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ORIGINAL ARTICLE

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Adaptability, agronomic performance and genetic divergence of castor genotypes grown in the Cerrado-Pantanal ecotone

Adaptabilidade, desempenho agronômico e divergência genética de genótipos de mamona cultivados no ecótono Cerrado-Pantanal

ABSTRACT: Under the hypothesis of distinction and characterization of promising genotypes in the genetic improvement of castor, the aim of this work was to evaluate the agronomic performance, phenotypic adaptability and genetic divergence between castor genotypes grown in the Cerrado-Pantanal ecotone. The experiment was conducted in 2010/2011 and 2011/2012 in the experimental area of the State University of Mato Grosso do Sul - UEMS. The treatments consisted of seven castor genotypes (BRS Energia, IAC 2028, IAC-Guarani, BRS Nordestina, BRS Paraguaçu, IAC-80 and IAC-226) arranged in a randomized block design with three replications. The following agronomic characters were assessed: plant height, stem diameter, number of fruits and productivity. Data were subjected to individual and combined analysis of variance, and means were compared by the Skott-Knott test. Phenotypic stability was estimated with productivity data by the Lins and Binns method. Genetic divergence between the genotypes studied was determined by the methods of Ward's and Tocher's, using the Mahalanobis's distance as dissimilarity measure. The BRS Energia genotype showed higher productivity and phenotypic adaptability. The crossing of the BRS Energia and BRS Paraguaçu genotypes can produce a hybrid with high heterosis effect and, consequently, of high productivity.

RESUMO: *Sob a hipótese de distinção e caracterização de genótipos promissores no melhoramento genético da mamona, objetivou-se, com este trabalho, avaliar o desempenho agronômico, adaptabilidade fenotípica e divergência genética entre genótipos de mamona cultivados no ecótono Cerrado-Pantanal. O experimento foi conduzido nos anos de 2010/2011 e 2011/2012 na área experimental da Universidade Estadual de Mato Grosso do Sul. Os tratamentos consistiram de sete genótipos (BRS Energia, IAC-2028, IAC-Guarani, BRS Nordestina, BRS Paraguaçu, IAC-80 e IAC-226) de mamona, dispostos em delineamento de blocos casualizados com três repetições. Avaliaram-se os seguintes caracteres: altura de plantas, diâmetro do colmo, número de frutos e produtividade. Os dados foram submetidos à análise de variância individual e conjunta e as médias comparadas pelo teste de Skott-Knott. A estabilidade fenotípica foi estimada com os dados de produtividade pelo método de Lins e Binns. A divergência genética entre os genótipos foi determinada pelos métodos de Ward e Tocher, tendo como medida de dissimilaridade a distância de Mahalanobis. O genótipo BRS Energia apresentou maior produtividade e adaptabilidade fenotípica. O cruzamento deste genótipo com BRS Paraguaçu pode obter um híbrido com elevado efeito de heterose, e, consequentemente, alta produtividade.*

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1 Introduction

Castor (*Ricinus communis* L.) belongs to the family Euphorbiaceae, being a valuable oilseed crop that provides almost the entire world's supply of hydroxy fatty acids. It is an essentially tropical/subtropical species and it grows naturally over a wide range of geographical regions including temperate areas. Exploitation of castor ranges from the simple harvesting of beans to wild plants, through the cultivation of hybrid varieties and use of improved cultivation methods. Wild plants are perennials, but where it is deliberately cultivated an annual production cycle is possible (Gogoi et al., 2009; Dhedhi et al., 2010).

The main product which is obtained from the industrialization of castor is the oil, which has industrial uses for the manufacturing of paints, varnishes, soaps, synthetic fibers, plastics, dyes, aniline and lubricants (Torres et al., 2013). The implementation of strategies to facilitate the development of castor genotypes with higher oil content and adjusted to different environmental conditions is vital for the castor to be consolidated as an important component of the national program for the production of biodiesel (Machado et al., 2013).

In recent years, the Federal Government through PROBIODIESEL, has encouraged the cultivation of oil-producing plants, in accordance with the potential of each region for biodiesel production. In the northeastern of Brazil, due to climate conditions, the chosen crop for biodiesel production was the castor. In addition to its adaptability to such conditions, castor has a great potential to create jobs and reduce the rural exodus (Oliveira et al., 2009).

The region of the Cerrado-Pantanal ecotone, Midwestern of Brazil, has its economy based on rural production, industry, mining, tourism and services, with its main economic activity of the extensive cattle breeding and rearing. With respect to agriculture, it highlights the growth of corn, cassava and vegetable crops. In a recent study, Torres et al. (2014) concluded that this region has favorable conditions for the production of soybean. However, researches on adaptation of castor genotypes are scarce in this region and it could generate a new source of income for farmers.

Phenotypic adaptation of castor genotypes to the most diverse regions of Brazil is one of the main demands that breeding programs have sought to meet. This adaptation will allow cultivation in many municipalities and regions which currently do not exploit this culture given the risk of obtaining lower productivity (Severino et al., 2006).

Under the hypothesis of distinction and characterization of promising genotypes in the genetic improvement of castor, the aim of this work was to evaluate the agronomic performance, phenotypic adaptability and genetic divergence between castor genotypes grown in the Cerrado-Pantanal ecotone.

2 Materials and Methods

The experiment was installed in the agricultural years 2010/2011 and 2011/2012 in the experimental area of the Universidade Estadual de Mato Grosso do Sul (UEMS), in the municipality of Aquidauana, located in the Cerrado-Pantanal ecotone, comprising the coordinates 20°27'S and 55°40'W with an average elevation of 170 m.

The soil was classified as Ultisol sandy loam texture (Schiavo et al., 2010), with the following layer 0 – 0.20 m: pH (H_2O) = 6.2; Al exchangeable ($cmol_c\ dm^{-3}$) = 0.0; Ca+Mg ($cmol_c\ dm^{-3}$) = 4.31; P ($mg\ dm^{-3}$) = 41.3; K ($cmol_c\ dm^{-3}$) = 0.2; organic matter ($g\ dm^{-3}$) = 19.7; V (%) = 45.0; m (%) = 0.0; sum of bases ($cmol_c\ dm^{-3}$) = 2.3; cation exchange capacity (CEC) ($cmol_c\ dm^{-3}$) = 5.1. The climate of the region, according to the classification described by Köppen-Geiger is Aw (Savanna Tropical).

The experimental design was a randomized block with three replications, and the treatments consisted of seven castor genotypes (BRS Energia, IAC-2028, IAC-Guarani, BRS Nordestina, BRS Paraguaçu, IAC-80 and IAC-226), acquired from Empresa Brasileira de Pesquisa Agropecuária (Embrapa) and from Instituto Agronômico de Campinas (IAC).

Sowings were made on the 10^{th} of December 2010 and 2011. The preparation of the area consisted of a mechanical mowing and disking, and placed two seeds per hole, with a depth of 15 cm, open manually with the assistance of a mattock. All other cultural practices were performed as described in Torres et al. (2013). During the first experiment, the cumulative rainfall was 450 mm and maximum and minimum average temperatures of 19 and 33 °C, respectively. During the second experiment, the cumulative rainfall was 400 mm and maximum and minimum average temperatures of 18 and 34 °C, respectively.

At harvest, the following characters were evaluated: plant height (PH), stem diameter (SD), number of fruits (NF), and productivity (PROD), following procedures preconised by Torres et al. (2013).

Data were submitted to analysis of individual variance, having considered the effect of treatments as fixed and the other effects randomly. For all variables, it was found that the relationship between the average square of the analysis of variance individual of the experiments did not exceed the ratio 7:1, thus allowing the implementation of joint analysis (Banzatto & Kronka, 2006).

Averages were compared by Scott and Knott test at 5% probability, in which the likelihood ratio attests to the significance of the division between the treatment groups. The Scott and Knott test was used as it is the most powerful test and because it adequately controls the rates of type I error.

The data PROD were subjected to analysis adaptability Lin & Binns (1988), in which the performance of superior genotype in the years evaluated is indicated by Pi value. This parameter is measured by the average square of the distance between this performance of genotype and the performance of the best genotype in each year. The parameter of stability Pi is given by $Pi = \frac{\sum_{j=1}^{n} (X_{ij} - M_j)^2}{2n}$, where: Pi = selection index of the i'th genotype; X_{ij} = productivity of i'th genotype in the j'th year; M_j = maximum productivity obtained from all genotypes in j'th year; n = number of years.

The genetic divergence between treatments was determined by multivariate techniques which are based on cluster analysis, using the agglomerative hierarchical Ward's method (Ward Junior, 1963) and the Tocher's optimization method (Cruz & Regazzi, 2007), with the dissimilarity measure Mahalanobis's distance (*d*).

Ward's method forms groups, minimizing the dissimilarity, or minimizing the sum of the sums of squares within a group, also known as sum of square deviations (SSD). At each step of the procedure, groups whose resulting solution have the lowest SSD within groups, are formed. Unions of all possible pairs of groups are considered in these steps, and the two resulting in a smaller increase SQD are grouped so that all groups form a single group, gathering all individuals (Cruz & Regazzi, 2007). The Tocher's optimization method constitutes a simultaneous cluster, where the separation of individuals at one time takes place. This method has the characteristic that the average dissimilarity measures within each group should be smaller than the average distance between any groups (Cruz & Regazzi, 2007).

Singh's criterion was applied (Singh, 1981) to quantify the contribution of the characters for the dissimilarity among genotypes. All statistical analyzes were performed with the application GENES (Cruz, 2013), and followed procedures preconised by Cruz & Regazzi (2007).

3 Results and Discussion

The analysis of the joint variance revealed a significant effect ($p < 0.01$), only for the genotypes (Table 1), allowing us to infer with the existence of genetic variability in the population. With respect PH and SD, it is noted that the BRS Nordestina, BRS Paraguaçu, IAC 2028, IAC 16 and IAC Guarani genotypes showed better development than the other. However, the IAC 2018 and BRS Nordestina genotypes obtained the highest average values for characters NF e PROD, respectively.

With the exception of BRS Nordestina and IAC 226 genotypes, the other genotypes showed development and higher productivity to values reported by Severino et al. (2006), Silva et al. (2007) and Souza et al. (2010).

By the method of Lin & Binns (1988), genotypes with lower Pi value are desirable, as obtained lower deviation from the maximum productivity for each year, i.e., close to the maximum performance obtained in the years (Cruz & Regazzi, 2007). Therefore, the BRS Energia and BRS Paraguaçu genotypes stand out for having the greater overall stability, both in favorable and unfavorable environments and obtained high levels of PROD (Table 2).

According to Beltrão (2004), castor is photoperiodic, on long days, it has a great variety of sexual expression, being sensitive to clouds and other atmospheric factors. According to Beltrão (2004), castor is photoperiodic, the long days, has a great variety of sexual expression, being sensitive to clouds and other atmospheric. Thus, in view of the agronomic performance and phenotypic adaptability, it can be inferred that BRS Energia and BRS Paraguaçu genotypes can be grown in Cerrado-Pantanal ecotone.

By the matrix of Mahalabobis's (Table 3), it was found high magnitude at distances (109.5< d <21,306), reinforcing the hypothesis of genetic variability among the genotypes.

The pair formed between the BRS Nordestina and BRS Paraguaçu genotypes (D=109.5) was the closest. These genotypes presenting the same patterns of similarity and loads of similar loci, are not recommended for use in breeding programs of hybridization, for the genetic variability, essential in any breeding program, it is not restricted, in order to derail the gains to be obtained by selection.

The pair formed between the genotypes BRS Energia and BRS Paraguaçu (D=21,306) was the furthest. This high divergence, in principle, allows recommending the intersection between these pairs in order to maximize heterosis in progeny and increase the possibility of segregants in advanced generations (Cruz et al., 2004). Moreover, these genotypes have high PROD and greater adaptability, which allows us to infer that a hybrid resulting from the cross between them, is highly productive due to the large heterotic effect.

At 10% of similarity, the Ward's clustering based on Mahalanobis's distance allowed the formation of three groups (Figure 1). Group 1 was composed of genotypes BRS Nordestina, BRS Paraguaçu and IAC 80, while Group 2 was formed by genotypes IAC Guarani and IAC 226. Group 3 was in turn composed of genotypes BRS Energia and IAC 2028.

The application of the Tocher's optimization method, based on the Mahalanobis's distance matrix, too, caused the formation of three groups (Table 4). The distribution of the groups was consistent with the grouping provided by grouping Ward's method, both set as the most similar at the divergent.

Table 1. Average values of the joint analysis of characters plant heigth (PH), steam diameter (SD), number of fruits (NF) and productivity (PROD), evaluated in seven castor genotypes grown in the Cerrado-Pantanal ecotone.

Tabela 1. Valores médios da análise de variância conjunta para os caracteres altura de plantas (PH), diâmetro do caule (SD), número de frutos (NF) e produtividade (PROD), avaliados em sete genótipos de mamona cultivados no ecótono Cerrado-Pantanal.

Genotype	PH	SD	NF	PROD
	(cm)	(mm)	---	(kg ha^{-1})
BRS Energia	162.43 b	25.32 b	80.34 b	3,395.84 a
BRS Nordestina	193.63 a	38.18 a	45.01 c	1,366.07 c
BRS Paraguaçu	225.19 a	43.16 a	45.72 c	2,063.41 b
IAC 2018	198.32 a	36.10 a	122.37 a	1,863.39 b
IAC 2028	188.82 a	34.42 a	86.26 b	2,139.27 b
IAC 226	148.84 b	30.96 b	75.23 b	607.17 c
IAC Guarani	203.50 a	37.48 a	72.04 b	2,295.61 b
Average	188.67	35.09	75.28	1,961.97
CV (%)	12.11	14.23	19.11	25.26

Table 2. Estimates of parameters of adaptability and phenotypic stability of seven castor genotypes grown in the Cerrado-Pantanal ecotone by Lin and Binns method.

Tabela 2. Estimativa dos parâmetros de adaptabilidade e estabilidade fenotípica de sete genótipos de mamona cultivados no ecótono Cerrado-Pantanal pelo método de Lins e Bins.

Genotype	$Pi_{general}$	$Pi_{favorable}$	$Pi_{desfavorable}$
BRS Energia	100,345	211,899	455,982
BRS Nordestina	789,488	337,045	792,861
BRS Paraguaçu	644,230	786,114	951,414
IAC 2018	2,121,972	1,407,222	2,836,722
IAC 2028	931,961	535,448	1,328,473
IAC 226	1,181,240	1,363,087	999,393
IAC Guarani	3,720,027	4,003,329	3,436,724

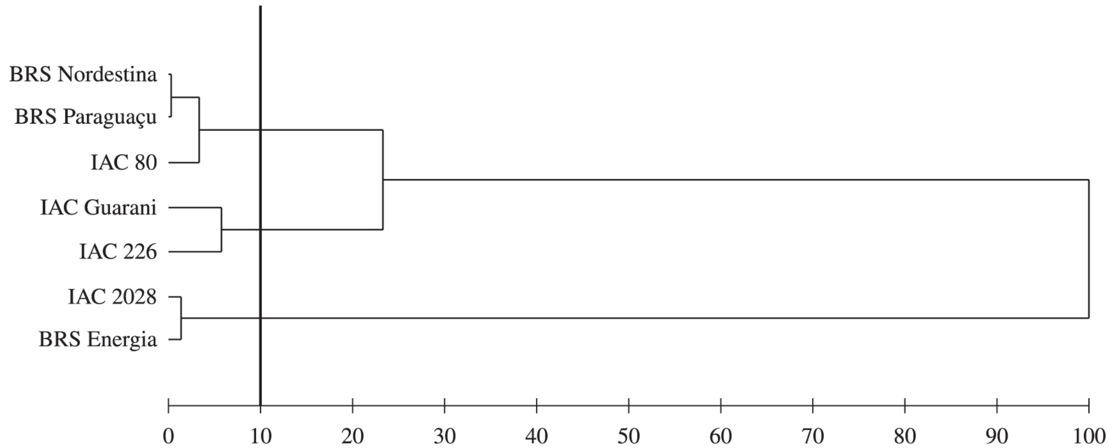

Figure 1. Dendrogram of genetic dissimilarity between seven castor genotypes obtained by Ward's clustering method, based on Mahalanobis's distance.

Figura 1. Dendograma da dissimilaridade genética entre sete genótipos de mamona obtidos pelo método de agrupamento de Ward, baseado na distância de Mahalanobis.

Table 3. Estimates of genetic dissimilarity between seven castor genotypes grown in the Cerrado-Pantanal ecotone by Mahalanobis's distance.

Tabela 3. Estimativas da dissimilaridade genética entre sete genótipos de mamona cultivados no ecótono Cerrado Pantanal pela distância de Mahalanobis.

	IAC 2028	IAC Guarani	BRS Nordestina	BRS Paraguaçu	IAC 226	IAC Guarani
BRS Energia	566.9	12,390.6	15,901.1	21,306.0	7,547.6	17,114.0
IAC 2028		13,527.7	20,580.5	16,235.8	9,638.0	21,063.7
IAC Guarani			5,916.7	7,488.4	1,295.6	3,494.7
BRS Nordestina				109.5	3,093.9	571.0
BRS Paraguaçu					3,950.3	1,164.1
IAC 226						2,372.2

Table 4. Clustering of seven castor genotypes obtained by Tocher's method, based on Mahalanobis's distance.

Tabela 4. Agrupamento de sete genótipos de mamona obtido pelo método de Tocher, baseado na distância de Mahalanobis.

Group	Genotypes
I	BRS Nordestina, BRS Paraguaçu and IAC 80
II	IAC Guarani and IAC 226
III	BRS Energia and IAC 2028

Table 5. Relative contribution (Sj) of characters for the genetic dissimilarity of seven castor genotypes by Singh's method.

Tabela 5. Contribuição relativa (Sj) dos caracteres para a dissimilaridade genética de sete genótipos de mamona pelo método de Singh.

Character	Sj	Sj (%)
Plant height (PH)	66,392.38	54.21
Stem diameter (SD)	545.44	0.45
Number of fruits (NF)	8,508.97	6.95
Productivity (PROD)	47,021.09	38.39

Among the characters, the most sensitive to provide the difference between the genotypes was PH (54.21%), followed by PROD (38.39%) (Table 5). Thus, the purpose of reducing efforts and make the breeding program of castor more efficient and economical, selection of genotypes differing in genebanks, where the large number of genotypes prevents the evaluation of a large number of characters, can be performed based on PH and PROD.

4 Conclusions

The BRS Energia genotype showed higher productivity and phenotypic adaptability in the Cerrado-Pantanal ecotone. The crossing of this genotype with BRS Paraguaçu genotype can obtain a hybrid with high heterosis effect, and consequently, high productivity.

References

BANZATTO, D. A.; KRONKA, S. N. *Experimentação agrícola*. 4. ed. Jaboticabal: FUNEP, 2006. 237 p.

BELTRÃO, N. E. M. *A cadeia da mamona no Brasil, com ênfase para o segmento P&D: estado da arte, demandas de pesquisa e ações necessárias para o desenvolvimento*. Campina Grande: Embrapa Algodão, 2004. 19 p.

CRUZ, C. D. GENES - a software package for analysis in experimental statistics and quantitative genetics. *Acta Scientiarum Agronomy*, v. 35, n. 3, p. 271-276, 2013. http://dx.doi.org/10.4025/actasciagron.v35i3.21251

CRUZ, C. D; REGAZZI, A. J. *Modelos biométricos aplicados ao melhoramento genético*. Viçosa: Imprensa Universitária, 2007. 480 p.

CRUZ, C. D; REGAZZI, A. J.; CARNEIRO, P. C. S. *Modelos biométricos aplicados ao melhoramento genético*. Viçosa: Imprensa Universitária, 2004. 480 p.

DHEDHI, K. K.; GHELANI, Y. H.; JOSHI, H. J.; DANGARIA, C. J. Correlation and path coefficient analysis in Castor (*Ricinus* *communis* L.) over environments. *Agricultural of Science Digest*, v. 30, p. 286-289, 2010.

GOGOI, S. N.; CHAKRAVORTY, R.; BARUA, P. K. Correlation and path analysis in local castor (*Ricinus communis* L.) genotypes, the host plant of eri silkworm. *Journal of Advanced Plant Science*, v. 22, p. 277-279, 2009.

LIN, C. S.; BINNS, M. R.; A superiority measure of cultivar performance for cultivar x location data. *Canadian Journal of Plant Science*, v. 68, n. 1, p. 193-198, 1988. http://dx.doi.org/10.4141/cjps88-018.

MACHADO, E. L.; SILVA, A. S.; SANTOS, A. G.; BASTOS, L. A.; PESTANA, C. N.; SANTOS, K. S.; FERREIRA, C. F.; DIAMANTIONO, M. S. A. S. Dissimilaridade genética entre cultivares de mamoneira por meio de marcadores RAPD. *Pesquisa Agropecuária Brasileira*, v. 48, n. 3, p. 342-345, 2013. http://dx.doi.org/10.1590/S0100-204X2013000300014

OLIVEIRA, I. A.; LIMA, J. R. S.; SILVA, I. F.; ANTONINO, A. C. D.; COUVEIA NETO, G. C.; LIRA, C. A. B. O. Balanço de energia em mamona cultivada em condições de sequeiro no Brejo Paraibano. *Revista Brasileira de Ciências Agrárias*, v. 4, n. 2, p. 185-191, 2009. http://dx.doi.org/10.5039/agraria.v4i2a11

SCHIAVO, J. A.; PEREIRA, M. G.; MIRANDA, L. P. M.; DIAS NETO, A. H.; FONTANA, A. Caracterização e classificação de solos desenvolvidos de arenitos da formação Aquidauana MS. *Revista Brasileira de Ciência do Solo*, v. 3, n. 3, p. 881-889, 2010. http://dx.doi.org/10.1590/S0100-06832010000300029

SEVERINO, L. S.; MILANI, M.; MORAES, C. R. A.; GONDIM, T. M. S.; CARDOSO, G. D. Avaliação da produtividade e teor de óleo de dez genótipos de mamoneira cultivados em altitude inferior a 300 metros. *Revista Ciência Agronômica*, v. 37, p. 188194, 2006.

SILVA, T. R. B.; LEITE, V. E.; SILVA, A. R. B.; VIANA, L. R. Adubação nitrogenada em cobertura na cultura da mamona em plantio direto. *Pesquisa Agropecuária Brasileira*, v. 42, n. 9, p. 1357-1359, 2007. http://dx.doi.org/10.1590/S0100-204X2007000900018

SINGH, D. The relative importance of characters affecting genetic divergence. *Indian Journal of Genetic and Plant Breeding*, v. 41, n. 1, p. 237-245, 1981.

SOUZA, N. C.; MOTA, S. B.; BEZERRA, F. L. M.; AQUINO, B. F.; SANTOS, A. B. Produtividade da mamona irrigada com esgoto doméstico tratado. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v. 14, n. 5, p. 478-484, 2010. http://dx.doi.org/10.1590/S1415-43662010000500004

TORRES, F. E.; SILVA, E. C.; TEODORO, P. E. Desempenho de genótipos de soja nas condições edafoclimáticas do ecótono Cerrado-Pantanal. *Interações,* v. 15, n. 1, p. 71-78, 2014.

TORRES, F. E.; TOLEDO, L. R.; RIBEIRO, M. H. P. G.; TEODORO, P. E.; RIBEIRO, L. P.; CORREA, C. C. G. Influência do manejo de plantas daninhas e da adubação nitrogenada no teor de óleo em cultivares de mamona (*Ricinus communis*). *Revista de Ciências Agrárias (Lisboa)*, v. 36, p. 357-362, 2013.

WARD JUNIOR, J. H. Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, v. 58, n. 301, p. 236-244, 1963. http://dx.doi.org/10.1080/01621459.1963.10500845

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