata* fruits remain appropriate for consumption, as well as the time to decay, we selected 12 infructescences from different individuals, collected at one of three stages of maturation. These stages were classified as unripe; nearly-ripe (fruits with a yellowish-green skin and a light yellow pulp); and ripe. From each infructescence, we selected three lots of ten fruits each and submitted them to three treatments: leaving the fruits attached to the infructescence; removing the rachillae with fruits attached; and removing the fruits completely (from the infructescence and the rachillae), leaving them loose and without sepals. The last treatment is the way in which the fruits are stored by the harvesters to be transported to street markets or delivered to cooperatives. The ripening of the fruits in each treatment was monitored until decay. We used ANOVA to compare the three treatments in terms of the time to decay (defined as decay of ≥ 50% of the fruits).

Results

Biometric parameters of the fruits

The fruits from the Fazenda Baixa site weighed more and had larger diameters (equatorial and longitudinal) in 2007 than in 2006. Infructescence characteristics did not differ between the two years (Tab. 1).

The fruits from the two populations differed regarding fresh weight but not regarding size, as expressed by the diameters ($p<0.05$, Tab. 2). The individuals evaluated at the Fazenda Baixa site produced more and larger infructescences, as well as producing more fruits and showing more variability, than did those evaluated at the Campos site (Tab. 2).

There were no correlations between the number of fruits in the infructescence and the size or fresh weight of those fruits, indicating the absence of a trade-off between quantity and size of fruits. There was a strong correlation between the fresh weight of the fruit and the fresh weight of the pulp (rs=0.99), as well as between the equatorial diameter of the fruit and the fresh weight of the fruit (rs=0.88)

Table 1. Mean, minimum and maximum values of the biometric parameters of the fruits and infructescences of the population of *Butia capitata* at the Fazenda Baixa site, in the north of the state of Minas Gerais, Brazil, for 2006 vs. 2007* and for 2006+2007.

Variable**	2006		2007		2006+2007
	Mean±SD	Range	Mean±SD	Range	Mean±SD
Fresh weight of the fruit (g)	6.15±2.41ª	2.25-12.50	6.94±1.74ᵇ	3.50-11.75	6.55±2.13
Longitudinal diameter of the fruit (mm)	26.81±2.36ª	18.37-32.18	25.21±2.97ᵇ	18.27-31.45	25.97±2.80
Equatorial diameter of the fruit (mm)	18.74±3.33ª	13.04-26.15	22.42±1.87ᵇ	17.54-27.95	20.58±3.37
Fruits per infructescence (n)	283.3±53.8ª	197-373	314±129ª	145-468	293.6±83.9
Fresh weight of the infructescence (g)	2.092±566ª	1.400-3.500	2.945±968ª	1.655-3.854	2.376±809
Length of the infructescence (cm)	42.83±5.82ª	30-53	48.50±5.61ª	43-57	44.72±6.22

SD – standard deviation.
*Values on the same row and followed by same superscript letter do not different significantly from each other (p>0.05).
**Samplings: for fresh weight and diameters, n = 60 for 2006 and 2007; and n = 120 for 2006+2007—for the remaining data, n = 6 for 2006 and 2007; and n = 12 for 2006+2007.

Table 2. Mean, minimum and maximum values of the biometric parameters of the fruits and infructescences of populations of *Butia capitata* in areas of *cerrado* areas in the north of the state of Minas Gerais, Brazil: for the Campos site, for the Fazenda Baixa site and for the sample as a whole (Overall).

Variable	Campos		Fazenda Baixa		Overall
	Mean±SD	Range	Mean±SD	Range	Mean±SD
Fresh weight of the fruit (g)	7.60±1.66ª	4.25-11.25	6.94±1.74ᵇ	3.50-11.75	7.30 ± 1.73
Fresh weight of the pulp (g)	6.35±1.51ª	3.40- 9.30	5.83±1.50ª	3.05-10.20	6.09 ± 1.53
Fresh weight of the pyrene (g)	1.25±0.20ª	0.75-1.90	1.11ᵇ± 0.29ᵇ	0.35-1.65	1.18± 0.28
Fresh weight of the seeds (g)	0.36±0.06ª	0.24-0.57	0.33ᵇ± 0.09ᵇ	0.15-0.51	0.35 ± 0.09
Fresh weight of the pyrene/ Fresh weight of the fruit	0.17±0.02ª	0.12-0.24	0.16±0.03ª	0.10-0.22	0.16 ± 0.03
Longitudinal diameter of the fruit (mm)	25.43±1.50ª	20.7-28.35	25.21±2.97ª	18.27-31.45	25.28 ± 2.35
Equatorial diameter of the fruit (mm)	23.18±2.48ª	18.25-28.35	22.42±1.87ª	17.54-27.95	22.80 ± 2.37
Fruits per infructescence (n)	134±66ª	67-247	314±129ᵇ	145-468	224 ±136
Fresh weight of the infructescence (g)	923±719ª	175-1.830	2.945±968ᵇ	1.655-3.854	1.934 ±1.332
Length of the infructescence (cm)	38.33±5.24ª	32-45	48.50±5.61ᵇ	43-57	43.42±7.41

SD – standard deviation.
*Values on the same row and followed by same superscript letter do not different significantly from each other (p>0.05).
**Samplings: for fresh weight and diameters, n = 60 for Campos and Fazenda Baixa; and n = 120 for the sample as a whole—for the remaining data, n = 6 for Campos and Fazenda Baixa; and n = 12 for the sample as a whole.

and the fresh weight of the pulp (rs=0.89), indicating that larger fruits have more pulp (Tab. 3). This correlation was expected, because 84% of the fresh weight of the fruit was pulp, whereas the pyrene and the seeds corresponded, respectively, to 11.3% and 4.7% of the total fresh weight of the fruit (Tab. 2). Most (90%) of the fruits from both populations had only one seed; 8,3% had two seeds and only 1.7% (all collected in January at Campos), had three seeds. The mean thickness of the pulp (± standard deviation), measured only in the Fazenda Baixa population (n = 240 fruits), was 3.28±1.5 mm.

Productivity and phenology

The reproductive individuals at the Campos site produced 1.7±1.89 inflorescences per year, of which 91.4% became mature infructescences, resulting in 1.6±1.6 mature infructescences per year per reproductive individual. More than a quarter (27.5%) of the adult individuals in this population did not reproduce during the study period. At the Fazenda Baixa site, only three (7.5%) out of 40 adult individuals, did not reproduce during the study period. In this population, the individuals produced 4.9±2.87 mature infructescences per year, a number significantly larger (p>0.05) than that of Campos, although the success rate of the development of inflorescences into infructescences was not estimated in this population. The production of fruits per individual varied between populations and years. Plants at the Fazenda Baixa site produced 197-373 fruits per individual in 2006 and 145-468 fruits per individual in 2007, whereas the individuals at the Campos site produced 67-247 fruits per individual in 2007 (Tab. 1 and 2). In 2007, each individual produced

Table 3. Spearman's rank correlation coefficient analyses between the characteristics of the fruits of *Butia capitata* in *cerrado* areas in the north of Minas Gerais, Brazil: for the Campos site, for the Fazenda Baixa site and for the sample as a whole (Overall).

Parameter	Site	Fresh weight			Diameter of the fruit	
		Fruit (g)	Pulp (g)	Pyrene (g)	Longitudinal (mm)	Equatorial (mm)
Fresh weight of the pulp (g)	Overall	0.99*				
	Campos	0.99*				
	Fazenda Baixa	0.98*				
Fresh weight of the pyrene (g)	Overall	0.72*	0.65*			
	Campos	0.74*	0.69*			
	Fazenda Baixa	0.73*	0.64*			
Longitudinal diameter of the fruit (mm)	Overall	0.54*	0.49*	0.66*		
	Campos	0.60*	0.58*	0.60*		
	Fazenda Baixa	0.53*	0.48*	0.72*		
Equatorial diameter of the fruit (mm)	Overall	0.88*	0.89*	0.56*	0.38	
	Campos	0.88*	0.88*	0.65*	0.54*	
	Fazenda Baixa	0.88*	0.89*	0.53*	0.30	
Fresh weight of the seeds (g)	Overall	−0.02	−0.04	0.09	0.08	−0.01
	Campos	0.24	0.25	−0.13	0.24	0.21
	Fazenda Baixa	−0.29	−0.35	−0.10	−0.08	−0.28

*p<0.05

a mean of 10.67 kg of fruits at the Fazenda Baixa site and only 1.63 kg of fruits at the Campos site.

At the Campos site, the *B. capitata* plants (n = 40) produced 7.66±1.1 leaves (range, 6-10 leaves) per individual. Leaf flushing was uniform throughout the year (Fig. 1). However, the production of reproductive structures was punctual (Tab. 4 and Fig. 2). Involucral bracts were visible mainly in April (at the end of the dry season) and remained so for 2.8±0.7 months.

The occurrence of inflorescences peaked in June. Over a period of 15-30 days, the involucral bract opens; the rachillae elongates; followed by the anthesis, pollination and abscission of the male flowers. Most immature infructescences were visible in July, and the fruits developed over a period of 3.8±0.8 months, at which point they were ripe and ready for dispersal. Ripe fruits occurred from August to March (Fig. 2), fruit maturation peaking in November, at the beginning of the dry season. The fruits ripened gradually, starting from the basal rachillae and ending with the rachillae at the extremities, and developing a bright yellow coloration. At the Fazenda Baixa site, some individuals also produced purple and greenish-white fruits, which can also occur in other populations of the region.

The mean time to development of a reproductive structure, from the appearance of the bract until fruit dispersal, was 7.1±0.9 months. The production of inflorescences and immature infructescences was correlated with periods of lower precipitation (Spearman rs=−0.68 and rs=−0.62, respectively) and lower relative humidity (rs=−0.63 and rs=−0.83, respectively).

The *B. capitata* individuals studied in the *cerrado* did not fruit throughout the year, but instead had their phenological events concentrated, with the production of involucral bracts occurring immediately after the end of the rainy season, which is subsequent to the flowering in the dry season.

According to observations of fructiferous *cerrado* species in the north of Minas Gerais during the study period, a pattern of constant annual distribution does not seem to be common. Most of the species tend to fruit at the same time, during the rainy season, resulting in an abundance of fruits during this period and a shortage of fruits during the dry season. This seasonality reduces the availability of fruits for harvesters during the dry season and results in an excess

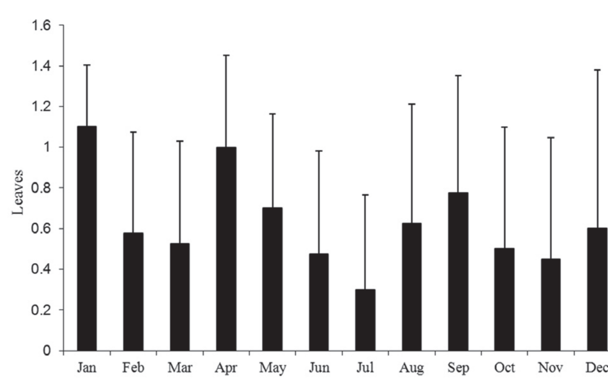

Figure 1. Number (mean±standard deviation) of leaves produced per individual (n = 40) in 2007 in a population of *Butia capitata* in an area of *cerrado* (savanna) in the rural community of Campos, in the state of Minas Gerais, Brazil.

Table 4. Periods of the year in which the production of reproductive and vegetative structures was concentrated, results from the Rayleigh test (Z), measure of the concentration (r) of the event and mean annual number of structures produced per reproductive individual (n = 40) in a population of *Butia capitata* in an area of *cerrado* in the municipality of Campos, in the state of Minas Gerais, Brazil.

Structure	Month	Z*	r	Number of events/individual (mean±SD)
Involucral bract	April	45.9	0.8	1.7±9.4
Inflorescence	June	35.6	0.7	1.7±8.1
Immature infructescence	July	35.5	0.7	1.6±7.5
Mature infructescence	November	45.1	0.9	1.6±9.5
Leaves	-	2.9	0.1	7.6±9.2

SD – standard deviation.
*p< 0.001

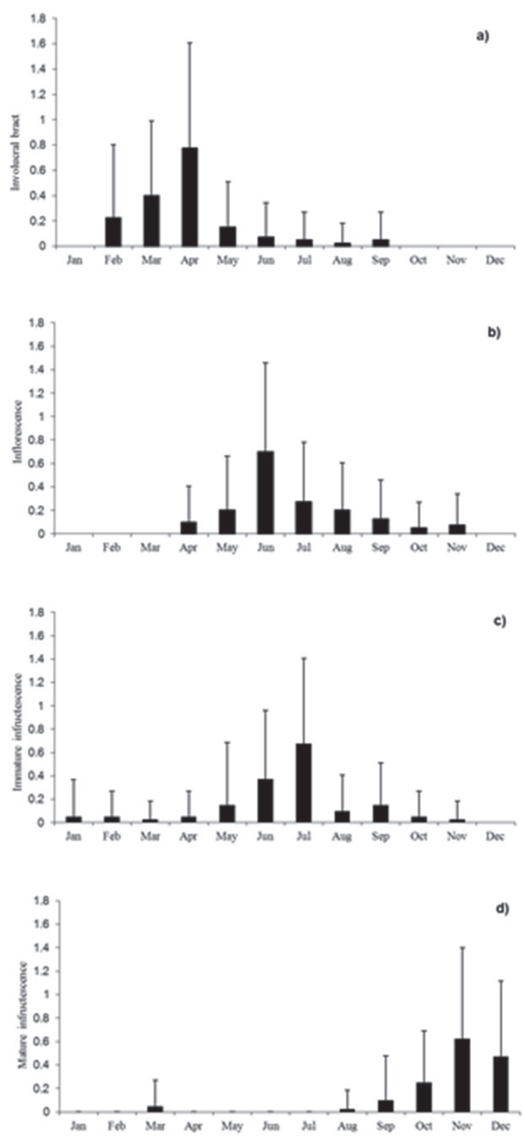

Figure 2. Number (mean±standard deviation) of reproductive structures—a) involucral bracts, b) inflorescences, c) immature infructescences, d) mature infructescences—produced per individual (n = 40) in 2007 in a population of *Butia capitata* in an area of *cerrado* (savanna) in the rural community of Campos, in the state of Minas Gerais, Brazil.

during the rainy season, causing losses for the cooperatives, which are not able to process the quantity of fruits provided by the harvesters in the region. However, a rapid diagnosis of the markets in the region shows that the consumer market is capable of receiving a greater quantity of pulp of native fruits and that the demand is greater than the supply.

The height of the individual was most strongly correlated with the number of leaves in the crown, leaf length and leaf width when evaluated in the sample as a whole—juveniles and reproductive adults together (Tab. 5). There was a significant, albeit weak, correlation between the height of the individual and the production of vegetative and reproductive structures, although the quantity of aerial biomass and photosynthetic potential, represented by the number of leaves in the crown, did not influence the production of infructescences (Tab. 5). The height of individuals had no significant effect on leaf length (linear regression: $F_{1,38}$=6.05; p=0.01; r^2=0.13), leaf width ($F_{1,38}$=3.65; p=0.06; r^2=0.09) or the leaf width/leaf length ratio ($F_{1,38}$=1.72; p=0.19; r^2=0.02).

Maturation of the fruits

The fruits of *B. capitata* decay quite rapidly. In the present study, the fruits that were picked when ripe began to decay within a day after picking. Although unripe fruits took longer to decay (Fig. 3), not all of them ripened and became edible. The maximum market yield of unripe fruits was of 60%, compared with 100% and 84%, respectively, for ripe and nearly-ripe fruits.

Independently of the stage of fruit maturation at the time of harvest, the percentage of fruits that ripened after harvest was highest (71%) when the harvested fruits remained attached to the infructescence, intermediate (62%) when the fruits were removed from the infructescence but remained attached to the rachillae and lowest (57%) when the fruits were fully detached (from the infructescence and from the rachillae), leaving them loose and without sepals (Fig. 4). The time to decay (defined as decay of ≥ 50% or more of the fruits) did not vary among those three treatments ($F_{1,34}$=0.16, p=0.85), being 3.8, 3.5 and 3.7 days post-harvest, respectively.

Table 5. Values of Spearman's rank correlation coefficient (rs) for the associations between the characteristics of adult individuals and the group of both adults and juveniles of *Butia capitata* in an area of *cerrado* (savanna) in the rural community of Campos, in the state of Minas Gerais, Brazil.

Variable	Adults (n = 40)					Juveniles and adults (n = 85)		
	Height	Number of leaves in the crown	Leaf length	Leaf width	Number of leaves/year	Height	Number of leaves in the crown	Leaf length
Number of leaves in the crown	0.47*					0.83*		
Leaf length	0.39*	0.26				0.84*	0.74*	
Leaf width	0.29	0.23	0.72*			0.75*	0.68*	0.89*
Number of leaves per year	0.33*	0.46*	0.19	-0.13				
Number of infructescences per year	0.38*	0.16	-0.02	0.12	0.23			

*p<0.05.

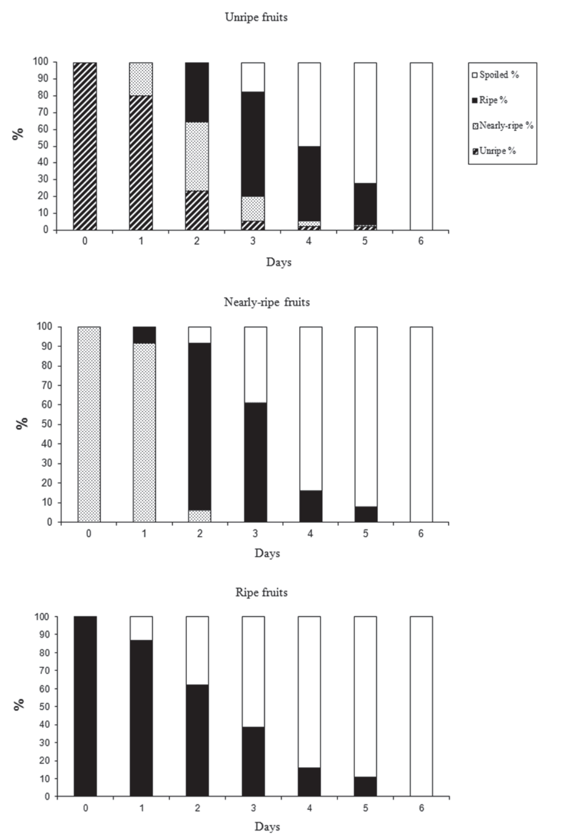

Figure 3. Post-harvest ripening of *Butia capitata* fruits collected at three stages of maturation: unripe (a), nearly-ripe (b) and ripe (c).

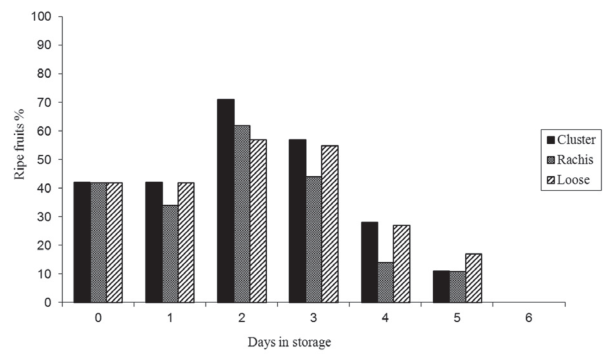

Figure 4. Proportion of *Butia capitata* fruits that remained undecayed (edible) over time after harvest, by treatment: Cluster (fruits left attached to the infructescence); Rachis (fruits removed from the infructescence but left attached to the rachises); and Loose (fruits removed from the infructescence and the rachillae, leaving them loose and without sepals).

Discussion

Biometric parameters of fruits

Biometric parameters of fruits can vary among populations and crops. The values found in this study are similar to those found in another population of *B. capitata* in the same region (Moura *et al.* 2010) and in populations of *B. odorata* in Uruguay (Rivas & Barilani 2004).

The mean fresh weight of the fruits in this study (for the two years at both sites, 6.5±2.1 g; and for the two sites, 7.3±2.1 g) was similar to that found for *B. odorata* in Uruguay (6.9±2.5g; Rivas & Barilani 2004) and lower than that found for another population of *B. capitata* in the north of Minas Gerais (8.2±1.7g; Moura *et al.* 2010). However, the pulp accounted for 84.0% of the total weight of the fruits in the present study and 79.5% of the total weight of the fruits in the study conducted by Moura *et al.* (2010), compared with 72.2% of the fresh weight of the fruits of *B. odorata* in the study conducted in Uruguay (Rivas & Barilani 2004). Therefore, the weight of the pyrene was greater in the population studied in Uruguay (accounting for 27.8% of the total weight of the fruit) than in those in the north of Minas Gerais (in which it accounted for 16.6% and 20.1% of the total weight of the fruit, respectively).

The fresh weight of the pulp was found to correlate strongly with the fresh weight and size of the fruit, the heaviest fruits being also the largest and with the largest quantity of pulp (Tab. 3), as was also reported by Moura *et al.* (2010). The number of fruits in the infructescence was not found to correlate with the size or fresh weight of the fruits, possibly indicating an absence of competition for resources during the development of those fruits.

In many species, the size of a seed is an indicator of its physiological quality (Popinigis 1977). Although there was no direct relationship between the fresh weight of the seeds and the remaining characteristics, it is possible to infer that larger fruits, and consequently, larger pyrenes, can generate seedlings with better development (Eriksson 1999), higher germinability and more vigor, as observed for *Euterpe edulis* (Lin 1988) and *E. espiritosantensis* (Martins *et al.* 2000). The populations of *B. capitata* in *cerrado* usually have one seed, occasionally have two seeds, and rarely have three seeds, unlike the populations of *B. odorata* in Uruguay, most (53%) of which have three seeds and few (only 8%) of which have only one seed (Rivas & Barilani 2004).

The correlations and variations in the biometric parameters are important when contextualized with the management of populations, because they can support the selection of populations, source trees and fruits with higher yield, considering that the end product of interest is the pulp. Such knowledge can also be useful in the selection of higher quality seeds for seedling production, because high quality seeds are fundamental for the success of a production system with high productivity and high product quality. The productivity of each individual, the taste and size of the fruits and the percentage of pulp can be used in the selection of source trees of *B. capitata* for the extraction of fruits, a process similar to that used for *Astrocaryum tucuma* in the Amazon forest (Schroth *et al.* 2004). These characteristics should be identified in each sample to be selected. Management techniques and environmental characteristics can also influence the availability of resources and thus should also be evaluated.

Phenology and height of the individual

Many species of tropical palms produce fruits throughout the year and thus serve as a key food source for frugivorous vertebrates, especially during the dry season (Peres 1994). Studies on palms in tropical forests indicate that this pattern of continuous fruiting is common (Peres 1994, Martén & Quesada 2001, Miller 2002, Sampaio & Scariot 2008), as is a pattern of flowering and fruiting concentrated in one of the seasons of the year (Ibarra-Manríquez 1992, Scariot *et al.* 1995, Henderson *et al* 2000).

Reproductive ability is correlated with the height of the individual, because larger individuals have a higher capacity to obtain resources, including those required for reproduction (Harper 1977). In *B. capitata*, height can be a good indicator of the productivity of infructescences or leaves, as has been observed for other species of palms such as those of the genera *Geonoma* (Chazdón 1992, Sampaio & Scariot 2008) and *Chamaedorea* (Otero-Arnaiz & Oyama 2001), as well as *Acrocomia aculeata* (Scariot *et al.* 1995). Similarly, the number of green leaves, which represents the foliar aerial biomass and the photosynthetic potential, is a good indicator of the productivity in *B. capitata*. However, an increase in height is followed by senescence of the individual, a process that can decrease the production of leaves and fruits, and, as observed here, productivity can be higher in the younger population, comprising shorter individuals, than in the population of older, taller individuals.

Productivity of fruits

The estimated annual production of infructescences per palm differed markedly between the two populations. Individuals at the Fazenda Baixa site produced three times more infructescences than did those at the Campos site, the former being comparable to the 4.68 infructescences per individual found by Moura (2008) in a population of *B. capitata* in the same area of *cerrado* evaluated in the present study. The production of the individuals at the Fazenda Baixa site was higher than the 2.24-3.08 infructescences per individual observed over two consecutive years in a population of *B. odorata* in an area of *restinga* (coastal woodland) in the southern region of Brazil (Rosa *et al.* 1998) and the mean of 2.0 infructescences per individual in two populations of *B. odorata* in Uruguay (Rivas & Barilani 2004).

The variation in the number of fruits per infructescence (67-468) in two consecutive years within the same population (Tab. 1) and between the two populations studied (Tab. 2) is similar to that found by Moura (2008) in a population of *B. capitata* in the same region (range, 145-465; mean, 235.5) but lower than that reported for two populations of *B. odorata* in Uruguay (Rivas & Barilani 2004). The fruit production per individual was 6.5 times higher at the Fazenda Baixa site than at the Campos site (10.67 kg vs. 1.63 kg), and similar to the 8.50 kg reported by Moura (2008). The low fruit production at the Campos site might be related to the predominance of shallow, rocky soils in the area.

In the present study, 28% of the inflorescences of *B. capitata* generated fruits. This proportion is similar to that observed for other palms in tropical forests, such as *Chamaedorea alternans* H. A. Wendl. (Otero-Arnaiz & Oyama 2001) and *Geonoma epetiolata* H. E. Moore (Martén & Quesada 2001), but higher than the 13.9-16.2% observed for *Acrococomia aculeta* in areas of *cerrado* (Scariot *et al.* 1995). The difference in fruit production between the two populations studied here can be associated with intrinsic genetic characteristics or with environmental characteristics, such as availability of resources, nutrients in the soil, herbivory, competition and pollination (Crawley 2003). Reproduction can also vary between years (Miller 2002), and reproductive success is restricted by certain ecological factors, such as percentage of individuals reproducing, distance between reproductive individuals, availability of pollinators and climatic variations (Berry & Gorchov 2004). Only longer and more detailed studies can determine the effects of these factors in the reproduction of *B. capitata*.

The annual rate of 7.6 leaves produced per adult observed in the present study was high in comparison with that reported for other tropical palms: 4.6 for adult individuals of *Geonoma schottiana* Mart. (Sampaio & Scariot 2008); 2.2 for *Chamaedorea tepejilote* (Oyama 1993); 4.0 for *Prestoea montana* (Lugo & Battle 1987); and 1.3-2.6 for *Astrocaryum mexicanum* (Piñero *et al.* 1984). This value can be highly variable between years and between individuals in a population, and caution should therefore be used when applying these values in the growth estimate (Tomlinson 1979). The reproductive individuals at the Campos site are notably older than are those at the Fazenda Baixa site, which could also be one of the causes of the lower productivity observed at the Campos site. The pattern of low productivity at more advanced stages is considered evidence of senescence and, although rarely described in the literature, was also noted by Barot & Gignoux (1999) for *Borassus aethiopum*, a palm typical of wet savannas in the Ivory Coast.

Maturation and post-harvest quality of the fruits

The collection of *B. capitata* fruits at the nearly-ripe stage is the best option for transporting these highly perishable fruits to market. Immediate refrigeration of the fruits is an expensive and unfeasible strategy for the harvesters and for most of the sellers. The harvest of fruits at an initial stage of maturation or nearly-ripe stage is ideal for collectors, because market yield of the fruits is higher. However, the conditions under which these fruits are stored and the time from their collection to their sale to the end consumer should also be considered.

Conclusion

Fruit biometric parameters differ between the populations of *B. capitata* in *cerrado*. The productivity of fruits also differs between the study sites sampled and is related to the height of individuals and to their foliar biomass. The reproductive events, in contrast to leaf flushing, are temporally concentrated and influenced by the distribution of rainfall. Fruit biometrys can be employed as criteria for the selection of seed source trees for the production of seedlings for species reintroduction and increase population density, although the heritability of these characteristics is not guaranteed.

The best option to obtain fruits appropriate for commercialization is to collect infructescences with nearly-ripe fruits and to keep the fruits attached to the infructescences until ripening. This minimizes losses during transport and ensures a higher percentage of fruits appropriate for consumption.

Considering that *B. capitata* is intensely harvested and is an endemic species, the persistence of populations will depend on the land use and management to which these populations are submitted (examples of management practices are available in Lima *et al.* 2010). Long term studies are needed in order to determine sustainable levels of extraction and the influence of environmental and anthropic gradients on the structure and persistence of populations.

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