Propriedades físicas dos grãos de feijão e híbridos de mamona em relação ao sistema de cultivo no Centro-Oeste brasileiro

Pysical properties from common beans grains and castor bean hybrids regarding the cultivation system in Brazilian Mid-West

Propiedades físicas de los granos de frijol común y de los híbridos de ricino con respecto al sistema de cultivo en el Medio Oeste brasileño

Received: 14/07/2020 | Reviewed: 13/08/2020 | Accept: 19/08/2020 | Published: 23/08/2020

Cristiane Fernandes Lisboa
ORCID: https://orcid.org/0000-0002-9930-8800
Universidade Federal Rural da Amazônia, Brasil
E-mail: cflisboa.engenharia@gmail.com
Itamar Rosa Teixeira
ORCID: https://orcid.org/0000-0001-6936-5823
Universidade Estadual de Goiás, Brasil
E-mail: itamar.texeira@ueg.br
Deyner Damas de Aguiar Silva
ORCID: https://orcid.org/0000-0002-6130-9525
Instituto Federal de Ciência e Tecnologia Goiano, Brasil
E-mail: deyner_damas@agronomo.eng.br
Luís César da Silva
ORCID: https://orcid.org/0000-0001-9582-3998
Universidade Federal de Viçosa, Brasil
E-mail: silvaluisc@yahoo.com
Alessandro Guerra Silva
ORCID: https://orcid.org/0000-0002-9556-0312
Universidade de Rio Verde, Brasil
E-mail: silvaag@yahoo.com.br
Ana Paula Freitas Coelho
ORCID: https://orcid.org/0000-0002-4144-8966
Universidade Federal de Viçosa, Brasil
E-mail: ana.p.coelho@ufv.br

Fernanda Lamede Ferreira de Jesus
ORCID: https://orcid.org/0000-0002-9183-6326
Universidade Federal Rural da Amazônia, Brasil
E-mail: fernanda.lamede@ufra.edu.br
Arthur Carniato Sanches
ORCID: https://orcid.org/0000-0003-2379-0634
Universidade Federal da Grande Dourados, Brasil
E-mail: arthursanches@ufgd.edu.br

Resumo

O objetivo deste trabalho foi avaliar as propriedades físicas de cultivares de feijão e híbridos de mamona, cultivadas em consórcio e monocultura. O delineamento experimental aplicado foi o de blocos casualizados, em esquema fatorial 4 x 2 + 6, com três repetições. Os tratamentos foram constituídos por grãos provenientes de quatro cultivares de feijão (BRS Pérola, BRS Pitanga, BRS Esteio e BRSMG Realce), produzidos em sistema consorciado com duas cultivares híbridas de mamona de pequeno porte (Tamar e Ag Ima 110204), acrescidas de tratamentos adicionais constituídos por material genético de feijão e mamona em monocultivo. Para avaliar os diferentes tratamentos quanto às propriedades físicas dos grãos foram considerados a massa aparente específica, tamanho (eixos octogonais a, bec), esfericidade e circularidade dos grãos. O consórcio de cultivares de feijoeiro com híbridos de mamona influenciou na massa aparente específica do feijoeiro. Nenhuma das propriedades físicas da mamona foi influenciada pelo consórcio de cultivares de feijão. O monocultivo de feijão e híbridos de mamona influenciou as propriedades físicas estudadas. Por fim, os grãos de feijão mantiveram maior comprimento em monocultivo e maior esfericidade e circularidade em consórcio com híbridos de mamona.

Palavras-chave: *Phaseolus vulgaris* L.; *Ricinus communis* L.; Grãos; Consórcio; Monocultivo.

Abstract

The aim of this study was to evaluate the physical properties of cultivars of common beans and castor bean hybrids, grow under intercropping and monocropping. The experimental outline applied was casual blocks in factorial scheme 4 x 2 + 6, with three replications. The treatments were constituted by grains coming from four cultivars of common beans (BRS Pérola, BRS Pitanga, BRS Esteio e BRSMG Realce), produced under intercropping system with two hybrid small sized castor cultivars (Tamar and Ag Ima 110204), added up by additional treatments constituted by genetic material of common beans and castor under monocropping. To evaluate the different treatments regarding the physical properties of the grains it has been considered the specific apparent mass, size (octagonal axles a, b and c), sphericity and circularity of grains. The cultivars intercropping for common beans with castor bean hybrids influenced the specific apparent mass of beans. None of the physical properties from castor grains were influenced by the cultivar intercropping of common beans. The monocropping of common beans and castor bean hybrids influenced the studied physical properties. Finally, the common beans grains held the greatest length under monocropping and greater sphericity and circularity when under intercropping with castor bean hybrids.

Keywords: *Phaseolus vulgaris* L.; *Ricinus communis* L.; Grains; Intercropping; Monocropping.

Resumen

El objetivo de este estudio fue evaluar las propiedades físicas de cultivares de frijol común e híbridos de ricino, cultivados bajo intercalación y monocultivo. El esquema experimental aplicado fue bloques casuales en esquema factorial 4 x 2 + 6, con tres repeticiones. Los tratamientos estuvieron constituidos por granos provenientes de cuatro cultivares de frijol común (BRS Pérola, BRS Pitanga, BRS Esteio y BRSMG Realce), producidos bajo sistema de intercalación con dos cultivares híbridos de ricino de pequeño tamaño (Tamar y Ag Ima 110204), sumados por adicionales tratamientos constituidos por material genético de frijol común y ricino en monocultivo. Para evaluar los diferentes tratamientos en cuanto a las propiedades físicas de los granos se ha considerado la masa aparente específica, tamaño (ejes octagonales a, byc), esfericidad y circularidad de los granos. Los cultivares intercalados de frijol común con híbridos de ricino influyeron en la masa aparente específica de frijoles. Ninguna de las propiedades físicas de los granos de ricino fue influenciada por el cultivo intercalado de frijoles comunes. El monocultivo de frijol común e híbridos de ricino influyó en las propiedades físicas estudiadas. Finalmente, los granos de frijol común mantuvieron la mayor longitud bajo monocultivo y mayor esfericidad y circularidad cuando se intercalaron con híbridos de ricino.

Palabras clave: *Phaseolus vulgaris* L.; *Ricinus communis* L.; Granos; Cultivos intercalados; Monocultivo.

1. Introduction

The common beans (*Phaseolus vulgaris, L.*) is one of the main vascular plants produced in Brazil and in the world. In the harvest as of 2018/2019, Brazil produced approximately 2,3 million tons of common beans, and a productivity average of 1,032 kg ha^{-1}, considered low (CONAB, 2020). Its importance extrapolates the economic aspects, for its relevance as a factor of nutritional and feed security, above all for needy classes of the population (EMBRAPA, 2012).

Because it is an inexpensive source of proteins, iron, calcium, zinc, complex B vitamins, carbohydrates, fibers and lysin. This way there is a great agronomic interest in the world for planting the common beans (Mesquita et al., 2007; Angioi et al., 2010).

As for castor planting (*Ricinus communis* L.), its commercial product is the oil extracted from its seeds, which contains 90% of ricinoleic fatty acid, the only hydroxylated fatty acid, which grants the oil singular characteristics, with value added and makes it possible a broader industrial usage, turning the castor plant into a strategic cultivar for the country (Beltrão et al., 2007).

Amongst the countless industrial usages of the castor oil, there are also: drugs, cosmetics, pigments, paint and varnish formulas, fungicide and insecticide, anti-corrosion protection, lubricants, greases, rubber and resin plasticizers, cleaning products, biodiesel raw material, etc. (De Oliveira et al., 2005; Costa et al., 2004). Despite all this potential to be used in industry, the Brazilian production is still small and it has been downsizing in the last years, producing 30.6 thousand tons of grains, with only 658 kg ha^{-1} of productivity in the harvest of 2018/19 (CONAB, 2020).

Common beans and castor productivity is strongly related to weather behavior, cultivars applied and machinery used in the production process, and in the majority of cases are pointed out as responsible factors for low productivity for both cultivars. Adding up the fact that common beans and castor planting is carried mostly by small producers, using low tech alongside with seed and equipment handling (CONAB, 2015).

Small producers are used to grow common beans in intercropping with castor. This cultivation system is a viable alternative, for optimization and use of land (Jesen et al. 2010) making it possible a greater area production and better space usage, nutrients and sunlight, besides the control of infestations of plants, plagues and diseases (Souza & Resende, 2003).

The intercropping between common beans and castor bean hybrids present a great potential when used by the producer, once, Cardoso et al. (2013) studying the influence of zinc doses in nutrition and cultivar production of beans BRS Pérola under intercropping with castor cultivar BRS Paraguaçu, large sized and irregular maturity, verified maximum productivity for common beans cultivar of approximately 1,500 kg ha^{-1}. However, Lisboa et al. (2018) studying common beans cultivar productivity BRS Pérola, BRS Pitanga, BRS Esteio and BRSMG Realce under intercropping with castor bean hybrids Tamar and Ag Ima 110204, small sized, uniform plant height, higher productive potential, precocity in relation to traditional materials, uniform maturity and the possibility of being mechanically harvested (Sá, 2015), obtained average productivity of 2,212.7 kg ha^{-1} for common beans cultivars , corresponding to a add up of 32.21% superior to the one found under intercropping involving non-hybrid cultivars.

Despite all this potential, one of the main obstacles for a wide use of the intercropping between common beans and castor cultivars is the development of proper machines for carrying out this kind of cultivation system and also, by the lack of information in the literature regarding the physical properties of the grains under intercropping and in special, of castor bean hybrids in cultivation system for they are a new product in the market, above all, in Brazilian Cerrado.

The physical properties of the grains can also be influenced by edaphoclimate in the harvest region, as observed in the culture of castor by Goneli (2008). The patterning of the physical properties of grains from the same species is important to adequate the machinery involved in the production chain, to set up control and quality parameters, as well as the prediction of the acceptance by the final consumer (Silva et al., 2003; Santos, 2014).

This way, studies about the physical properties of the grains which evaluate the interactions between genetic material, the place and the cultivation system are of utmost importance to evaluate the quality patterns and the development of effective machines for the production and processing steps. After all that was mentioned, the aim of this study was to evaluate the physical properties of the cultivar grains of common beans and castor bean hybrids, harvested under intercropping and monocropping, under edaphoclimatic conditions in Cerrado region in Goiás, Brazil.

2. Material and Methods

The grains used in this research were from the experiment performed in field by Lisboa et al. (2018). This way, all information about the experiment performance and harvest, can be found in the aforementioned study.

The outline with casual blocks was applied in factorial scheme 4 x 2 + 6, with three replications. The treatments were constituted by four cultivars of common beans widely used by producers (BRS Pérola [carioca grain] - type II/III – undetermined growth and semi-erect size; BRS Pitanga [purple grain] type II - undetermined growth and erect size; BRS Esteio [black grain] type II - undetermined growth and erect size; BRSMG Realce [tabby grain] type I - determined growth and erect size), in intercropping with two hybrid small sized castor cultivars (Tamar and Ag Ima 110204), added up by additional treatments constituted by genetic material of common beans and castor under monocropping.

The aforementioned cultivars of common beans and castor bean hybrids, presented the following characteristics: BRS Pérola - cycle of 85 to 95 days and semi-prostate size; BRS Esteio – cycle of 80 to 90 days and erect size; BRSMG Realce - cycle of 75 to 85 days and erect size; BRS Pitanga – cycle of 85 to 95 days and semi-erect size. The castor bean hybrid Tamar – cycle of 140 to 160 days, height 1.60 a 1.70 m, sympodial growth and first raceme appearance at 30 DAE; The castor bean hybrid Ag Ima 110204 – cycle of 140 to 160 days, height 1.70-1.80 m, sympodial growth and first raceme appearance at 35 DAE.

The grains after harvest, observing the different treatments mentioned above, were subjected to evaluation of the following physical properties: grain dimension, sphericity, circularity and specific apparent mass.

To determine the dimensions of the grains, a digital caliper was used, with 0,01mm precision, and the dimensions from three orthogonal axles were taken (length (a), width (b) and thickness (c) (Resende et al., 2008; Nunes, 2009), of 25 grains from each treatment, considering an average of four replications. The dimensions of size were also used in the calculation of sphericity, according to suggested equation by Mohsenin, (1980) (equation 1) and of circularity, considering the natural stationary position of the grain (equation 2):

$$\varphi = \frac{(a \times b \times c)^{1/3}}{a} \tag{1}$$

Where:

φ = sphericity, %;

a = measure of the bigger axle of the grain, (mm);

b = measure of the normal axle to axle a (mm);

c = measure of the normal axles to axles a e b (mm).

$$C = \frac{d_i}{d_C} * 100 \qquad (2)$$

di = diameter of the bigger circumscribed circle (axle b), in mm; and
dc = diameter of the smaller circumscribed circle (axle a), in mm.

The determination of the specific apparent mass was performed in six replications for each parcel, a scale of specific apparent mass was used. The scale has a cylinder with a known volume, which allows to determine specific apparent mass with a simple grain weighing, which are placed in the container.

The data gathered were subjected to variation analysis by the F test, at 5% of probability, and when pertinent the Skott-Knott test was carried out, at 5% of probability. For such statistics procedure, the program SISVAR 5.3 was used (Ferreira, 2010).

3. Results and Discussion

It has been observed by the variance analysis (Table 1) that the interaction F x M presented a significant difference at 5% of probability by the F test only for specific apparent mass. Regarding experimental precision, it has been observed the low variance coefficient, according to the criteria of Gomes (1990).

Table 1. Variance Analysis of the average values of specific apparent mass (ρ), size (a, b e c), sphericity (φ) and circularity (C) of grains of common beans produced under intercropping system with castor hybrid under monocropping.

Variance Source	L.G.	QM					
		ρ (kg m^{-3})	a (mm)	b (mm)	c (mm)	ϕ (%)	C (%)
Block	2	529.19^{ns}	0.06^{ns}	0.02^{ns}	0.04^{ns}	0.51^{ns}	0.72^{ns}
Common bean cultivars (F)	3	183.46^{ns}	17.71**	0.92**	0.31**	161.17**	271.98**
Castor bean hybrids (M)	1	1.91^{ns}	0.02^{ns}	0.08^{ns}	0.03^{ns}	0.06^{ns}	0.75^{ns}
F x M	3	1016.22*	0.07^{ns}	0.02^{ns}	0.03^{ns}	1.49^{ns}	1.00^{ns}
Error	14	226.56	0.11	0.01	0.02	0.49	1.73
Additional Treatments (AT)	-	593.39^{ns}	8.42**	0.68**	0.18**	76.74**	133.47**
Intercropping x AT	-	6.47^{ns}	0.95**	1.48^{ns}	1.16^{ns}	94.40**	86.14**
CV (%)	-	1.97	3.16	1.82	2.82	1.07	2.14

L.G. Liberty Grades; *Significative at 5% probability by the F test; ** Significative at 1% by the F test; ^{ns} Non-Significative; CV (%) Variance Coefficient from common beans under intercropping with castor bean hybrids. F_{cal} for intercropping interaction x TA. Source: Ferreira (2010).

Analyzing the effect of intercropping between cultivars of common beans and castor bean hybrids (Table 2), it has been observed that a significant difference has not occurred for specific apparent mass amongst the common beans cultivars under intercropping with the hybrid Ag Ima, however, the common beans cultivars under intercropping with the hybrid Tamar presented a significative difference for specific apparent mass, considering that the cultivars BRS Pitanga and BRS Pérola presented the higher average values.

Table 2. Averages of specific apparent mass (ρ), in kg m^{-3}, of cultivar grains of common beans under intercropping with castor bean hybrids.

Castor bean hybrids	Beans cultivars			
	Esteio	Pitanga	Pérola	Realce
Tamar	747.16Bb	787.42Aa	770.11Aa	754.02Ba
Ag Ima	776.65Aa	755.19Ab	765.08Aa	764.03Aa
Averages	761.90	771.30	767.59	759.02

Averages followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically by Scott-Knott test at 0.05 probability level. Source: Ferreira (2010).

Throughout the performance of the experiment, still in the field phase, it has been observed that the cultivars BRS Esteio and BRS Pitanga, under intercropping with the hybrids Ag Ima and Tamar, respectively, presented better vegetative vigor, which may have contributed to a greater cumulation of biomass in those grains, showing that the intercropping between these cultivars have not harmed the development of the plants and may have contributed in mass gain by the grains. For Matos et al. (2009) the architecture of the plant is constituted of an inherent factor to genotype and it could be related to the vegetal productivity, in a way that plants which show more vigor have a tendency of cumulating more biomass in the grains.

Regarding the characteristics of size and shape for the common beans cultivars conducted under monocropping, it has been observed significant differences for all evaluated physical properties (Table 3).

Table 3. Averages for size (a, b, c), from sphericity (φ) and from circularity (C) of grains from the common beans cultivars under monocropping system.

Common bean cultivars	a (mm)	b (mm)	c (mm)	φ (%)	C (%)
Esteio	9.74c	6.48d	4.98a	69.76a	66.48a
Pitanga	9.41c	5.91b	4.53b	67.11c	62.76b
Pérola	10.30b	6.92a	5.04a	69.00a	67.21a
Realce	13.09a	6.90c	5.04a	58.76b	52.72c
Average	10.64	6.55	4.90	66.16	62.29

Averages followed by the same low case letter in the column, do not differ statistically by Scott-Knott test at 0.05 probability level. Source: Ferreira (2010).

In relation to sphericity and circularity, the cultivars BRS Esteio and BRS Pérola presented higher average value for those characteristics and differ statistically from the remaining cultivars.

Soares Junior, et al. (2015), evaluated the physical and chemical properties from red beans grains, traditional cultivar kidney beans, observed different values for the orthogonal axles A, B, e C, to be equal to 10.14, 6,98 and 5.48 mm, respectively. Jesus et al. (2013) evaluated the sphericity and circularity of seeds from cultivars of beans BRS Valente and BRS Pontal in function of water content, observing average values of 71.32% for sphericity and 68.30% for circularity for BRS Valente and 66.96% for sphericity and 65,99% for circularity for BRS Pontal. To Araújo et al., (2014), values of sphericity and circularity below 80% disable grain classification under spherical or circular.

Amongst the diverse beans' genotypes available in the market, mainly those with lesser degree of genetic enhancement, morphological differences may be spotted in any part of the plant, inclusive weight and size of grains (Drun et al., 2017), according to what has been observed in the study of these authors. Although such variations may be intrinsic to genetics, to environmental conditions, to harvesting factors or to the combination of them all, they can represent a difficulty for the different stages of the production process. Accordint to Nikoobin et al. (2009) and Isik e Isik (2008) the physical properties of the grains are relevant for the dimensioning of equipment and cultivation system, handling, transportation, drying and storage, as well as the acceptance of the grain into the consumer market.

Moreover, according to Melo et al. (2007), bigger beans grains with strainers above 12 (12/64'' pol.) proved to have more acceptance into the market. Furthermore, packing companies starting 1998 adopted the tendency to join the "brand to the product" to the kind of grain, alongside with a whiter coloration, and consumers associated bigger grains to a better efficiency while in the pan, constituting a higher expanse after they are cooked (Carbonell et al., 2010).

Comparing the cultivation system (Table 4) it can be observed that the measures concerning length, sphericity and grain circularity of beans grains were influenced by the cultivation system, considering that monocropping yielded grains with a higher average value for length, whereas intercropping yielded grains with higher average value for sphericity and circularity.

Table 4. Averages for size (a), sphericity (φ) and circularity (C) for common beans grains under monocropping and intercropping

Cultivation System	a (mm)	φ (%)	C (%)
Monocropping	10.63a	66.16b	62.29b
Intercropping	10.62b	68.80a	66.04a
Average	10.63	67.48	64.17

Averages followed by the same low case letter in the column, do not differ statistically by Scott-Knott test at 0.05 probability level. Source: Ferreira (2010).

Intraspecific and interspecific competitively under intercropping cultivation system tend to be more expressive, what may have appeased a smaller length to the beans grains in this research, this hypothesis corroborates to the affirmatives observed in a study conducted by Oliveira Filho et al., 2016. As a consequence, for smaller length measures, the grains appeared to be more spherical and circular, for such characteristics are inversely proportional (Mohsenin, 1980).

The physical properties of the hybrid grains of castor under intercropping with common beans were not influenced by the intercropping system as it can be observed in the interaction (F x M) (Table 5). Regarding experimental precision, it has been observed a lower variance coefficient, according to the criteria adopted by Gomes (1990).

Table 5. Variance analysis from the averages of the specific apparent mass (ρ), size (a, b e c), sphericity (φ) and circularity (C) of hybrid grains of castor produced under intercropping system with common beans cultivars under monocropping.

Variance source	L.G.	QM					
		P	A	b	c	φ	C
Block	2	160.2372 ^{ns}	0.0463^{ns}	0.0176^{ns}	0.0179^{ns}	0.2599^{ns}	0.6216^{ns}
Common bean cultivars (F)	1	309.4501^{ns}	0.0297^{ns}	0.0346^{ns}	0.0211^{ns}	0.7688*	1.9015*
Castor bean hybrids (M)	3	133.6861 ^{ns}	0.5430**	0.1785**	0.0137^{ns}	19.3860**	61.6321**
F x M	3	205.8961 ^{ns}	0.0248^{ns}	0.0131^{ns}	0.0022^{ns}	0.1974^{ns}	0.6991^{ns}
Error	14	341.5006	0.0329	0.0126	0.0086	0.1766	0.4254
Additional Treatments (TA)	-	18.1656 ^{ns}	0.4760*	0.0067^{ns}	0.0037^{ns}	7.1504**	23.2067**
Intercropping x TA	-	0.5432**	3.4871^{ns}	0.1362**	1.2469^{ns}	1.4715^{ns}	1.5027^{ns}
CV (%)	-	3.9168	1.48	1.24	1.52	0.59	0.89

L.G. Liberty Grades; *Significative at 5% probability by the F test; ** Significative at 1% by the F test; ^{ns} Non-Significative; CV (%) Variance Coefficient from castor bean hybrids under intercropping with common beans cultivars. F_{cal} for intercropping interaction x TA. Source: Ferreira (2010).

In relation to additional treatments (AT), which consisted in the monocropping for castor bean hybrids, it has been observed a significant difference for length, sphericity and circularity. Regarding intercropping interaction x AT, it has shown a significant difference for density and width (Table 5).

It can be observed in Table 6 that the hybrid Ag Ima presented a higher average value for length and sphericity, whereas the hybrid Tamar presented a higher average value for circularity.

Table 6. Averages for size (a), sphericity (φ) and circularity (C) for castor bean hybrids under monocropping system.

Castor bean hybrids	a (mm)	φ (%)	C (%)
Tamar	11.87b	72.43a	75.26a
Ag Ima	12.39a	74.24b	71.33b
Average	12.13	73.33	73.29

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i9.6709

Averages followed by the same low case letter in the column, do not differ statistically by Scott-Knott test at 0.05 probability level. Source: Ferreira (2010).

Comparing both cultivation system for castor bean hybrids, it has been observed that under monocropping grains belonging to castor bean hybrids presented higher average of specific apparent mass, and when under intercropping with beans cultivars these grains presented higher width (Table 7).

Table 7. Averages from specific apparent mass (ρ) and from size (b) of castor bean hybrids grains under monocropping system and intercropping with common beans plants.

Cultivation System	ρ (Kg m^{-3})	b (mm)
Monocropping	478.30 a	8.87 b
Intercropping	471.80 b	9.06 a
Average	475.05	8.96

Averages followed by the same low case letter in the column, do not differ statistically by Scott-Knott test at 0.05 probability level. Source: Ferreira (2010).

Reis et al. (2010), working with castor cultivar Paraguaçu, found superior values for specific apparent mass (ρ), 865.19 Kg.m^{-3}. Regarding grain width of the castor seeds of BRS Nordestina, studied by Lucena et al. (2010), it has been observed superior averages, 11.93 mm. Whereas Nobre et al., (2014), working with castor cultivar BRS Energia, found widths equal to 8.5 mm.

In general, it was possible to observe in this research that only the specific apparent mass from common beans cultivars were significantly influenced by the intercropping with the hybrid Ag Ima presented higher average value for this characteristic, indicating that this cultivar presented lower impact in the characteristics of the common beans grains.

On the other hand, the physical properties of the grains for castor bean hybrids were not significantly influenced by the intercropping with common beans cultivars. This shows that, the use of intercropping among hybrid cultivars of castor and common beans can be applied without significant changes in physical properties of the produced grains.

Finally, under monocropping, the castor bean hybrids presented significant difference for length, sphericity and circularity, and that the hybrid Ag Ima presented higher average for length (12.39 mm) and the hybrid Tamar presented a higher average value for sphericity (72.43%) and circularity (75.26%). Furthermore, with the data observed in this research, it is feasible to dimension proper strainers for the harvest of castor bean hybrids.

Taking these questionings into account, one may say that the use of intercropping system is viable for agriculture production, for it has yielded good quality common beans grains, not influencing significantly the majority of its physical properties, such as length, width, thickness, sphericity and circularity. Moreover, the common beans grains presented aspects regarding good quality for human consumption with lack of heavy defects such as dead insects, moldy, acid and germinated grains which are indicators of quality for this type of product stablished by the Normative Instruction Nº 12/2008 (MAPA, 2008). Regarding castor bean hybrids grains, they did not have any of their physical properties significantly influenced by the intercropping system, and besides that, they presented a good conservation status and did not present a general moldy aspect, fermentation and rancidity which are the characteristics that classify allotments of castor according to Ordinance Nº65/1993 (MAPA).

4. Conclusions

The intercropping of common beans cultivar and castor bean hybrids influences the specific apparent mass of beans grains, that is, the hybrid Ag Ima yields a higher average value for this characteristic.

The physical properties of castor grains are not influenced by the intercropping with common beans cultivars.

The monocropping of common beans and castor bean hybrids influences the length, width, thickness, sphericity and circularity of the grains.

Common beans grains presented a higher length under monocropping and higher sphericity and circularity when under intercropping with the hybrids of the castors Tamar and Ag Ima. The castor grains presented a larger specific apparent mass under monocropping and higher width measures when under intercropping with the common beans.

For future work, it is recommended to develop, based on research such as this, equipment for harvesting areas with a consortium system, especially with regard to specialized machines for harvesting castor beans, thus minimizing losses during harvesting.

Acknowledgments

To National Council for Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES), Instituto Mato-

Grossense do Algodão (IMAMT), Kaiima and Universidade Estadual de Goiás for supporting this research project.

Declarations of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Angioi, S. A., Rau, D., Attene, G., Nanni, L., Bellucci, E., Logozzo, G., NegrI, V., Spagnoletti Zeuli, P.L & Papa, R. 2010. Beans in Europe: origin and structure of the European landraces of Phaseolus vulgaris L. *Theoretical and applied genetics*, 121, 829-843.

Araujo, W. D., Goneli, A. L. D., Souza, C. M. A., Gonçalves, A. A. & Vilhasanti, H. C. B. 2014. Propriedades físicas dos grãos de amendoim durante a secagem. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, 18(3), 279-86.

Beltrão, N. E. M., Azevedo, D. M. P., Lima, R. L. S. & Queiroz, W. N. 2007. In: Azevedo, D. M. P., & Beltrão, N. E. M. In: Embrapa Informação Tecnológica. *O agronegócio da mamona no Brasil*, Campina Grande, 44-72.

Carbonell, S. A. M., Chiorato, A. F., Gonçalves, J. G. R., Perina, E. F., & Carvalho, C.R.L. 2010. Tamanho de grão comercial em cultivares de feijoeiro. *Ciência Rural*, Santa Maria, 40 (10), 2067-2073.

Companhia Nacional de Abastecimento. 2016. *12º Levantamento da safra Brasileira de grãos 2015/2016*. Recuperado de http://www.conab.gov.br/conteudos.php?a=1253&>.

Companhia Nacional de Abastecimento. 2020. *5º Levantamento da safra Brasileira de grãos 2019/202*0,1-25.

Costa, H. M., Ramos, V. D., Abrantes, T. A. S., Castro, D. F., Visconte, L. L.Y., Nunes, L. C. R. & Furtado, C. R. G. 2004. Efeito do óleo de mamona em composições de borracha natural contendo sílica. *Polímeros*, São Carlos, 14 (1), 46-50.

Oliveira, D., Luccio, M. D., Faccio, C., Dalla, C.R., Bender, J. P., Lipke, N., Amrogismki, C., Dariva, C., & Oliveira, J. V. 2005. Optimization of alkaline transesterification of soybean oil and castor oil for biodiesel production. *Applied Biochemistry and Biotechnology*, 121 (7), 553-560.

Drun, R. P., Grigolo, S., Fioreze, A. C. C. L. &, Fioreze, S. L. 2017. Parâmetros produtivos do feijão vermelho em função do tamanho de sementes. *Colloquium Agrariae*, 13 (3), 41-48.

Empresa Brasileira de Pesquisa Agropecuária. 2012 a. Informações técnicas para o cultivo do feijoeiro-comum na Região Central-Brasileira: 2012-2014. *Documentos Embrapa*, 1, 15.

Ferreira, D. F. 2010. *Sisvar - Sistema de análise de variância*. Versão 5.3, Lavras.

Gomes, F. P. 1990. Curso de estatística experimental, *Nobel*, São Paulo,

Goneli, A. L. D. 2008. Variação das propriedades físico-mecânicas e da qualidade da mamona (*Ricinus communis* L.) durante a secagem e o armazenamento. 1-199. *Tese*,Universidade Federal de Viçosa.

Jesen, E. S., & Peoples, M. B. 2010. Hauggaard-Nielsen, H. Faba bean in cropping systems. *Field Crops Research*, 115, 203- 216.

Jesus, F. F., Souza, R. T. G., Teixeira, G. C. S., Teixeira, I. R.& Devilla, I. A. 2013. Propriedades físicas de sementes de feijão em função de teores de água. *Engenharia na agricultura*, Viçosa, 21(1).

Lisboa, C. F., Silva, D. D. A., Teixeira, I. R., Silva, A. G. & Mota, J. H. 2018. Agronomic characteristics of common bean and castor bean hybrids in intercropping and monocropping. *Engenharia Agrícola e Ambiental*, 22 (3), 200-205.

Lucena, A. M. A., Severino, L. S., Beltrão, N. E. M., & Bortoluzi, C. R. D. 2010. Caracterização física e química de sementes da mamoneira cv. brs nordestina pela cor do tegumento. *Revista Brasileira . Ol. Fibras*, Campina Grande, 14 (2), 83-90.

Matos Filho, C. H. A., Gomes, R. L. F., Rocha, M. M., Freire Filho, F. R., & Almeida, A.C. 2009. Potencial produtivo de progênies de feijão-caupi com arquitetura ereta de planta. *Ciência Rural*, 39 (2), 348-354.

Melo, L. C., Melo, P. G. S., Faria, L. C., Diaz, J. L. C., Peloso, M. J. D., Rava, C. A., & Costa, J. G. C. 2007. Interação com ambientes e estabilidade de genótipos de feijoeiro-comum na Região Centro-Sul do Brasil. *Pesquisa Agropecuária Brasileira*, Brasília, 42, 715-723.

Mesquita, R. F., Corrêa, D. A., Abreu, P. M. C., Lima, Z. A. R., & Abreu, B. F. A. 2007. Linhagens de feijão (*Phaseolus vulgaris* L.): Composição química e digestibilidade protéica. *Ciência e agrotecnologia*, 31 (2), 1114-1121.

Ministério da Agricultura, Pecuária e Abastecimento. *Portaria 12/2008*. Recuperado de https://www.embrapa.br/busca-de-publicacoes/-/publicacao/949273/manual-de-classificacao-do-feijao-instrucao-normativa-n-12-de-28-de-marco-de-2008.

Ministério da Agricultura, Pecuária e Abastecimento. *Portaria 65/19***93**. Recuperado de <http://sistemasweb.agricultura.gov.br/sislegis/action/detalhaAto.do?method=visualizarAtoPortalMapa&chave=1144760946>.

Mohsenin, N. N. 1980. Thermal properties of foods and agricultural materials. *Gordon & Breach science Publeshers*, London, 407.

Nikoobin, M., Mirdavardoost, F., Kashaninejad, M., & Soltani, A. 2009. Moisture- dependet physical properties of chickpea seeds. *Journal of Food Process Engineering*. 32, 544-564.

Nobre, D. A. C., Silva Neta, I. C., David, A. M. S. S., Gonçalves, N. P., & Amaro, H. T. R. 2014. Desempenho físico e fisiológico de sementes de mamona produzidas no norte de Minas Gerais. *Revista Agrarian*, Dourados, 7(24), 218-225.

Nunes, D. M. C. 2009. Propriedades físicas, térmicas e aerodinâmicas de grãos de quinoa (*Chenopodium quinoa willd*). *Dissertaçã***o,** Universidade Estadual de Goiás, Anápolis.

Oliveira Filho, A. F., Bezerra, F. T. C., Pitombeira, J. B., Dutra, A. S., & Barros, G. L. 2016. Eficiência agronômica e biológica nos consórcios da mamoneira com feijão-caupi ou milho. *Revista Ciência Agronômica*, 47(4), 729-736.

Percentage of contribution of each author in the manuscript

Cristiane Fernandes Lisboa – 25%

Itamar Rosa Teixeira – 15%

Deyner Damas de Aguiar Silva – 10%

Luís César da Silva – 10%

Alessandro Guerra Silva – 10%

Ana Paula Freitas Coelho – 10%

Fernanda Lamede Ferreira de Jesus – 10 %

Arthur Carniato Sanches – 10 %