Journal of Experimental Agriculture International

41(4): 1-7, 2019; Article no.JEAI.52238
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Morphobiometry and Ecophysiology of *Caryocar coriaceum* Wittm. (Pequi) in Cerrado Areas of Northeast Brazil

Beatriz da Silva Rodrigues[1*], Maria do Amparo Ferreira[1], Tony César Sousa Oliveira[2] and Maria da Conceição Prado de Oliveira[1]

[1]*Federal University of Piauí, Teresina, PI, Brazil.*
[2]*University of São Paulo, Ribeirão Preto, SP, Brazil.*

Authors' contributions

This work was carried out in collaboration among all authors. Authors BSR and MCPO designed the study and managed the search. Author BSR wrote the first draft of the manuscript. Authors TCSO, MAF and BSR performed data analysis and interpretation. Authors MCPO, TCSO and BSR substantially added the concept and design of the study, data interpretation and contributed to manuscript preparation. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v41i430406
Editor(s):
(1) Dr. Rusu Teodor, Professor, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
Reviewers:
(1) Phillip P. Minnaar, Agricultural Research Council, South Africa.
(2) Miguel Guzman-Rivero, Universidad Mayor de San Simón, Bolivia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52238

Original Research Article

Received 15 August 2019
Accepted 18 October 2019
Published 09 November 2019

ABSTRACT

Many studies have reported that native plant species can contribute to ensuring food security in the world. Among the Brazilian species, the *Caryocar coriaceum* has a high utility value for the communities in Northeast Brazil but it is under threat due to the degradation of the Cerrado savannah. One way to mitigate threats is to produce large-scale seedlings. Thus, it was attempted to evaluate methods to overcome dormancy of *C. coriaceum* to increase and standardize germination and to analyze its morphobiometric characteristics. The fruits were weighed, measured and subjected to the selected treatments. Tests were performed to overcome dormancy The fruits were planted at a depth of 5 cm. The results showed that the fruits of *C. coriaceum* presented asymmetric frequency distribution with high variability for the characteristic of weight. However, a marked variation of the literature data was found. About the germination treatments tested in the

**Corresponding author: E-mail: beatrizrodriguesk888@gmail.com;*

laboratory, none was effective in overcoming dormancy, which may be due to the presence of inhibitory substances. Concerning seed planting, a germination index of 35% was recorded after 12 months. The conclusions suggest that there is a high phenotypic variability of the genus in the cerrado and probably the presence of germination inhibitors in seeds of this species, which should be addressed to ensure germination.

Keywords: Biodiversity; climate change; food security; germination.

1. INTRODUCTION

One of today's challenges is to mitigate the risks of climate change, variability and extreme climate events for food security [1]. The term food security is considered as a situation in which people at all times obtain physical, social and economic access to sufficient, safe and nutritious food, thus satisfying the nutritional needs of an active and healthy life [2].

Numerous studies have found strategies to ensure food safety in wild plant species [3,4,5] since they are used as a source of daily livelihood and health care [6]. Wild plant species can provide nutrients for human development, which in many cases have higher nutritional qualities than domesticated plant species [7].

Of the more than 400,000 wild plant species catalogued in the world, about 30,000 bears edible fruit, of which only 200 are consumed by humans [2]. In this scenario, Brazil is considered the holder of the greatest botanical diversity on the planet, with 15 901 species catalogued in herbariums [8]. This however only represents a fraction of the biodiversity of the Brazilian flora. One of the contributors to this wealth is the Cerrado biome, recognized as the most diverse savannah in the world [9].

This diversity is also manifested in the abundance of potentially economic species as a food source, medicinal properties, ornamental use, forage, apiaries, and logging [10]. Among the Cerrado species, *Caryocar coriaceum* Wittm. (Pequi), is endemic in the northeastern region of Brazil where it grows in abundance [11]. The fruit is widely consumed in natura or dishes.

However, the native Cerrado formations are being intensely degraded by anthropic activity, either by f crops or pastures, removal of wood but mainly the lack of knowledge and appreciation of the economic potential of plant species. In addition to non-compliance with environmental legislation [1]. Thus, when the ecosystem suffers aggression, the recovery of vegetation by succession may not occur and/or be very slow. Conditions favourable to environmental degradation will, therefore, persist [12].

This species which has the potential for future food security [13] is threatened because once the ecosystem has been altered, its dispersion is compromised [11]. A recovery option is based on the use of seedlings as it accelerates the succession process. However, one of the impediments to its production is dormancy; a common characteristic of plant species [14], which is considered a mechanism created by the plant to resist external factors; it is present in either the tegument, embryo, or caused by imbalance of the substances responsible for the inhibition or induction of germination [15].

This characteristic usually causea problem in the uniform attainment of seedlings, both in the natural environment and in nurseries [16]. This work aims to obtain morphological information about the dormancy of *C. coriaceum* to anticipate and standardize the germination for large-scale production and characterization of seeds.

2. MATERIALS AND METHODS

The fruits of *C. coriaceum* were collected in two stages; the first being performed during the first months of the year 2018, both at the São Francisco Farm (Fig. 1), located in the municipality of Curralinhos-PI (60 km from Teresina), coordinates 5°33'39.2'' S 42°56'45.7'' W, 126 meters above sea level. After collection, the fruits were packed in a plastic pouch and transported to the laboratory of plant ecophysiology of Universidade Federal do Piauí-UFPI (CMPP/Teresina-PI), where 25 fruits for their pyrenes and seeds were selected for morphology and biometrics evaluation.

The width (transverse diameter) and the length (longitudinal diameter) of the fruits, the pyrenes and the seeds were measured using a digital calliper for the biometric characterization and weighed separately using an analytical balance with an accuracy of 0.1.

Fig. 1. Geographical location of Fazenda São Francisco, Curralinhos-PI

The germination tests were performed in two stages, considering the different collection dates (January and February). The first one was carried out with fruits collected in January 2018. The processing was initially performed manually and whereafter the pyrenes were submitted to the treatments described in (Table 1).

The second stage of the germinative analysis was carried out with fruits collected in February 2018. The sample was submerged in water for 48 h to facilitate manual removal of the mesocarp. Then, the Pyrenes were allowed to dry for 48h at room temperature (25 ± 2°C and 60% RH), to facilitate the removal of the endocarp around the seed. The endocarp was removed with the aid of a "Tico-Tico" apparatus, through a fissure in the pyrene, and submitted to the treatments listed in (Table 2). After the treatments, the seeds and/or pyrenes were distributed in plastic trays (5.2 cm high, 23.5 in length and 14 cm wide), containing vermiculite as substrate and kept moist (the water placed corresponded to 60% of the capacity of retention).

For the field test, 150 ripe fruits (fallen fruits from the tree) were collected in December 2017 which is the beginning of the fruiting period. After collection, the fruits were left for 15 days in a dry, ventilated and shaded environment, to facilitate the removal of the mesocarp of the fruit. Subsequently, the pyrenes were planted in a ditch of 1 m^2 and arranged in such a way to leave a space between them twice the average diameter of the pyrenes to the depth of 5 cm and in a shaded environment, close to the place of collection of the fruits. Soil moisture was obtained by the Gravimetric method and the temperature with a maximum and minimum thermometer. Soil moisture was maintained so that the variation was between 50% (dry period) and 85% (rainy season) and the temperature ranged from 20 to 35°C.

Table 1. Treatments to which the pyrenes (endocarp + seed), from the first collection, were submitted

Treatment	Procedure	Number of seeds	Reference
T1	Control	25	-
T2	Soak in hydrochloric acid for 10 min.	25	Own authors
T3	Soak in the water at 100°C for 1 min	25	Adapt. de Abdo e Fabri [17]
T4	Cracked endocarp, subsequent soaking in water for 2 h	25	Próprio autor
T5	Soak in water for 72 h	25	Adapt. de Abdo e Fabri [17]

Table 2. Treatments to which the seeds of the second collection were subjected to

Groups	Number of seeds	Treatment
B1	10	Soak in gibberellic acid for 72 h
B2	10	Soak in gibberellic acid for 72 h
B3	10	Control

Data analysis was carried out through packages made available for the CRAN software R. Data on fruit biometrics was calculated: mean (MD), maximum (max), minimum (min), standard deviation (SD) and coefficient of variation (CV). The following germination percentages were analyzed: G = (N/100) x 100, where: N = number of seeds germinated at the end of the test. The data were submitted to the Shapiro-Wilk test to assess the normality of the data.

3. RESULTS AND DISCUSSION

The data showed a normal statistical distribution, and the analyzed fruits presented asymmetric frequency distribution with high quantitative variability in the characteristic of fresh mass (Table 3) and homogeneous data for longitudinal and transverse diameter (Table 3). Similar results in diameter characteristics were found in the work of Moura et al. [18] analyzing another species of this genus, *C. brasiliense.* Arlene and Medeiros [19], using fruits of *C. coriaceum*, observed similar values concerning the longitudinal diameter, showing fruits that ranged from 58 mm to 74 mm.

About the average fruit mass, the result found in this study can be compared to the values reported by Alves et al. [20] for *C. Brasiliense* from the Brazilian states of Tocantins, Goiás and Minas Gerais. The fruits of the region of Piauí have a mean H weight than those from Tocantins and Goiás. However, variations in the fresh mass of fruit from the regions of Minas Gerais and Goiás were higher than those found in the present study [20], indicating a greater variation in the populations in these regions for this species.

In another study by Ramos et al. [21] found similar values for the average fruit mass of *C. coriaceum* from the cities of José de Freitas-PI and Barras-PI, however, fruits from the municipality of Alto Longá-PI had higher values. These authors, currently studying fruits of *C. coriaceum* from the state of Maranhão, found that for the three cities where the fruits were collected (Afonso Cunha, Caxias and Timon), the mean values of mass were lower than those collected in the municipality of Curralinhos-PI. Moura et al. [18] also analyzed the biometrics of *C. brasiliense*, and found values different from those listed in (Table 3). Arrange of variations for fruit mass from 22 g to 484 g were obtained, indicating a variation in the population. Ramos et al. [21] found values varying from 116 g to 184 g.

The characteristics related to the pyrene did not present large variations, being the highest in fresh mass (MF) (Table 3). A greater variation was found by Alves et al. [20]. Ramos et al. [21] found lower mean MF values of *C. coriaceum* pyrene from Maranhão, when compared to those of the studied area. Fruit from the cities of Barras-PI and José de Freitas-PI had similar values of MF; but those of Alto Longá-PI had higher MF values [21]. For the characteristics related to seeds, the quantitative variation was also low, i.e. the largest related to MF (Table 3). The MF values were higher than those found by Alves et al. [20] in the states of Tocantins, Goiás and Minas Gerais (in *C. brasiliense*) and those found by Ramos et al. [21] in the cities of Piauí and Maranhão (in *C. coriaceum*).

Table 3. Biometry of *C. coriaceum* fruits, pyrenes and seeds from the city of Curralinho-PI. Fruits – measures. DLF: longitudinal diameter (mm); DTF: transverse diameter (mm); MF: total fresh mass (g). Pyirene – measurements. DLP: mean longitudinal diameter (mm); DTP: mean cross-sectional diameter; MF: total fresh mass (g). Seeds – measures. DLF: longitudinal diameter (mm); DTF: transverse diameter (mm); MF: total fresh mass (g)

Variables	Fruits			Pyrenes			Seeds		
	(mm)		(g)	(mm)		(g)	(mm)		(g)
	DLF	DTF	MF	DLP	DTP	MF	DLP	DTP	MF
Média	66.2	65.3	161.4	35.7	43.6	26.6	15.6	26.8	3.1
Mínimo	54.7	53.3	86.4	32.0	37.1	19.8	13.2	23.1	1.5
Máximo	80.7	91.4	300.0	39.0	51.4	40.0	17.9	32.0	4.5
Desvio padrão	7.5	10.5	68.0	2.1	3.2	5.2	1.2	2.6	0.6
CV %	11.3	16.1	42.1	6.5	9.0	1.,5	7.7	9.7	19.3

These results show that there is a wide morphological variation for fruit traits in the genus Caryocar L. When compared with the literature data. According to Moura et al. [18], this is since species of this genus are plants with wide geographic distribution, different environmental conditions may cause the species to have a high degree of phenotypic plasticity. Oliveira et al. [22] point out that, due to this marked variability among the populations of *C. coriaceum* and *C. brasiliense*, these are considered allogamous species.

To the germinative treatment, none were effective to overcome the dormancy of the studied species. Souza et al. [23] tested several methods for overcoming seed dormancy of the genus *Caryocar* L. The highest germination rates were obtained when the seeds had the endocarp cracked or removed, as well as those that were exposed to gibberellic acid. The authors also found that seeds treated with fungicide had a higher germinative rate, compared to controls. In the present study, these methods were not effective, with a germination rate equal to 0%.

One of the factors that may have led to this result is the presence of certain inhibitory chemicals, such as gibberellic acid [24]. However, Leão Peixoto and de Morais [25] also studied the dormancy of *C. coriaceum* using gibberellic acid and obtained low germination rates, close to 0%. Phenolic compounds may also be associated with inhibition of seed germination [26] since carbohydrate metabolism such as sucrose and maltose can prevent the dormancy process. Other factors, such as phenolic compounds in the tegument that control the intake of oxygen in the seed, can also be critical to germination [27].

Also, studies indicate that *C. coriaceum* has a secondary dormancy [19], when there is a natural alternation between the states of non-dormancy and numbness, where the seed establishes its total maturation after, for example, is planted throughout the year [28]. This response was observed in the germination results of the pyrenes planted in this study. It was possible to verify that the onset of twinning occurred after 10 months of assembly of the experiment; in the interval between December 20, 2017, and January 6, 2019, with a germination index of 35%. This value is higher than the values found in the laboratory, indicating the importance of the natural environment in the promotion of the germinative process, since studies indicate that, for the germinative process to occur, a series of metabolic activities are needed [28]. In a controlled environment, the germination process can be affected by several factors, among which are substrate, light, oxygen, pH and diurnal temperature, which cannot be simulated in a laboratory.

4. CONCLUSION

The morphometric data were homogeneous within the population, except for the weight of the fruits, which were heterogeneous. Comparing the data obtained with the literature data, it was possible to verify that there is a large variation in the morphometric data for different populations of pequi; a fact that can be attributed to allogamy present in the species of *Caryoca*r Genus. Also, the studied seeds presented higher MF values than the literature consulted, which may contribute to greater exploitation of this part of the fruit.

Regarding the part of overcoming dormancy in the laboratory, it is necessary to verify the presence of germination inhibitors in *C. coriaceum* seeds, as well as to identify the mechanism responsible for this inhibition, whereby seeking alternatives to overcome dormancy that allow germination in a shorter time than the planted experiment carried out.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52238