Acta Iguazu
ISSN: 2316-4093

Physical characterization of fruits and seeds of jambolan [*Syzygium cumini* (L.) Skeels] (Myrtaceae)

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Artigo enviado em 26/03/2017, aceito em 30/09/2017.

Abstract: The main physical and biometric characteristics of fruits and seeds of *Syzygium cumini* (L.) Skeels, and correlation estimates between these characteristics were investigate in this study. Mature fruits of *S. cumini* were collected from ten matrices trees in Marechal Cândido Rondon, Paraná, Brazil. The longitudinal and transversal diameters of 100 fruits and 100 seeds were measured. The mass of fresh and dry matter, water content of fruits and seeds, and pulp yield of the fruits were quantified. Data were analyzed by using descriptive statistics, adjustment of statistical distributions, and Spearman's correlation analysis. The *Syzygium cumini* (L.) Skeels ("jambolan") presents variation in fruit, pulp and seed mass, which can be explored for breeding projects and should be considered in the formation of seed lots that are more homogeneous. There were significant positive correlations between the fruit pulp yield (FPY) and the fresh fruit mass (FFM), dry fruit mass (DFM) and fruit water content (FWC). The *S. cumini* fruits present great socioeconomic potential for the food industry in Brazil due to the high pulp yield of the fruits (72.93 ± 7.41%). The high fruit pulp yield can be optimized with the selection of plants with fruits of greater fresh mass or dry mass or water content due to the high degree of association between these characteristics and the pulp yield.

Key words: jambolan, Brazilian Savannah, pulp yield.

Caracterização física de frutos e sementes de jambolão [*Syzygium cumini* (L.) Skeels] (Myrtaceae)

Resumo: Conduziu-se este trabalho, com os objetivos de determinar as características biométricas e físicas dos frutos e sementes de *Syzygium cumini* (L.) Skeels e estabelecer estimativas de correlação entre as variáveis. Os frutos maduros de *S. cumini* foram coletados em dez árvores matrizes, no município de Marechal Cândido Rondon (PR). Mediu-se o diâmetro longitudinal e transversal de 100 frutos e de 100 sementes de *S. cumini*. Quantificaram-se as massas de matéria fresca e seca, o teor de água dos frutos e sementes, e o rendimento de polpa dos frutos de *S. cumini*. Os dados foram analisados por meio de estatística descritiva, de ajuste de distribuições estatísticas e de análise de correlação de Spearman (rS). O jambolão apresenta variação na massa de frutos, polpa e sementes que podem ser

exploradas nos programas de melhoramento genético e devem ser consideradas na formação de lotes de sementes homogêneos. Os resultados evidenciaram que houve correlação significativa e positiva entre o rendimento de polpa e a massa fresca dos frutos, massa seca dos frutos e teor de água de frutos. Os frutos de *S. cumini* apresentam grande potencial socioeconômico para a indústria de alimentos no Brasil devido ao alto rendimento de polpa dos frutos (72,93 ± 7,41%). O alto rendimento de polpa dos frutos pode ser otimizado com a seleção de plantas com frutos de maior massa fresca ou massa seca ou teor de água, devido ao alto grau de associação entre essas características e o rendimento de polpa.

Palavras-chave: jambolão, Cerrado, rendimento de polpa.

Introduction

Syzygium cumini (L.) Skeels, Myrtaceae, is a fruit commonly known in Brazil as "jambolan" or "jamelão" that, when ripe, presents intense purple color – very attractive for industrial processing. It is a perennial plant, native from India, Ceylon, Malaysia, and Australia (Chandrasekaran and Venkatesalu, 2004), and currently, it has been widely cultivated in many countries. In Brazil, jambolan is widely cultivated as ornamental and shade plant in several states of the Southeast, Northeast and North regions (Migliato et al., 2006; Lorenzi et al., 2006; Soares et al., 2008). The fruit is small and has very attractive characteristics, especially the high anthocyanins content that gives the skin its intense purple color characteristic of ripe fruit (Brandão et al., 2011). As jambolan fruits are an excellent source of antioxidants, these have been included in the ranking of the fruits with the greatest nutraceutical potential (Brandão et al., 2011; Ayyanar and Subash-Babu, 2012; Veber et al., 2015). *Syzygium cumini* trees start flowering from September to November and flowers are scented, greenish-white, and small, about 5 mm in diameter. The fruits develop by May or June and are berries, oblong, 1.5 to 3.5 centimeters long, luscious, fleshy, and edible; each fruit contains a single large seed (Lorenzi et al., 2006). The fruit color changing from green to pink to blood red to dark-purple or nearly black as it matures. The fruit has a combination of sweet, mildly sour and astringent flavour and tends to colour the tongue purple (Ayyanar and Subash-Babu, 2012).

The large variability existing in tropical tree species from Myrtaceae family in respect to morphological and physical characteristics of fruits and seeds has been confirmed by several authors, such as in studies of Rebouças et al. (2008); Dresch et al. 2013; Ferraz et al. (2014). These studies are important to aid in the characterization of families or species of the same genus plants (Lorenzi et al., 2006; Zuffo et al., 2016), identification and certification of plant material used in seed analysis (Gusmão et al., 2006) and to contribute in studies of ecological

succession and regeneration of forest ecosystems (Rodrigues et al., 2006; Rebouças et al., 2008). However, given the great diversity of tree species there are few studies evaluating the physical characteristics of the fruits and seeds for species of the family Myrtaceae.

An improved understanding about tropical tree species is a requirement for their use in commercial plantation and agroforestry systems (Gusmão et al., 2006). Therefore, the objective of this study was to determine the main physical characteristics of fruits and seeds of jambolan [*Syzygium cumini* (L.) Skeels] (Myrtaceae), and to establish the correlations estimates among these characteristics.

Material and Methods

Mature fruits of *Syzygium cumini* (L.) Skeels ("jambolan") were collected from ten matrices trees, in an native forest area of the municipality of Marechal Cândido Rondon, located in the western region of the State of Paraná, Brazil (latitude 23º47'40" S, longitude 54º41'07" W and altitude of 420 m), during the rainy season, in January 2009. The regional climate is relatively warm and wet. The 30-year mean annual temperature is 21.4 °C with a July minimum of 14.7 °C and a January maximum of 28.6 °C, and mean annual precipitation of 1,500 mm.

The fruits were placed in polyethylene bags and taken to the Seed Technology Laboratory of Western Parana State University (UNIOESTE), in Marechal Cândido Rondon – PR, where the study was carried out immediately. In the laboratory, the fruits were previously selected, discarding those visually impaired or deformed, and a sample of 100 fruits was taken for measurement of physical characteristics.

The longitudinal and transversal fruit diameters were measured using a digital caliper with 0.01 mm accuracy, considering the largest diameter; fruit and pulp mass, in grams, was obtained by individual weighing in a digital precision balance with 210 g capacity and 0.0001 g accuracy; pulp mass, in grams, was measured using digital precision balance. Pulp mass was calculated as percentage of the fruit mass.

After the biometric characterization of the fruits, the seeds were manually extracted and then it was determined the longitudinal and transverse seed diameter, fresh and dry mass and water content of jambolan seeds using a digital caliper with 0.01 mm accuracy and digital precision balance with 210 g capacity and 0.0001 g accuracy. The water content (%) and dry mass (g) of fruits and seeds were determined by the oven dry method at 105 ºC (± 3 ºC), for 24 h (Brasil, 2009).

The biometric data of the fruits and seeds were analyzed using the adjustment of statistical distributions and descriptive statistics, who understood the measurements of

position (average, minimum and maximum values) and dispersion (coefficient of variation, skewness and kurtosis). Spearman's correlation coefficients *(*rS) were estimated at the level of 5% probability for the association between the biometric characteristics of fruits and seeds. All analyses were performed using BIOESTAT version 5.0 software for Windows (Ayres et al. 2007).

Results and Discussion

Some of the results of descriptive statistical analysis for the physical characteristics of the fruits and seeds of *Syzygium cumini* (L.) Skeels ("jambolan") are shown in Table 1. Mature fruit of jambolan presented average dimensions of 28.07 mm of longitudinal diameter, 16.67 mm of transverse diameter and 4.82 g of fresh mass (Table 1). The seeds presented 18.80 mm of longitudinal diameter, 9.35 mm of transverse diameter and 1.23 g of fresh mass (Table 1). The pulp (epicarp + mesocarp) represents about 73% of the fresh weight of the fruit, with an average value of 3.59 g. Seeds represent about 27% of the fresh weight of the fruit, with an average value of 1.24 g (Table 1). These characteristics were similar to fruits of guavira [*Campomanesia adamantium* (Cambess.) O. Berg – Myrtaceae] that presented fruit fresh mass of 3.77 g, longitudinal diameter of 22.74 mm and transverse diameter of 18.02 mm, while seeds weighed 0.50 g, observing the longitudinal and transverse diameter of 6.64 and 4.81 mm, respectively (Dresch et al., 2013).

Table 1. Physical characteristics of the fruits and seeds of jambolan [*Syzygium cumini* (L.) Skeels].

Characteristic	Average[1]	Minimum	Maximum	Skewness	Kurtosis	CV (%)
			Fruit			
Longitudinal fruit diameter (mm)	28.07±2.98	20.46	37.00	0.44	0.72	10.63
Transverse fruit diameter (mm)	16.67±2.34	10.64	26.64	0.47	2.34	14.08
Fresh fruit mass (g)	4.83±1.25	2.66	8.17	0.62	0.01	25.94
Dry fruit mass (g)	1.49±0.28	0.96	2.18	0.32	–0.93	18.78
Fruit water content (%)	68.30±3.52	58.40	75.17	–0.74	1.26	5.17
Fruit pulp yield (%)	72.93±7.41	56.63	86.06	–0.06	–0.75	10.17
			Seed			
Longitudinal seed diameter (mm)	18.80±2.11	14.47	24.80	0.49	0.36	11.27
Transverse seed diameter (mm)	9.35±0.89	7.34	11.40	0.11	–0.67	9.57
Fresh seed mass (g)	1.24±0.22	0.81	1.61	0.02	–1.34	17.90
Dry seed mass (g)	0.56±0.08	0.39	0.71	0.05	–0.85	14.51
Seed water content (%)	54.14±3.72	49.68	65.15	1.22	1.11	6.88

[1] Data refer to mean values (n = 100) ± standard deviation. CV: coefficient of variation.

The skewness and kurtosis values were close to zero (i.e., lower than 1.0) for the longitudinal fruit diameter (LFD), fresh fruit mass (FFM), dry fruit mass (DFM), pulp yield (FPY), longitudinal seed

diameter (LSD), transverse seed diameter (TSD) and dry seed mass (DSM) (Table 1). These findings indicate an approximately normal distribution for these variables. Evaluating the biometric characteristics of the fruit and seeds of maripa palm [*Attalea maripa* (Aubl.) Mart.], Zuffo et al. (2016) also found normal distribution for the variables here reported.

The values of the coefficients of variation ranging from 5.17% to 25.94% for fruits and 6.88 to 17.90% for *S. cumini* seeds (Table 1).

Coefficients of variation for water content of fruits (5.12%) and seeds (6.88%) and the transverse seed diameter (9.57%) indicated that the data observed in these variables have a more homogeneous distribution (less dispersed) than the fresh fruit mass and dry mass of the fruits and seeds whose values of the coefficients of variation were greater than 15% (Table 1). These results suggest that for maximum efficiency in industrial processing, the variability in fresh weight require proper selection of matrices plants and/or classification by mass after the harvest of *S. cumini* fruits. The fruits of higher fresh mass should be preferred for manufacturing, because they have higher percentage of pulp mass and therefore higher yield in processing.

The values of the variation coefficients presented here were similar to values reported by Zuffo et al. (2014) to the physical characteristics of baru (*Dipteryx alata* Vog.), Zuffo et al. (2016) in fruits and seeds of tarumarana (*Buchenavia tomentosa* Eichler) and maripa palm (*A. maripa*), and Zuffo et al. (2017) in canafistula (*Peltophorum dubium* (Sprengel) Taubert).

Fruits of *S. cumini* were slightly oblong, with fresh mass, longitudinal and transverse diameters ranging from 2.66 to 8.17 g, 20.46 to 37.00 mm and 10.64 to 26.64 mm, respectively (Table 1), predominating values between 16.19 to 21.35 g (Figure 1c), 25.97 to 28.73 mm and 13.30 to 18.64 mm (Figure 1b), of fresh mass, longitudinal and transverse diameters, respectively. The longitudinal and transverse diameters values were within the range reported by Ferraz et al. (2014) for *S. jambolanum* Lam. fruits. These authors showed that approximately 44% of the longitudinal diameter of the fruits showed values between 20.90 to 25.40 mm, and 49% of the transverse fruit diameter had values ranging from 14.90 to 16.40 mm. Morphological characterization of fruits can provide information on the handling and packaging of the jambolan, and more advanced stage of commercial and industrial exploitation, assisting in the design of machinery and equipment.

With respect to the frequency distribution for the fresh fruit mass (FFM), it can be verified that 80% of the fruits had values in three weight classes – i.e., from 16.19 to 21.35 g (Figure 1c). For the dry mass, at around 37% of the fruits had mass in the range of 1.16 to 1.36 g (Figure

1d). Around 53% of the fruits had water content in one humidity class ranging from 66.78 to 69.58% (Figure 1e).

Fruit pulp yield (epicarp + mesocarp) ranging from 56.62 to 86.06%, with approximately 64% of the fruits presenting values in three pulp yield classes between 66.43 to 81.15% (Figure 1f). The pulp yield values of *S. cumini* fruits are considered high and were within the fruit pulp yield range of other Myrtaceae. In guava-pear (*Psidium acutangulum*) and cagaita (*Eugenia dysenterica*), the pulp yield ranging from 55.01 to 75.98% (Andrade *et al.*, 1993) and 80 to 87% (Silva *et al.*, 2001), respectively. In cambuci (*Campomanesia phaea*), jambolan (*Syzygium jambolana*) and araçá-boi (*Eugenia stipitata*), the pulp yield of the fruits was 46.39 to 92.53% (Vallilo *et al.*, 2005), 60.8% (Ram, 1986) and 63% (Ferreira, 1992), respectively.

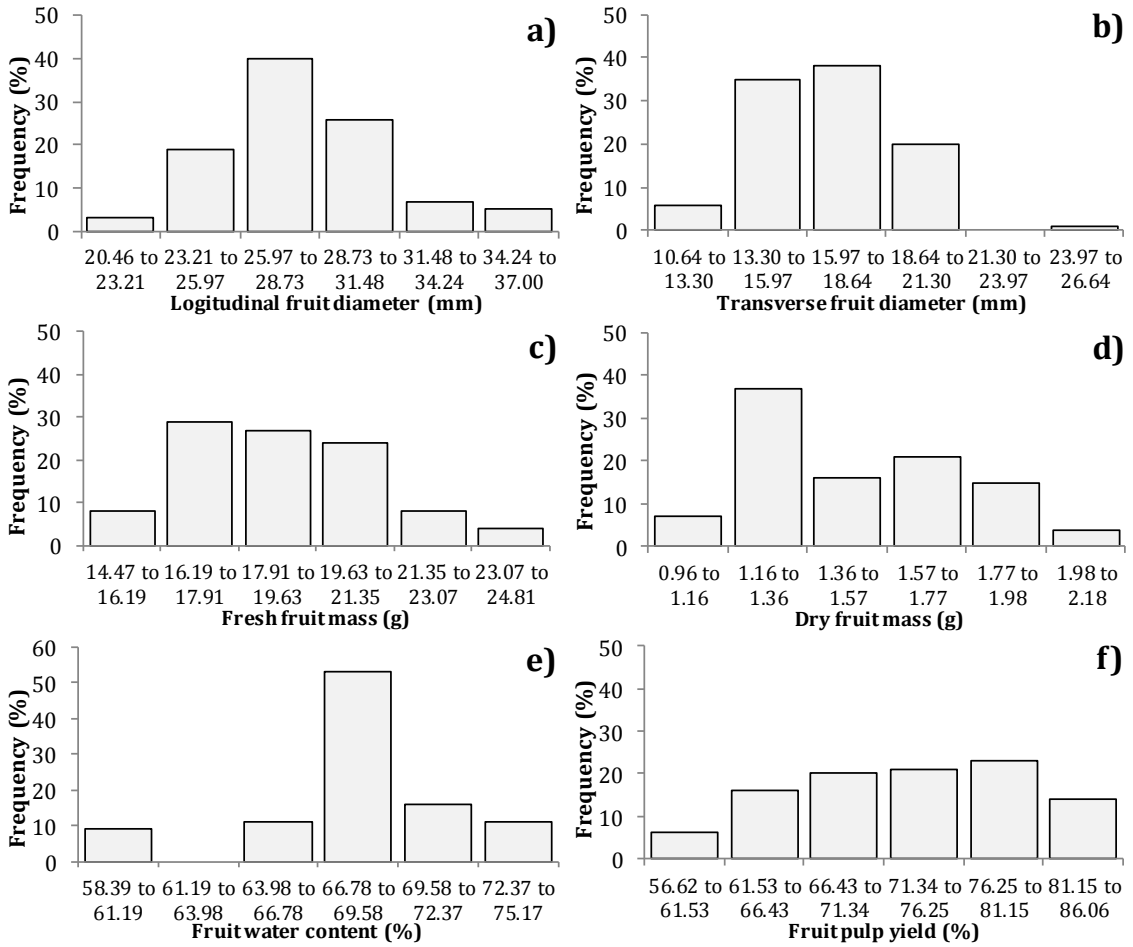

Figure 1. Distribution of frequencies for the different physical characteristics of the fruits measured: a) longitudinal fruit diameter (LFD); b) transverse fruit diameter (TFD); c) fresh fruit mass (FFM); d) dry fruit mass (DFM); e) fruit water content (FWC) and f) fruit pulp yield (FPY) of jambolan [*Syzygium cumini* (L.) Skeels] collected in the municipality of Marechal Cândido Rondon, PR, Brazil. N = 100 fruits.

For the traits obtained in the jambolan seeds, about 80% of the seeds presented longitudinal seed diameter (LSD) values comprised in three distribution classes, – i.e., from 16.19 to 21.35 mm (Figure 2a), with average value of 18.80 mm (Table 1). The average value of transverse seed diameter (TSD) was 9.35 mm, and 72% of the seeds had TSD values in three size classes (from 8.01 to 10.04 mm) (Figure 2b).

For the fresh seed mass (FSM), at around 44% of the seeds had mass in the range of 0.94 to 1.20 g, while 23% of the seeds had mass in the range of 1.34 to 1.47 g (Figure 1d). These results show that 67% of the seeds had FSM in only three classes of frequency distribution (Figure 2c), with a mean value of 1.23 g. This mean value of FSM is higher than that reported by Ferraz *et al*. (2014), which showed that the mean values of FSM of the *S. jambolanum* Lam. fruits were 0.78 g.

With respect to the frequency distribution for the dry seed mass (DSM), at around 31% of the seeds had mass in the range of 0.49 to 0.55 g (Figure 2d), with average value of 0.56 g. Around 42% of the seeds had water content in one humidity class ranging from 49.68 to 52.26% (Figure2e). The seed water content was the physical characteristic with the lowest variation observed between the fruits and the seeds of *S. cumini* (Table 1).

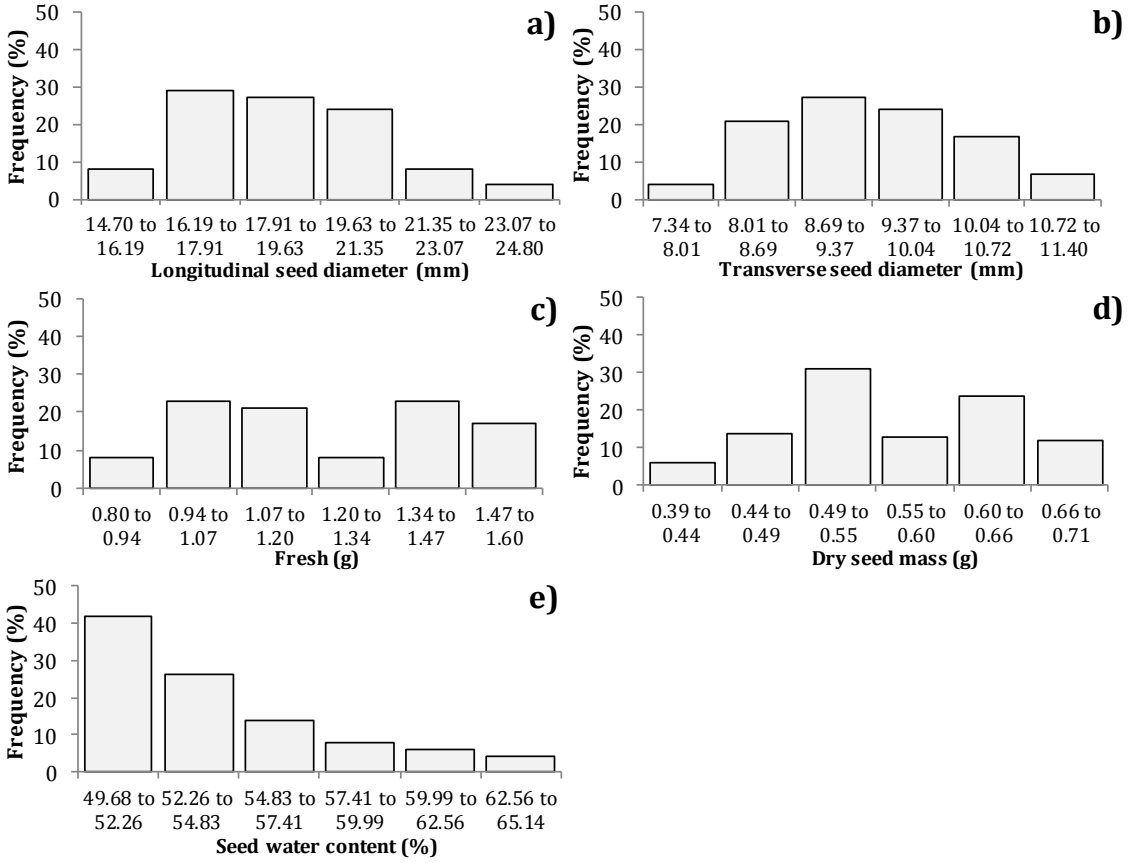

Figure 1. Distribution of frequencies for the different physical characteristics of

the seeds measured: a) longitudinal seed diameter (LSD); b) transverse seed diameter (TSD); c) fresh seed mass (FSM); d) dry seed mass (DSM); and, e) seed water content (SWC) of jambolan [*Syzygium cumini* (L.) Skeels] collected in the municipality of Marechal Cândido Rondon, PR, Brazil. N = 100 seeds.

In addition to the study of the measurement of physical characteristics of fruits and seeds, it is also necessary to evaluate the association between these characteristics (Zuffo *et al*., 2016). These authors also report that the association between the characteristics is important because it allows to verify the degree of interference of a characteristic in another characteristic of economic interest, as well as to practice the indirect selection. In this context, the Spearman's rank correlation coefficient *(*rS) is used to express the degree of association between two numerical characteristics. A positive or negative Spearman correlation coefficient corresponds, respectively, to an increasing or decreasing monotonic trend between two variables (*X* and *Y*).

The values obtained for the Spearman's correlation coefficient of the physical characteristics of the fruits and seeds of *S. cumini* (Table 2) indicated that there was a positive and significant association between the longitudinal fruit diameter (LFD) with the transverse fruit diameter (TFD) and seed water content (SWC). The transverse fruit diameter correlated significantly with the fruit water content (FWC), whereas the fresh fruit mass (FFM) correlated significantly with the dry fruit mass (DFM), fruit water content (FWC) and fruit pulp yield (FPY). The dry fruit mass (DFM) correlated significantly with the fruit water content (FWC) and fruit pulp yield (FPY); the fruit water content (FWC) with the fruit pulp yield (FPY), fresh seed mass (FSM), dry seed mass (DSM) and seed water content (SWC). The longitudinal seed diameter (LSD) with the transverse seed diameter (TSD); the fresh seed mass (FSM) with the dry seed mass (DSM) and seed water content (SWC); and the dry seed mass (DSM) with the seed water content (SWC).

The highest values of the Spearman's correlation coefficients (rS) were observed between the fresh fruit mass (FFM) and dry fruit mass (DFM) (rS=0.949; p=0.01), between the fresh seed mass (FSM) and dry seed mass (DSM) (rS=0.864; p=0.01), and between fresh fruit mass (FFM) and fruit pulp yield (FPY) (rS=0.794; p=0.01) (Table 2). Based on these results, it is possible to identify and select *S. cumini* fruits with higher pulp yield by other physical characteristics such as fresh fruit mass (FFM), dry fruit mass (DFM) and fruit water content (FWC). Therefore, the selection of plants with fruits of greater fresh or dry mass or water content favors the breeding programs of the species, since, the selection of plants that have fruits

with higher values of some of these characteristics, resulted in the increase of pulp yield.

Table 2. Spearman's rank correlation coefficient *(*rS) between the different physical characteristics of the fruits and seeds of jambolan [*Syzygium cumini* (L.) Skeels].

	LFD	TFD	FFM	DFM	FWC	FPY	LSD	TSD	FSM	DSM
TFD	0.699**									
FFM	–0.133^{NS}	0.039^{NS}								
DFM	–0.232*	–0.073^{NS}	0.949**							
FWC	0.172^{NS}	0.341**	0.598**	0.357**						
FPY	–0.147^{NS}	–0.011^{NS}	0.794**	0.761**	0.390**					
LSD	–0.240**	–0.359**	0.137^{NS}	0.178^{NS}	0.0008^{NS}	0.075^{NS}				
TSM	–0.052^{NS}	–0.146^{NS}	0.007^{NS}	0.005^{NS}	0.0009^{NS}	–0.057^{NS}	0.268**			
FSM	0.067^{NS}	0.006^{NS}	0.110^{NS}	0.060^{NS}	0.283**	–0.459**	0.103^{NS}	0.098^{NS}		
DSM	–0.074^{NS}	–0.062^{NS}	0.119^{NS}	0.121^{NS}	0.191*	–0.392**	0.110^{NS}	0.141^{NS}	0.864**	
SWC	0.194*	0.129^{NS}	0.154^{NS}	0.058^{NS}	0.356**	–0.275**	0.008^{NS}	–0.008^{NS}	0.727**	0.366**

^{NS}: not significant. *: *P* = 0.05. **: *P* = 0.01. LFD: longitudinal fruit diameter. TFD: transverse fruit diameter. FFM: fresh fruit mass. DFM: dry fruit mass. FWC: fruit water content. FPY: fruit pulp yield. LSD: longitudinal seed diameter. TSD: transverse seed diameter. FSM: fresh seed mass. DSM: dry seed mass. SWC: seed water content.

On the other hand, there was a negative and significant correlation between longitudinal fruit diameter (LFD) with the dry fruit mass (DFM) and longitudinal seed diameter (LSD); transverse fruit diameter (TFD) with the longitudinal seed diameter (LSD) (CLS); and fruit pulp yield (FPY) with the fresh seed mass (FSM), dry seed mass (DSM) and seed water content (SWC) (Table 2). These results indicate that there is an inversely proportional relation between these characteristics. The highest values of the Spearman's correlation coefficients (rS) were observed between the fruit pulp yield (FPY) and fresh seed mass (FSM) (rS = –0.459; p=0.01). The increase in the values of these physical characteristics are undesirable for the economic exploitation of the *S. cumini* fruits, since the pulp is the only part of the fruit which is consumed. In this sense, the improvement of this characteristic should be prioritized in breeding programs.

The knowledge of the degree of association between two variables allows defining the interference of the selection performed in one characteristic in another, as well as the indirect selection for difficult-to-measure characteristics (Zuffo *et al*., 2016). Thus, according to the results obtained in this study, it is possible to verify that some physical characteristics of the fruits and seeds evaluated in the *S. cumini* "jambolan" presented a high correlation, being possible to practice direct and

indirect selection for these characteristics.

Conclusions

The *Syzygium cumini* (L.) Skeels ("jambolan") presents variation in fruit, pulp and seed mass, which can be explored for breeding programs and should be considered in the formation of seed lots that are more homogeneous.

The *S. cumini* fruits present great socioeconomic potential for the food industry in Brazil due to the high pulp yield of the fruits (72.93 ± 7.41%).

The high fruit pulp yield can be optimized with the selection of seed with fruits of greater fresh mass or dry mass or water content due to the high degree of association between these characteristics and the pulp yield.

Acknowledgements

To CAPES (Coordination for the Improvement of Higher Education Personnel) for financial support and providing scholarship for the second author.

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