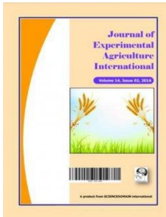

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Evaluation of Morphometry, Chemical Composition and Physiological Quality of Castor Seed of Different Cultivars and Orders of Racemes

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JAC, KPL and ASS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LAS, NFH and AHMS wrote manuscript. Authors JAC, JGS and NAEP managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: It was aimed to evaluate the physical, physiological quality and the chemical composition of castor seeds of different cultivars originating from different orders of racemes.
Study Design: The experimental design used was the completely randomized design with four repetitions.
Place and Duration of Study: The present research was developed in the Laboratory of Seed Analysis and Seedlings in the Center for Food Science and Technology of the Federal University of Campina Grande (UFCG), Campus Pombal, PB, Brazil, between the period of March to November of 2011.

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Methodology: The study was conducted using seven cultivars of castor seeds, BRS Nordestina, BRS Energia, BRS Paraguaçu, AL Guarany 2002, IAC Guarani, IAC 80 and IAC 202, from different racemes. The seeds were submitted to the tests of humidity, the weight of thousand seeds, germination, first germination count, biometry, chemical composition, emergence and emergence speed index.

Results: It was not observed significant differences for the variables of ash content, seed length, emergence and emergence speed index. For the other variables, significant differences were observed by the Tukey test at 5% probability.

Conclusion: The seeds originated from primary racemes presented greater weight of thousand seeds and physiological quality. The protein content of seeds originated from primary, secondary and tertiary racemes was variable according to cultivar. The seeds originated from primary and secondary racemes presented a greater oil content. The seeds width was influenced by the racemes order only in the cultivars of BRS Nordestina and BRS Paraguaçu, where that seed originated from secondary and primary racemes presented greater width, respectively. The seeds originated from primary and tertiary racemes presented greater thickness, however, it was variable according to cultivar. The order of raceme interferes in the physical and physiological quality, as well as in the chemical composition of the castor seeds.

Keywords: Ricinus communis L.; vigor; biometry; oil content; protein content.

1. INTRODUCTION

Among the promising oleaginous for biodiesel production, the castor (*Ricinus communis* L.) stands out as an interesting option of semi-arid regions, because of its ability to produce reasonably well under conditions of low rainfall [1], becoming an important alternative of work and income for farmers in these regions. Moreover, its oil content is more dense and viscous than that from other plants such as palm, sunflower and cotton, being the only one in the nature soluble in alcohol, it is versatile in terms of application, and can be used in the plastic, resins, enamels, fibers, cosmetics and pharmaceuticals industry [2].

The plants of castor are polymorphic, with the habit of sympodial growth, undetermined, with continuous flowering and production. In general, these species are cultivated as an annual culture, with the emission of several inflorescences throughout its cycle [3]. The harvest process according to [4], is carried out in a fractional way in function of the formation of different orders of racemes and depends on the sum of the caloric units (degree-day).

Castor seeds are rich in oil, with contents ranging from 45 to 50%, being the main component of oil, ricinoleic acid (Table 1). A large amount of hydroxides contained in such a component imparts unique characteristics desirable for use in industrialized products, such as stability, high viscosity, oxidative stability, alcohol solubility and low-temperature solidification [5].

These species are considered rustic, however, regarding of seed germination, the selected varieties for cultivation present, in general, unevenness and low percentage [6]. The viability of castor seeds can be affected by dormancy which according to [7], can be caused by fruit position in the plant, the fruit in the infructescence or even the seed in the fruit, as a consequence of dormancy, it will entail to germination failures, slow emergence and uneven growth of plants. Besides that, according to [1], the physiological quality of castor seeds is influenced by the position of raceme in the plant.

Characteristic morphological factors of the seed itself as color, size, firmness and the chemical composition, also can influence its vigor [8]. The temperature, which alters the water absorption by the seed and biochemical reactions which regulate the metabolism involved in this process, also can influence the percentage and the speed of germination in castor seeds [9].

To obtain a suitable plant stand and high productivities in a crop of castor, it is essential to use seeds of high physical, physiological and sanitary quality [10]. In this context, it was aimed to evaluate the physical, physiological quality and the chemical composition of seeds of castor seeds of different cultivars positioned in primary, secondary and tertiary racemes, aiming to highlight its viability and vigor.

2. MATERIALS AND METHODS

The present research was developed in the Laboratório de Análise de Sementes e Mudas in the Centro de Ciências e Tecnologia Agroalimentar of the Universidade Federal de Campina Grande (UFCG), campus Pombal, PB, using castor seeds of these cultivars, BRS Nordestina, BRS Energia, BRS Paraguaçu, AL Guarany 2002, IAC guarani, IAC 80 and IAC 2028.

The seeds were produced in the Comunidade Monte Alegre, located in the city of Pombal, Paraíba, placed to 06º46' "S" and 37º48' "W", with an altitude of 184 meters [11] in the period of March to November of 2011. The climate, according to Köppen's classification is Aw, which means, hot and wet with summer/fall rains, annual rainfalls around 800 mm and thermal amplitude less than 5ºC [12]. In the experimental period, the rainfall was 563 mm, with irregular distribution, concentrating on the months of March of July and October to November.

The soil in the area was classified as Neossolo Flúvico. Prior to sowing the crops was performed a soil analysis with depth of 0-30 cm for soil and growing area physical-chemical characterization [13]. Samplings were carried out to obtain a composed sample which results were: pH ($CaCl_2$) = 6.17; P = 11 mg dm^{-3}; K^+ = 0.23 cmolc dm^{-3}; $Al3^+$ = 0.0 cmolc dm^{-3}; Ca^{2+} = 4.10 cmolc dm^{-3}; Mg^{2+} = 2.20 cmolc dm^{-3}; Na^+ = 0.05 cmolc dm^{-3}; H + Al = 2.15 cmolc dm^3; organic matter = 26 g kg^{-1}; sand, silt and clay corresponded to 755; 87 e 158 g kg^{-1}, respectively.

The fertilizing was carried out in pits, it was applicated 60 kg ha^{-1} of nitrogen, 40 kg ha^{-1} of phosphorus and 40 kg ha^{-1} of potassium, respectively, using as sources, urea, simple superphosphate and potassium chloride, following values from [14]. The foundation fertilizing was carried out in the sowing moment applying all phosphorus and potassium and 1/3 of nitrogen recommended. The remaining N was split in two times and applied in cover at 40 and 60 days after sowing (D.A.S).

The seeds were harvest when reached the physiological maturity point (150 days after the anthesis), with water content around 13% and, posteriorly, processed and stored in zipped plastic bags at the temperature of 4º C during all analysis' period. It was considered as treatments the different orders for racemes, which means, primary, secondary and tertiary racemes, which was used completely randomized experimental design with four repetitions.

To evaluate seeds physical, physiological quality and chemical composition, were carried out the following evaluations:

- Weight of thousand seeds: It was used eight samples write 100 seed for each treatment, where the weight was obtained by a precision analytical balance, according to a recommendation from Rules for Seed Analysis [15].
- Germination test: The seeds were disinfested in 2% sodium hypochlorite solution of one minute. Next, were sowed in germitest paper previously moistened with distilled water, in an equivalent water volume of 2.5 times the weight of the dry substrate. It was used four subsamples of 25 seeds, on germitest paper, after making the rolls, they were packed in transparent plastic bags, and placed in a germination chamber type B.O.D in a temperature of 25ºC [15]. The percentage of germinations was evaluated at 14 days after sowing and the results expressed in percentage of normal seedlings.
- First germination count: It was jointly determined with the germination test, being the counts made at seven days after sowing and the results expressed in percentage.
- Germination speed index: It was jointly determined with the germination test with diary counting until the 14 days after the installation of the experiment. The formula proposed by [16] was used.
- Biometry: It was evaluated the seeds dimensions (length, width, thickness) with the aid of digital caliper, with 4 repetitions of 50 seeds for each treatment.
- Oil content: initially the castor' seeds were macerated with the aid of pistil and mortar. From this material was collected 3 g in an extraction cartridge, then transferred to the extractor of Soxhlet type, previously filled with Hexane reagent. The equipment was coupled to the other components of the extraction set (flat bottom flask and heating plate), to obtain the greater possible fraction of extract. About 20 (twenty) refluxes of reagent were adopted, between the bottom flask and the Soxhlet, corresponding to 5 hours. The bottom flask was taken to a kiln (105ºC) for a period of

2 hours and then transferred to desiccator with silica gel until its cool to room temperature and, finally, weighed in analytical balance. The weight of oil was determined by subtracting the bottom flask weight from the value obtained (bottom flask + oil). The percentage of castor oil was calculated multiplying the oil mass by 100 and the result divided by the seed' mass [17]. Two repetitions were conducted for each treatment. The results were expressed in percentage.

- Protein content: 0.2 g of the macerated sample was weighed and added 0.05 M sulfuric acid and catalytic mixing in kjeldahl tubes, the tubes were placed in a digester for about 20 minutes and set to cool at room temperature, after cooling it was added 40 ml of water and 3 drops of phenolphthalein under stirring, it was transferred for a distillation equipment and added 20 ml of 63% sodium hydroxide solution, after collecting 40 ml of the distillate and titrated in a 0.1 M of HCl solution [17]. The results were expressed in percentage.
- Ash content: It was used a 5 g of macerated sample, then it was placed in porcelain crucibles previously dried in muffle at 500ºC and weighed in analytical balance. After a period of 48 hours of muffle the crucibles were removed and weighed in analytical balance [17]. The results were expressed in percentage.
- Seedlings emergence: 150 seeds were used, divided into three replicates of 50 seeds, sown 0,05 m depth in ridges (9.5 x 0.65 x 0.2 m, respectively LxWxT) at field. The evaluations were carried out from the 14 to 21 days after sowing, then it was determined the total percentage of emerged seedlings.
- Emergence speeds index: It was jointly determined with normal seedlings emergence. Diary counts of the number of emerged seedlings was carried out, considering those with two completely open leaflets, until the stabilization of the booth. It was calculated the IVE [16].

The averages were submitted to analysis of variance and when significant by the F test at $p \leq 0.01$ e $p \leq 0.05$, and when significant, the averages were compared by Tukey's test at 5% of probability. To carry out the statistical analysis was used the R statistic software.

3. RESULTS AND DISCUSSION

3.1 Summary of Variance Analysis

From the analysis of variance, it was possible to observe that in ash content, in length of seeds, in emergence and emergence speed index do not had difference by Tukey's test at 5% of probability, independent of the cultivar and the raceme order (Table 1), the other variables presented significance response to the raceme order.

3.2 Weight of a Thousand Seeds

Regarding to the weight of thousand seeds (Fig. 1), it was observed that the cultivars BRS Energia, IAC – 80, IAC – Guarani, AL – Guarany and IAC – 2028 presented seeds with lower weigh as the racemes were harvested, the seeds from the primary raceme presented a greater weight of thousand seeds than the seeds from the secondary and tertiary raceme, the last ones also differing statistically from itself, the seeds from the secondary raceme presented a weight greater than the seeds from the tertiary raceme.

The seeds from the cultivar BRS Nordestina harvested from the primary and secondary raceme do not presented significant weight difference, however, the seeds from the tertiary raceme had a lower weigh in comparison with seeds from the other racemes (Figure 1). The seeds from the cultivar BRS Paraguaçu harvested from the secondary and tertiary raceme did not differ among themselves in terms of weight of thousand seeds, however, the seeds from the primary raceme presented a greater weight than the other racemes.

The differences of weight founded in seeds from different racemes (Fig. 1), mainly in those who were produced in terminal racemes of the cycle, which presented a lower weight of thousand seed, can be related to the decrease of the photosynthetic apparatus, which reduces the production and displacement of photoassimilates to the drains in development. This distribution of photoassimilates between organs can be altered during the filling of grains and the limitations of the biomass gain can occur in a moment of the development of the plant [18].

Table 1. Table of analysis of variance of the following variables: weight of thousand seeds (WTS), germination (GER), first germination count (FGC), germination speed index (GSI), length (LEN), width (WID) and thickness (THI) of seed, protein content (PRO), oil content (OIL), ash content (ASH), seedlings emergence (EME) and emergence speed index (ESI) of castor seeds from different cultivars and raceme order. Pombal, PB-Brazil 2018

S. Var.	DF	WTS (g)	GER (%)	FGC (%)	GSI	LEN (mm)	WID (mm)	THI (mm)	PRO (%)	OIL (%)	ASH (%)	EME (%)	ESI (%)
Raceme	2	**	**	**	**	ns	*	**	*	**	ns	ns	ns
Residue	6		-	-	-	-	-	-	-	-	-	-	-
Total	8		-	-	-	-	-	-	-	-	-	-	-
C.V. (%)	-	2.3	7.9	11.7	7.9	1.0	3.0	1.3	7.1	2.8	10.3	20.2	22.6
O. Aver.	-	366.5	86	78	2.98	13.58	9.44	6.41	16.8	47.4	3.2	75	4.05

**significant to 5% ($p\leq0.05$); **significant to 1% ($p\leq0.01$), ^{ns}not significant; S. Var.: Source of Variation; DF: degrees of freedom; C.V. (%)= coefficient of variation. O. Aver.: Overall average*

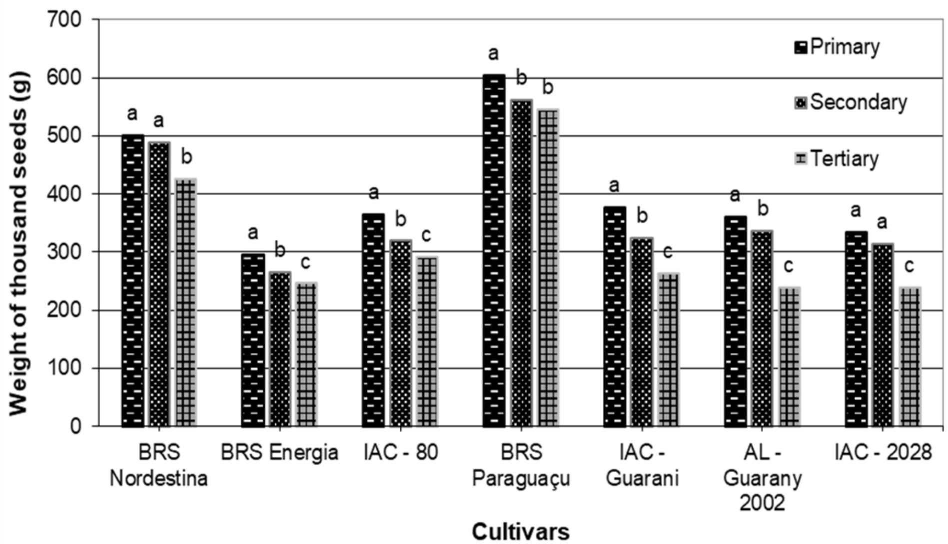

Fig. 1. Weight of thousand castor seeds from different cultivars from different orders of racemes. Pombal, PB-Brazil. 2018. *Averages followed by the same minute letter in each cultivar, did not differ by the Tukey test at 5% ($p\leq0.05$) probability

3.3 Germination

For germination was possible to observe that the seeds from the cultivar BRS Paraguaçu presented a germination statistically similar, regardless of the order of racemes (Table 2). For the cultivars IAC – 80 and AL – Guarany 2002, the seeds from the primary (96 and 87%, respectively) and secondary (98 and 94%, respectively) racemes presented a greater percentage of germination, in comparison with those from the tertiary raceme (66 and 62%, respectively) (Table 2). For the cultivars IAC – Guarani and IAC-2028, the seeds from the primary raceme presented statistically the greatest percentage of germination (95 and 98%, respectively), while the seeds from the secondary raceme presented an intermediate percentage of germination (86 and 82%, respectively), and the seeds from the tertiary raceme presented statistically the lowest percentages of germination (Table 2).

Based on these results, it was possible observe that for most of the cultivars the seeds from the tertiary raceme presented the percentage of germination lower than the minimum standards for commercialization which is 80% [19], that is, the racemes order (in this case the tertiary) influenced in a negative way the seeds germination, which did not obtain minimum germination rate to be commercialized.

For the cultivar BRS Nordestina, it was observed a different behavior from other cultivars observed, the seeds from the secondary raceme presented a greater percentage of germination (97%), however, they were statistically similar to those which were produced in the primary raceme (89%), while the seeds from the tertiary raceme presented the lowest percentage of germination (81%), but, statically similar to those from the primary raceme (Table 2).

It is important to emphasize that the seeds from the primary and secondary racemes for all cultivars presented percentage of germination greater than 80%, while those from the tertiary raceme, for the cultivars IAC – 80, IAC – Guarani, AL – Guarany 2002 and IAC -2029, presented a percentage of germination of 66%, 67%, 62% and 70%, respectively (Table 2).

These low percentages of germination values for these cultivars may have occurred because of the seeds dormancy caused by the hardness of the integument [20,21]. Seeds which present this kind of dormancy show an irregular germination, it may affect negatively the plants stand [22]. Although, according to [20], the castor seeds dormancy are overcome through storage, being practically null after nine months.

The results obtained in this study disagree with those describe by [7] and by [1], who observed that the castor seeds percentage of germination is not influenced by the order of raceme. The racemes is formed into different soil and climatic conditions, before and during its formation the seeds are exposed to different environmental conditions, and the quality may be affected [7].

This can explain the results observed in this research, where the seeds formed in different racemes presented different values of germination (Table 2). In this context, it is important to emphasize the importance of harvesting the castor seeds in a staggered way, with the objective of reducing the damage to the quality of seeds [23].

Table 2. Percentage of germination of castor seeds from different cultivar and orders of racemes. Pombal, PB-Brazil 2018

	Germination (%)		
Cultivar	**Racemes**		
	Primary	**Secondary**	**Tertiary**
BRS Nordestina	89 ab*	97 a	81 b
BRS Energia	95 a	82 b	89 ab
IAC – 80	96 a	98 a	66 b
BRS Paraguaçu	99 a	96 a	94 a
IAC - Guarani	95 a	86 b	67 c
AL - Guarany 2002	87 a	94 a	62 b
IAC - 2028	91 a	82 b	70 c
Average	93 a	91 a	76 b
C.V. (%)	4.28	4.39	5.27

**Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability (p≤0.05). C.V. (%)= coefficient of variation*

For the cultivar BRS energia, the seeds from the primary raceme presented a greater percentage of germination (95%), although, were statistically similar to those which were from the tertiary raceme (89%), while the seeds from the secondary raceme presented the lower percentage of germination (82%), however, the seeds from the tertiary racemes were statistically similar (Tables 2).

3.4 First Germination Count

For the first count of germination, it was observed that the seeds from the cultivar BRS Nordestina from the primary and secondary racemes presented a greater vigor (89 and 95%, respectively), while the seeds from the tertiary raceme presented lower vigor (81%) (Table 3). Similar results were observed for the cultivar of IAC-2028, in this case the seeds from de primary and secondary raceme presented greater vigor (74 and 72%, respectively), while the seeds from the tertiary racemes presented lower vigor (50%) (Table 3).

Similarly, for the cultivar IAC-80, the seeds from the primary and secondary racemes presented a greater vigor (92 and 98%, respectively), so those seeds from the tertiary racemes presented lower vigor (58%) (Table 3). For the cultivar BRS Energia, the seeds from the primary and tertiary racemes presented greater vigor (92 and 85%, respectively), while the seeds from the secondary racemes presented lower vigor (70%). For the cultivar BRS Paraguaçu, the seeds from the primary and tertiary racemes presented greater vigor (98 and 92%, respectively), however, the seeds from the secondary racemes presented lower vigor (86%) (Table 3).

For the cultivar of IAC-Guarani, it was observed that the seeds from the primary racemes presented greater vigor (88%), while the seeds from the secondary racemes presented an intermediate vigor (79%) and the seeds from the tertiary racemes presented lower vigor (53%) (Table 3). Regarding of the cultivar AL-Guarany 2002, it was observed that the seeds from the secondary racemes presented a greater vigor (87%), those seeds from the primary racemes presented an intermediate vigor (65%) and those seeds from the tertiary racemes presented lower vigor (42%) (Table 3).

These results, in general, corroborate with those describes by [24], which observed that the seeds from the primary racemes present greater vigor in this variable. Although, in research carried out by [25], it was observed that in the first count of germination the seeds from the secondary and tertiary racemes presented greater vigor. Similar results from these were described by [26], which observed that the castor seeds from the primary racemes presented lower vigor in the first count of germination. According to these authors, these results were caused by the excess of rain during the harvest of the primary racemes, showing that are an intense relation between the environmental conditions and the physiological quality of castor seeds formed in different racemes.

Table 3. First germination count of castor seeds from different cultivar and orders of racemes. Pombal, PB-Brazil 2018

First germination count (%)			
Cultivar	**Racemes**		
	Primary	**Secondary**	**Tertiary**
BRS Nordestina	89 a*	95 a	81 b
BRS Energia	92 a	70 b	85 a
IAC – 80	92 a	98 b	58 b
BRS Paraguaçu	98 a	86 b	92 a
IAC - Guarani	88 a	79 b	53 c
AL - Guarany 2002	65 b	87 a	42 c
IAC - 2028	74 a	72 a	50 b
Average	85 a	84 a	66 b
C.V. (%)	6.57	6.70	8.53

**Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability (p≤0.05). C.V. (%)= coefficient of variation*

3.5 Germination Speed Index

Regarding to the germination speed index, it was possible to observe that the seeds from the cultivar of BRS Paraguaçu do not differ statistically (Table 4). For the cultivar of BRS Nordestina the seeds from the secondary racemes presented statistically greater values, however, those were statistically similar to values observed for seeds from the primary racemes, while seeds from the tertiary racemes presented lower values, however, those were statistically similar to those values observed for seeds from the primary racemes (Table 4).

For the cultivar of IAC-80, IAC-Guarani and IAC-Guarany 2002, it was observed that the seed from the primary and secondary racemes presented greater values of this index, while the seeds from the tertiary racemes presented lower values (Table 4). The seeds from the cultivar BRS Energia from the primary racemes presented greater values, however, were statistically similar to those observed in seeds from the tertiary racemes, while seeds from the secondary racemes presented lower index, although, were statistically similar to those observed in seeds from the tertiary racemes (Table 4).

For the cultivar of IAC-2028, it was observed that the seeds from the primary racemes presented greater values, however, were statistically similar to those observed in seeds from the secondary racemes, while seeds from the tertiary racemes presented lower values, but they were statistically similar to those observed in seeds from the secondary racemes (Table 4).

In general, the results of germination speed index were very similar to those observed in the germination test, showing coherence in the obtained results, the seeds originated from primary and secondary racemes presented greater percentage of germination and greater germination speed index, independently of the cultivar (Table 4).

According to [27], batches of seed with percentage of germination similar can present differences in terms of vigor, in this context, the germination speed index is an efficient test to detect these differences, being that the greater the values of this index the greater will be the vigor of the seeds batch. Based on this information, it is possible to say that seeds from the primary and secondary racemes present greater vigor in comparison with those from the tertiary racemes.

3.6 Protein Content

The protein content was statistically similar for seeds from primary, secondary and tertiary racemes in cultivars BRS Energia, IAC-Guarani and IAC-2028, they did not differ statistically regarding of protein content (Table 5). For the cultivar of BRS Nordestina, it was observed that the seeds from the primary and secondary racemes presented, statistically, the greatest protein contents, comparatively to seeds from the tertiary racemes, which presented the lowest protein contents (Table 5).

Table 4. Germination speed index of castor seeds from different cultivar and orders of racemes. Pombal, PB-Brazil 2018

Germination speed index			
Cultivar	**Racemes**		
	Primary	**Secondary**	**Tertiary**
BRS Nordestina	3.17 ab*	3.37 a	2.88 b
BRS Energia	3.41 a	2.81 b	3.13 ab
IAC - 80	3.37 a	3.49 a	2.29 b
BRS Paraguaçu	3.52 a	3.26 a	3.34 a
IAC - Guarani	3.29 a	3.01 a	2.21 b
AL - Guarany 2002	2.93 a	3.28 a	1.91 b
IAC - 2028	2.95 ab	2.82 a	2.22 b
Average	3.23 a	3.15 a	2.57 b
C.V. (%)	4.64	4.76	5.83

Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability ($p \leq 0.05$). C.V. (%)= coefficient of variation

The seeds originated from the tertiary racemes in the cultivar of IAC-80 presented the greatest protein contents, however, these results were statistically similar to those observed in seeds from the primary racemes, while, the seeds from the secondary racemes presented the lowest protein contents, but, were statistically similar to the seeds from the primary racemes (Table 5).

The seeds of BRS Paraguaçu originated in the secondary and tertiary racemes presented greater protein content, while those from the primary racemes presented lower protein content (Table 5). For the cultivar of AL-Guarany 2002, the seeds from the primary racemes presented greater protein content, those from the tertiary racemes presented an intermediary protein content and the seeds from the secondary racemes presented lower protein contents.

Seeds with more vigor present greater protein contents in comparison with seeds with less vigor [28]. Besides vigor, other factors may influence the protein content as the irrigation, temperature, nutrient availability, environmental conditions, mainly in the seed filling, as well as the cultivars' genetic characteristics [29,30,31]. This explains the fact that in this research the seeds protein contents varied from function of the order for racemes, probably by the fact that exists differences in terms of vigor, and still in function of the cultivars due the genetic differences between them.

Furthermore, the protein accumulation is intensified in the final stage of maturation, being crucial that the plant, in this phase, being with a high photosynthetic rate and with available nitrogen for production of amino acids and protein synthesis, mainly in the group called LEA (*Late Embryogenesis Abundant*). The proteins of this group are accumulated in the last stages of maturation in orthodox seeds and have a protective role in the cells in the dry state, contributing to the desiccation tolerance, although its mode of action is not clear [32], they are fundamental in the process of natural desiccation at field.

3.7 Oil Content

The seeds of BRS Nordestina and IAC-Guarani did not present statistical difference in oil content, independent of the order of racemes (Table 6). For cultivars of BRS Energia and AL-Guarany 2002, the seeds from the primary and secondary racemes presented greater values of oil content, while those seeds originated from the tertiary racemes presented lower values of oil content (Table 6).

The seeds from IAC-80 and BRS Paraguaçu originated from the primary racemes presented greater values of oil content, however, statistically, these values were similar to those observe for seeds from the secondary racemes, while seeds from the tertiary racemes presented lower values of oil content, but, statistically these values were similar to those observed for seeds originated from the secondary racemes (Table 6).

Table 5. Protein content of castor seeds from different cultivars and orders of racemes. Pombal, PB-Brazil 2018

	Protein (%)		
Cultivar	**Racemes**		
	Primary	**Secondary**	**Tertiary**
BRS Nordestina	18.60 a*	17.76 a	15.26 b
BRS Energia	16.43 a	16.13 a	17.16 a
IAC – 80	18.06 ab	16.30 b	20.23 a
BRS Paraguaçu	13.66 b	17.66 a	17.30 a
IAC - Guarani	17.16 a	17.16 a	17.03 a
AL - Guarany 2002	19.20 a	12.63 c	15.43 b
IAC - 2028	16.73 a	17.03 a	17.76 a
Average	17.12 a	16.29 a	17.17 a
C.V. (%)	5.19	5.46	5.18

**Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability (p≤0.05). C.V. (%)= coefficient of variation*

Table 6. Oil content of castor seeds from different cultivars and orders of racemes. Pombal, PB-Brazil 2018

	Oil content (%)		
Cultivar	Racemes		
	Primary	Secondary	Tertiary
BRS Nordestina	52.63 a*	51.93 a	50.06 a
BRS Energia	50.30 a	48.80 a	45.60 b
IAC - 80	48.23 a	46.50 ab	45.23 b
BRS Paraguaçu	49.43 a	48.06 ab	46.70 b
IAC - Guarani	50.03 a	49.33 a	49.08 a
AL - Guarany 2002	48.23 a	46.20 a	41.53 b
IAC - 2028	46.30 a	48.83 b	38.66 c
Average	49.30 a	47.52 b	45.54 c
C.V. (%)	2.04	2.11	2.21

**Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability ($p \leq 0,05$). C.V. (%)= coefficient of variation*

The seeds from the cultivar of IAC-2028 originated from the primary racemes presented the greater values of oil content, while those from the secondary racemes presented intermediate value of oil content and the lower values were observed in those seeds from the tertiary racemes (Table 6).

These data do not corroborate with those observed by [26],that observed that seeds originated from primary, secondary and tertiary racemes do not differ statistically among themselves regarding of oil content. According to [33], the seeds oil content has a strong relation of its vigor, besides that, this variable may be heavily influenced by the environmental conditions and by the mass of the seeds which varies according to the order of racemes [34].

3.8 Width

Regarding to the variable width, it was observed that for cultivars BRS Energia, IAC-80, IAC-Guarani, AL-Guarany 2002 and IAC- 2028 did not have a statistical difference, independent of the order of racemes (Table 7). For the cultivar of BRS Nordestina, it was observed that seed from the secondary racemes presented greater values, while seeds from the primary and tertiary racemes presented lower values of seeds' width (Table 7).

The seeds of BRS Paraguaçu originated from the primary racemes presented the greater values of width, comparatively to those originated from the secondary and tertiary racemes presented lower values (Table 7). For the cultivars of BRS Nordestina, IAC-Guarani, AL-Guarany 2002 and IAC-2028 the seeds did not have statistical difference regarding to thickness, independent of the order of racemes (Table 7).

The results observed in this study for the cultivars of BRS-Energia, IAC-80, IAC-Guarani, AL-Guarany 2002 and IAC-2028 corroborate with those describe by [6], who observed that did not have statistical differences between values width of seeds from different racemes, although, the results observed by these authors do not corroborate with the results observed in this study for the cultivars of BRS-Nordestina and BRS-Paraguaçu. In a study carried out by [3], it was observed that for the cultivar BRS-Nordestina the seeds originated form the primary racemes presented greater width than the seeds originated from the other racemes.

3.9 Thickness

For the cultivar BRS Energia, it was observed that the seeds originated from the primary racemes presented greater values of thickness, although, these values were statistically similar to those observed for seeds from the secondary racemes, while seeds from the tertiary racemes presented lower values of thickness, however, these value were statistically similar to those observed to seeds from the secondary racemes (Table 8).

For the cultivar IAC-80, the seeds from the tertiary racemes presented the greater values of thickness, while the seeds originated in the primary and secondary racemes presented the lower values for thickness and did not statistically differ among themselves (Table 8). Regarding the cultivar BRS Paraguaçu, it was observed that seeds from the primary and secondary racemes

Table 7. Average values of width of castor seeds in different cultivars and orders of racemes. Pombal, PB-Brazil 2018

Cultivar	Width (mm) Racemes		
	Primary	Secondary	Tertiary
BRS Nordestina	11.02 b*	11.34 a	10.94 b
BRS Energia	8.27 a	8.19 a	8.15 a
IAC – 80	9.03 a	9.19 a	9.19 a
BRS Paraguaçu	12.73 a	12.11 b	12.16 b
IAC - Guarani	8.40 a	8.32 a	8.23 a
AL - Guarany 2002	8.50 a	8.47 a	8.37 a
IAC - 2028	8.60 a	8.57 a	8.49 a
Average	9.51 a	9.45 a	9.36 b
C.V. (%)	3.00	3.00	3.10

**Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability (p≤0.05). C.V. (%)= coefficient of variation*

presented greater values of thickness, they did not differ statistically among themselves, while, seeds from the tertiary racemes presented lower values of thickness (Table 8).

Regarding seeds values of thickness obtained in this study, it was possible to observe that for cultivars BRS Nordestina, IAC-Guarani, AL-Guarany 2002 and IAC-2028 did not occurred statistical difference, independent of the order of racemes (Table 8).

These results corroborate with those describes by [35], who observed that seeds' thickness were statistically similar, independent of the order of racemes, although, the results described by these authors do not corroborate with those observed in this study for the cultivars BRS Energia, IAC-80 and BRS Paraguaçu, which present statistical difference regarding to seeds' thickness depending on the order of racemes. Similar results were described by [36], who observed that thickness from seeds originated from different orders for racemes presented statistical difference.

In the culture of castor, the chronological order for formation of racemes can have a significant effect on the seeds productivity, as well as in the seeds mass, length, width and thickness. However, this effect can be conditioning to environmental variations, depending on the seeding season and cultivar [36].

Table 8. Average values of thickness of castor seeds in different cultivars and orders of racemes. Pombal, PB-Brazil. 2018

Cultivar	Thickness (mm) Racemes		
	Primary	Secondary	Tertiary
BRS Nordestina	6.80 a*	6.69 a	6.72 a
BRS Energia	6.06 a	5.98 ab	5.87 b
IAC - 80	6.43 b	6.46 b	6.73 a
BRS Paraguaçu	7.32 a	7.12 b	6.31 a
IAC - Guarani	6.15 a	6.09 a	6.10 a
AL - Guarany 2002	6.15 a	6.13 a	6.06 a
IAC - 2028	6.15 a	6.15 a	6.20 a
Average	6.43 a	6.37 b	6.43 ab
C.V. (%)	1.30	1.40	1.30

**Averages followed by the same lowercase in the line do not differ statistically among themselves by the Tukey's test at 5% of probability (p≤0.05). C.V. (%)=coefficient of variation*

4. CONCLUSION

The seeds originated from primary racemes present greater weight of thousand seeds and better physiological quality.

The protein content from seeds originated from primary, secondary and tertiary racemes are variable according to cultivars.

The seeds originated in the primary and secondary racemes present greater oil content.

The seeds' width was influenced by the order for racemes only in the cultivars BRS Nordestina and BRS Paraguaçu, where those seeds originated in the secondary and primary racemes presented greater width, respectively.

The seeds originated in the primary and tertiary racemes presented greater thickness, however, it was variable according to cultivar.

The order of racemes interferes in the physical and physiological quality, as well as in the chemical composition of castor seeds.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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