Evaluation of seed yield and oil contents in four materials of *Ricinus communis* L.

Evaluación del rendimiento de semilla y contenido de aceite en cuatro materiales de *Ricinus communis* L.

Roberto Antonio Cabrales R.[1,4], José Luis Marrugo N.[2], and Guido Armando Plaza T.[3]

ABSTRACT

Four castor materials were evaluated in 2009 in the middle region of Valle del Sinu, Colombia. The variables were phenological development, plant height, seed production and oil yield, in order to determine the best material for commercial purposes. All materials reported high yields of oil seeds and highlighting the commercial genotype Nordestina BRS149, 2.2 t ha^{-1} seed and 47% oil content. Planting distances were 1.5 x 1.5 m and 2.0 x 2.0 m, with densities of 6,666 and 3,906 plants ha^{-1}, respectively. The plant height, seed productivity and oil yield showed significant differences for the interaction density × material; while comparing each material density, seed production only showed differences. These variables were significantly different between population densities, which shows that the higher the plant height, lower productivity. The planting distance of 2.0 x 2.0 m, provides higher productivity per plant values but seed oil yields were not different between densities. The oil quality parameters were assessed using free fatty acid value, iodine, acidity index, saponification, refraction and specific gravity, found that planting distance does not affect the quality of oil.

Key words: Castor bean, castor oil, biofuels, seed yield, oil yield.

RESUMEN

Se evaluaron cuatro materiales de higuerilla en la región media del Valle del Sinú, en el año 2009. Las variables fueron desarrollo fenológico, altura de planta, producción de semillas y rendimiento de aceite, con la finalidad de determinar el mejor material para fines comerciales. Todos los materiales reportaron altos rendimientos en semillas y aceite destacándose el genotipo comercial Nordestina BRS149, con 2,2 t ha^{-1} en semillas y 47% en aceite. Las distancias de siembra fueron 1,5 x 1,5 m y 2,0 x 2,0 m, con densidades de 6.666 y 3.906 plantas ha^{-1}. Las variables altura de planta, productividad de semillas y rendimiento de aceite, presentaron diferencias significativas para la interacción material × densidad; por otra parte, al comparar la densidad de cada material, solo la producción de semillas mostró diferencias. Estas variables fueron significativamente diferentes entre densidades poblacionales, lo cual muestra que, a mayor altura de planta menor productividad. La distancia de siembra de 2,0 x 2,0 m, proporcionó los valores más altos de productividad de semillas por planta, en tanto que los rendimientos de aceite no presentaron diferencias entre densidades. La calidad de los aceites se evaluó mediante su contenido de ácidos grasos libres y yodo, y los índices de acidez, saponificación y refracción, así como la gravedad específica, encontrándose que la distancia de siembra no afecta la calidad de los aceites.

Palabras clave: frutos de higuerilla, aceite de higuerilla, biocombustibles, productividad de semillas, productividad de aceite.

Introduction

The castor bean (*Ricinus communis* L.) is a plant that is distributed throughout much of the world in the wild and small crops in warmer regions (Tongoona, 1993; Vijaya, 1997). Its great feature is the potential for the production of industrial oils, which have various applications in fields such as medicine, cosmetics and more recently, the energy in the production of biodiesel that aims to reduce consumption of petroleum and reduce environmental pollution, making the species in an operational alternative for men (Gutierrez *et al.*, 2007). In Colombia, the castor is a promising species due to the great adaptability in most of its thermal levels, achieving high yields of seed yield and quality of their oils, allowing its application in various industrial sectors (Delgado, 2006). In some Colombian regions, such as Antioquia, Caldas, Santander and Tolima, were evaluated on a small scale some native materials using pattern matching as Brazilian and Ecuatorian genotypes. These in order to improve farming techniques and to obtain

Received for publication: 11 July, 2010. Accepted for publication: 2 February, 2011.

[1] Department of Agronomy, Universidad de Cordoba. Monteria (Colombia).
[2] Department of Chemistry, Universidad de Cordoba. Monteria (Colombia).
[3] Department of Agronomy, Faculty of Agronomy, Universidad Nacional de Colombia. Bogota (Colombia).
[4] Corresponding authors: r-cabrales-2009@hotmail.com y jlmarrugon@hotmail.com

high quality oils and yields, which determine the viability of castor crop projection on a large scale for industrial production of the oils in these areas. Gutierrez *et al*. (2007) confirm this with the evaluation of four genotypes of castor oil in warm area of the department of Caldas, where the two genotypes identified imported from Ecuador show higher productivity (12.74 kg plot^{-1}) from the National Native Cauca Valley Coffee region of Manizales (average of 6.0 kg plot^{-1}). As for the quality of castor oil, Bailey *et al*. (2005) recommended some of the characteristics established by the American Oil Chemists Society (AOCS) of the Tab. 1.

TABLE 1. Physicochemical parameters for the evaluation of castor oil (AOCS, 1990 and Akpan *et al.,* 2006).

Parameters	Value	Author
Refractive index	1.473 – 1.477	AOCS, 1990
Acidity index	1.48	Akpan *et al.*(2006)
Saponification index	176 - 187	AOCS
Iodine value	81 - 91	AOCS
Specific gravity	0.9587	Akpan *et al.*(2006)

Castor oil is distinguished from others by its high rate of acetyl or hydroxyl, and other oils with similar iodine because of its high density. Unlike other oils, is miscible in all proportions with alcohol, but at room temperature is only slightly soluble in petroleum ether (Bailey, 2005).

Currently, the department of Cordoba, where the castor grows wild in most parts of the territory, reaching heights up to 4 m and there is no knowledge on the productive performance in terms of seeds and oils of native and imported materials that could be grown in warm weather conditions and silty clay soils that characterize this region (IGAC, 1983). Therefore, this study aims at evaluation of four materials of *R. communis* in the production and the quality of the oils, in search of alternatives viable and profitable production in the study area, Valle del Sinu.

Materials and methods

Agronomic evaluation

This study was conducted at the Experimental Farm, Faculty of Agricultural Sciences, University of Cordoba (Unicor), located in the middle region of Valle del Sinu, which belongs to the municipality of Monteria, Cordoba, located 15 meters, annual rainfall of 1,303 mm, 80% relative humidity and average temperature of 28° C. The area is characterized by a soil usually composed of fine materials (silt, clay and fine sand), less permeable, allowing water logging in rainy and dry periods cracking (IGAC, 1983).

The four materials used in this research Castor were three natives: Monteria, Ciénaga de Oro and Los Córdobas (names taken from the collection sites in the department) and the improved variety and imported from Brazil (Nordestina BRS149). The planting was three (3) seeds per site, making a thinning at 40 days, leaving only one plant (1) and a population of 100% between plots and subplots. In the test group, the materials were evaluated during a period of 8 months. Planting was done the first week of February 2009 (summer time and application of sprinkler irrigation). We used a split-plot experimental design, arranged at random with three repetitions. The main plots were the genotypes Monteria, Cienaga de Oro and a commercial control Nordestina BRS 149. The subplots were in two-plant spacing of 1.5 m x 1.5 m in subplots of 6 x 7.5 m, with 30 plants for a plant density of 6,666 plants ha^{-1} (A), and 2 x 2 meters, in subplots of 8 m x 8 m, with 25 plants for planting density of 3906 plants ha^{-1} (B). The total experimental units were 12 plots and 24 subplots for a total area of 1,344 m^2 per experimental sampling unit and as all the plants in each subplot (including plants border).

The variables evaluated were: phenological development, days to germination, days to produce the first flowers, days to flowering, days from start to completion of harvest (these variables were assessed at the time when the population reached more than 50% change phenological stage), plant height and seed production. The data of plant height and seed production were analyzed with the method of analysis of variance (ANOVA $P \leq 0.05$) and mean comparison tests (Duncan test) with SAS software version 9.1.

Oil extraction

The seeds collected from each material were dried initially grown under conditions suggested by Madrid *et al*. (1997) (Tab. 2). This process prior to oil extraction, was required to determine the water content of castor seeds for experimental material, in plots and subplots (A and B). Subsequently, each subplot was taken by three (3) samples of 10 g. Dry seed, crushed shell and for determining the oil content by ether extraction method (AOAC, 1990) using benzine as extractant (Tab. 2). Thus extractions were performed 24 total, 6 per material and 4 plot subplot. The data obtained were analyzed using analysis of variance (ANOVA $P \leq 0.05$) and mean comparison tests (Duncan test) with SAS software version 9.1.

Evaluation of oil quality

The oil quality analysis were made according to ASTM standards (2000), for the determination of free fatty acid content (ASTM D5555), saponification value (ASTM D5558) and iodine value (ATSM D5554), as well measurement of specific gravity (ASTM D5355). Moreover, the refractive index was calculated using an Abbe refractometer Model LR45227 (Fisher Scientific) with a temperature of 25 °C.

TABLE 2. Experimental conditions used for determining the oil content of castor seeds.

Process	Parameters	Value
Drying	Amount of seed	10 g. approx.
	Drying temperature	110 ± 2 °C
	Drying time	4 hours
Solvent extraction	Sample shell crushed dried	10 g. approx.
	Amount of solvent	180 ml
	Extraction temperature	58°C
	Rate of condensation	3-6 drops/sec.
	Extraction time	8 hours
Distillation	Mixture distilled time	3 hours
	Temperature of distillate	>58°C

Results and discussion

The seedling emergence was between 7 and 9 days after sowing, highlighting the potential for germination earliness and Nordestina BRS149 genotype, this is most certainly improved the quality of the seed. It is established that the emergence of the seedling of castor in hot weather (typical of the middle region of Valle del Sinu, 28° C) with temperatures above 30° C, occurring at 6 days (Soares and Souza, 2007) (Fig. 1).

As at the beginning of flowering, native material was the most precocious Monteria (53 days) on the other materials, Ciénaga de Oro, Los Cordobas and Nordestina BRS149 (60, 65 and 76 days respectively), the latter being the latest. In other places where the material is grown Nordestina BRS149, the onset of flowering was 80 days (Camacho *et al*., 2008). The duration of the flowering stage of the four materials averaged 82 days, however, there was contrast between the times of flowering of native materials with the commercial, as this was more delayed 102 days, which may be favorable to obtain high yields of seed and oil yield.

The harvest of native materials initiated earlier (109 days on average) than the material Nordestina BRS149 (137 days), presenting the material Monteria earlier age (103 days). Normally the seed crop is considered precocious if it started at 120 days and 150 days late (MAG, 2006). Furthermore, the completion of the harvest which determines the cycle of the crop of castor, did not show marked differences between native materials (243 days on average), which proved to be more precocious than the commercial genotype statistically significant difference, culminating the growth cycle in 273 days. With respect to the duration of the harvest was so prominent earlier material (Monteria) with completion of harvest to 241 days and Nordestina BRS149 (late variety) with production times of 188 and 197 days respectively, while the other materials (Los Cordobas and the Ciénaga de Oro) had less productive ranges (180 and 183 days respectively). The production time was considered from the beginning of flowering until the end of the harvest.

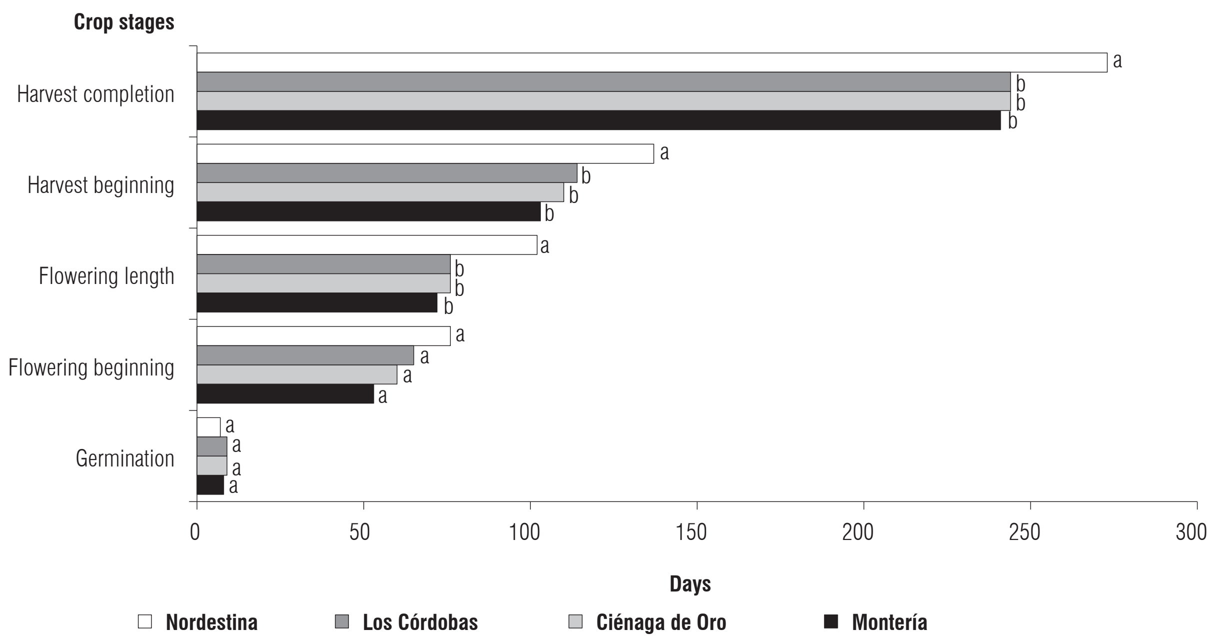

FIGURE 1. Development of materials castor from central part of the Valle del Sinu, Cordoba (Colombia).

As shown in height of the plant parameter and seed production, genotypes, no statistically significant differences, while the oil yield significant differences between native and commercial materials. The genotype Nordestina BRS149 stands with higher values in oil yield (3% higher), probably due to the duration of flowering and production (Gutierrez *et al.*, 2007). Among the native materials were no significant differences (P = 0.05) in mean values for the variables seed production and oil yield. The Ciénaga de Oro native material stands with values greater seed production (0.73 kg) the materials Monteria and Los Cordobas, which presented similar productions (9.72 and 9.34 kg).

Plant height of the four materials tested showed a mean of 3.50 ± 0.10 m, which allows sorting of tall (values greater than 2 m size are considered high) (Escoto, 2006).

The values obtained for plant height, seed production and oil yield for each material densities (subplot A: 1.5 x 1.5 m: 6,666 plant ha^{-1} and subplot B: 2.0 x 2.0 m: 3,906 plant ha^{-1}) are shown in Tab. 3.

The effect of competition between plants is clearly reflected in the variable height, where taller plants presented with planting distance of 1.5 meters (higher density of planting), except, in the Cienaga de Oro material in the which the highest value was obtained at a greater distance (shortest distance from sowing) (Tab. 3).

Regarding seed production, the highest values were obtained with the material and within the Nordestina with the greatest distance (12.52 kg $plant^{-1}$). Among the native materials, it is highlighted Monteria production of 10 kg $plant^{-1}$ at planting distance 1.5 x 1.5 m. It is important to note that seed production was higher at greater distances from seed, except in Monteria in which material was greater than 1.5 x 1.5 m (Tab. 3). On the other hand, the material at a shorter distance Los Cordobas showed the lowest seed yield with 37% less production than the highest value obtained at follow up (Nordestina: 2.0 x 2.0 m).

The highest values of the percentage of oil yield improved material presented in the two planting distances, values statistically higher than those obtained with native materials. Among the group of native materials are not significant differences and the highest values were obtained with the distance of 1.5 x 1.5 m except Ciénaga de Oro, the least explicit material difference between the two distances (0.46 %) (Tab. 3).

By adding the above results to those obtained in the variables beginning of flowering, flowering time, start and end of crop harvest, there is the benefit to the genetic improvement of native materials, Nordestina BRS149 case, expressed in facilities benefit agronomic management of these cultivars as cash crops. The same comparison between native materials does not show significant differences.

The results presented in Tab. 4, indicate that the four materials tested can be adapted for planting densities of 6,666 plants ha^{-1}, using plant spacing of 1.5 x 1.5 m, giving an average production of seeds 2,126 kg ha^{-1} (2.2 t ha^{-1} approximately) and average oil yield of 44%. Which turns out to be quite good when compared to the improved material, such as BRS149 Northeastern variety, in other places its production of seeds was 2 to 5 t ha^{-1} oil yields reaching 49% (Embrapa, 2008). It also emphasized that the results obtained in this study for the four materials evaluated in seed production and oil yield were good. The having better commercial production Nordestina BRS149 genotype (2177.8 kg ha^{-1}) and oil yield of 47 %, followed

TABLE 3. Response of four materials of castor seed at two densities in plant height (m), seed production (kg $plant^{-1}$) and oil yield (%).

Materials	Treatments	Planting density	Distance between plants (m)	Height (m)	Seed production (kg $plant^{-1}$)	Oil yield (%)
Montería	A	6,666	1.5 x 1.5	3.79 ab	10.00 bcd	43.87 bc
	B	3,906	2.0 x 2.0	3.25 bc	8.68 cd	42.45 c
Ciénaga de Oro	A	6,666	1.5 x 1.5	3.14 c	9.57 bcd	43.15 bc
	B	3,906	2.0 x 2.0	3.25 bc	11.33 ab	43.61 bc
Los Córdobas	A	6,666	1.5 x 1.5	3.77 ab	7.91 d	44.14 bc
	B	3,906	2.0 x 2.0	3.27 bc	11.52 ab	42.87 c
Nordestina	A	6,666	1.5 x 1.5	4.04 a	10.80 abc	45.55 ab
	B	3,906	2.0 x 2.0	3.15 c	12.52 a	47.63 a
			Squares means	0.26 ns	6.25 *	4.09 ns

*The mean plant height and oil yield for each variety of population density are not significantly different by (least squares means at P = 0.05), in seed production if significant differences.

TABLE 4. Effect of two-plant spacing on the variables of plant height (m), seed production (kg plant^{-1}) and oil yield (%).

Treatments & distance between plants	Planting density (ha plant^{-1})	Height (m)	Seed production (kg plant^{-1})	Oil yield (%)
A: 1.5 x 1.5 m	6,666	3.68 a	9.57 b	44.18 a
B: 2.0 x 2.0 m	3,906	3.22 b	11.56 a	44.14 a
Squares means†		1.25 **	12.57 *	0.10 ns
Error		0.10	1.65	1.96

† The mean plant height and seed production among population densities are significantly different by multiple range test of Duncan (P = 0.05), while the oil yield no significant differences.

by material Cienaga de Oro (1948.0 kg ha^{-1}) and oil yield of 43%, those of lower production were Monteria and Los Cordobas with values of 1788.8 kg ha^{-1} and 1779.2 kg ha^{-1} respectively and the same oil yields (43%).

In Tab. 5 are the average values of physicochemical analysis evaluated oils castor materials. Through an analysis of variance shows no significant differences between the results obtained for the subplots A and B of any of the four materials, therefore studied planting distances are not a factor influencing the quality of oil.

Of particular interest is lower acidity and percentage of free fatty acids in native materials (Monteria, Ciénaga de Oro and Los Cordobas) which for all parcels were below the Nordestina commercial material, indicating that the oils of the materials natives could be oxidized with a bit more difficult.

Point is very important too, that all the parameters are within the ranges of the Tab. 1, except some saponification values that are above what is expected for all native materials (Monteria, Los Cordobas and Ciénaga de Oro) showing another difference with the commercial material Nor destina. Although saponification is usually related to the average molecular weight of oil, this is a difficult measure accurately when defining oil.

Conclusions

This research showed that agro-climatic conditions of the middle region of Valle del Sinú are suitable for the cultivation of castor, for it was evident that the four materials tested had good results in production of seed and oil yield, also showed a characteristic phenology early materials, which may allow the development of two production cycles per year.

It highlights the commercial genotype for high seed production (2,177.75 kg ha^{-1}) and oil yield (47%) compared to native materials analyzed.

The Ciénaga de Oro native material is known for its high seed yield (1948.03 kg ha-1) with no difference in the yield of oil (43%).

The comparison between densities shows significant differences in plant height and seed production and, at higher altitudes lowers productivity but no differences in oil yield.

The study highlights the planting distance of 2.0 x 2.0 m, with values higher seed productivity than the distance of 1.5 x 1.5 meters.

TABLE 5. Mean values for physicochemical parameters evaluated at the four materials oils of castor.

Materials	Treatments	Free fatty acids (%)	Acidity index ** (mg KOH g^{-1})	Iodine value (g.I100g^{-1})	Saponification index (mg KOH g^{-1})	Refractive index	Specific gravity
Montería	A	0.48	0.96	87.86	187.7	1.47511	0.960
	B	0.48	0.96	87.85	187.8	1.47511	0.960
Los Cordobas	A	0.47	0.94	87.08	188.6	1.47181	0.959
	B	0.47	0.93	87.08	188.3	1.47182	0.959
Ciénaga de oro	A	0.55	1.10	87.03	188.4	1.47513	0.959
	B	0.56	1.11	87.03	188.4	1.47512	0.959
Nordestina	A	0.90	1.79	87.46	186.9	1.47639	0.960
	B	0.90	1.79	87.46	186.9	1.47638	0.960

**The acid index was calculated by multiplying the experimental values of % free fatty acids by a factor of 1.99 (Akpan *et al.,* 2006).

The quality of the oils is not significant differences by relating them to the variable spacing. Meanwhile, some physicochemical properties such as acidity and saponification, show different values together for all native materials compared to commercial material Nordestina.

Literature cited

Akpan U.G., A. Jimoh and A.D. Mohammed. 2006. Extraction, characterization and modification of Castor seed oil. Leonardo J. Sci. 5(8): 43-52.

AOAC (Association of Official *Analytical* Chemists). 1990. Official Methods of Analysis. 15th edition. AOAC. Washington D.C. 1422 p.

ASTM (American Society for Testing and Materials). 2000. Methods of Analysis D5355, D5554, D5555 and D5558. Book of Standards, Volume 15.05. Washington D.C. 2959 p.

Bailey, A.E. 2005. Industrial Oil and Fat Products. 6th edition. Volume 1. Jhon Wiley & Sons. New Jersey, USA, 606 p.

Camacho, A., L. Soares y J. Águila. 2008. Evaluación de cuatro cultivares de higuerilla (*Ricinus communis* L.) en la selva del Perú, región de Ucayali (2007). In: III Congreso Brasileiro de Mamona. Salvador- Bahía (Brasil), http://cnpa.embrapa.br/produtos/mamona/publicacoes/cbm3/trabalhos/MELHORAMENTO%20GENETICO/MG%2017.pdf; consulta: abril de 2010.

Delgado, F. 2006. La Higuerilla: petróleo verde. In: http://rds.org.co/aa/img_upload/fc51bb4fd8b1d87cba819ab602ad30b8/La_Higuerilla.pdf; consulta: enero de 2010.

Embrapa (Empresa Brasilera de Pesquisa Agropecuaria). 2008. Higuerilla BRS 149 Nordestina. In: http://colbio.com/nordestina.pdf; consulta: enero de 2010.

Escoto, T. 2006. Taller para el aprovechamiento de la higuerilla y tule en la elaboración de amate y papiro en Amatitán. Revista Vinculación y Ciencia, 9: 54-58.

Gutierrez, G., A. Hurtado y J.F. Restrepo. 2007. Evaluación de cuatro genotipos de higuerilla (*Ricinus communis* L.) en zona cálida del departamento de Caldas. In: Memorias Primer Congreso Internacional del Cultivo, Procesamiento y Aplicaciones de la Higuerilla. Universidad Eafit, Medellin (Colombia), 220p.

IGAC (Instituto Geográfico Agustín Codazzi). 1983. Estudio general de los suelos de los municipios que conforman la parte media y baja de la cuenca del Sinú (Departamento de Córdoba). Informe Técnico. Litografía IGAC, Bogotá, 236 p.

Madrid, V., C. Del Castillo y C. Madrid. 1997. Manual de Aceites y Grasas Comestibles. Primera edición. Ediciones Madrid Vicente. Barcelona, España, 345p.

MAG (Ministerio de Agricultura y Ganadería). 2006. Aspectos técnicos sobre 45 cultivos agrícolas de Costa Rica: Higuerilla. Dirección General de Investigaciones y extensión Agrícola. San José, Costa Rica. In: http://www.mag.go.cr/bibioteca_virtual_ciencia/tec-higuerilla.pdf; consulta: febrero de 2010.

Soares, L. y T. Souza. 2007. El cultivo de la higuerilla. In: Memorias Primer Congreso Internacional del Cultivo, Procesamiento y Aplicaciones de la Higuerilla, Universidad Eafit, Medellin (Colombia), 220p.

Tongoona, P. 1.993. Castor (*Ricinus communis* L.) research and production prospects in Zimbabwe. Industrial Crops and Products, 1: 235-239.

Vijaya, P. 1.997. Influence of moisture, thermal and photoperiodic regimes on the productivity of castor beans (*Ricinus communis* L.). Agricultural and Forest Meteorology, 88: 279-289.