Tropicalization of canola (*Brassica napus* L.): commercial hybrids show potential for cultivation in the Brazilian Cerrado

Tropicalización de canola (*Brassica napus* L.): híbridos comerciales muestran potencial de cultivo en el Cerrado brasileño

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Abstract

Given its high energetic efficiency, canola (*Brassica napus L.*) constitutes a potential biodiesel feedstock. However, since this crop is native to temperate regions, Brazil has not yet consolidated its production. Thus, the objective of this study was to evaluate agronomic performance of canola hybrids grown in the tropical Brazilian Cerrado (15° 35'18" S, 47° 43'57" W at 999 m), aiming to select promising candidates for crop expansion. Our hypothesis states that obtaining high canola yields in Cerrado conditions is possible given a favorable agronomic adaptation of the species to this environment. Eight commercial canola hybrids were evaluated for seven agronomic traits in three experiments. Data were subjected to joint ANOVA and Tukey test. Grain yield of the evaluated hybrids resulted higher than the national average, including southern plantations. Hyola 61 and Hyola 76 hybrids outperformed regarding grain yield, followed by Diamond which, in addition to high productivity, exhibited a short crop cycle, even in rainfed conditions. Given these characteristics, Diamond hybrid can be considered the best option for crop rotation system. These promising results reveal the adaptability and cultivation potential of these hybrids in the Brazilian Cerrado.

Keywords

Brassica • crop cycle • oilseed • productivity

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Resumen

La canola es una materia prima potencial para la producción de biodiesel debido a sus altos niveles de eficiencia energética. Sin embargo, Brasil aún no ha consolidado su producción pues se desarrolla en las regiones templadas. Este estudio tuvo la hipótesis de que es posible obtener altos rendimientos de canola en condiciones de Cerrado. Así, el objetivo de este estudio fue evaluar el comportamiento agronómico de los híbridos de canola en las condiciones tropicales de la Sierra brasileña - Cerrado - (15 ° 35'18 "S, 47 ° 43'57" W a 999 m) para seleccionar candidatos que contribuyan con la expansión del cultivo de canola en el país. Se evaluaron ocho híbridos comerciales de canola para siete características agronómicas, en tres experimentos. Los datos obtenidos para cada variable se sometieron a análisis conjunto de varianza y se compararon las medias mediante la prueba de Tukey. El rendimiento de grano de los híbridos evaluados fue superior al promedio nacional, que incluye plantaciones solo en la región sur. Los híbridos que destacaron en productividad de grano fueron Hyola 61 y Hyola 76 seguidos por Diamond, que además de su alta productividad, tuvo un ciclo de cultivo más corto incluso en condiciones de secano. Por sus características, el híbrido Diamond puede considerarse la mejor opción para ser incluido en el sistema de rotación de cultivos. Estos resultados prometedores revelan la adaptabilidad y el potencial de cultivo de estos híbridos en el Cerrado Brasileño.

Palabras clave
Brassica • ciclo de cultivo • oleaginosas • productividad

Introduction

Canola (*Brassica napus L.*) is a Brassicaceae oilseed developed by genetic enhancement of two rapeseed species: *Brassicas oleracea* and *Brassica rapa* (7). Besides being responsible for 15% of worldwide edible vegetable oil production, it integrates a select feedstock group producing 95% of biodiesel, globally (8). Thus, canola outstands as an alternative to oil-sourced dependence, increasing renewable energy and reducing greenhouse gas emissions.

Despite its potential, canola is not fully consolidated in Brazil since its cultivation is indicated within 35° and 55° latitudes, in temperate regions. Currently, Brazilian production is concentrated in the south portion of the country, with over 90% of production located in Rio Grande do Sul (3). However, studies have shown that this oilseed could be produced in a tropical area such as Cerrado (15° 35'18" S, 47° 43'57" W at 999 m) (1, 13). Additionally, canola has the advantage of being an interesting Safrinha crop, where short-cycle annual crops such as soybeans and maize can grow in crop rotation systems. Incorporating canola in the soybean/maize system could also reduce disease incidence and enable winter production of vegetable oils when large areas of cultivation remain unoccupied.

Thus, canola tropicalization in Cerrado would expand oil production for energy purposes and human consumption, generating job positions and reducing deforestation. However, canola cropping in the Cerrado, requires evaluating hybrid agronomic performance, assisting decision making and choosing appropriate management, and technologies and equipment. Therefore, our objective was to evaluate agronomic performance of canola hybrids in the tropical Brazilian Cerrado, selecting promising candidates to contribute to crop expansion.

Materials and methods

Experiment installation and conduction

Eight spring commercial canola hybrids were evaluated: Hyola 50, Hyola 61, Hyola 76, Hyola 433, Hyola 571, Hyola 575, ALHT B4 and Diamond. Experiments I and II were irrigated by a fixed sprinkler, applying a total of 163 and 520 mm water, respectively, throughout the whole experiment. Experiment III received 182 mm of irrigation just before flowering onset.

Experiment I was conducted from June 17 to September 14, 2017, experiment II from April 23 to September 6, and experiment III from April 11 to August 24, 2019, in the experimental area of Embrapa Cerrados, located at 15° 35'18" S, 47° 43'57" W, at 999 masl.

The soil is classified as a Red Latosol with high clay content. According to Köppen & Geiger (1936), the regional climate is tropical with dry winter and rainy summer (Aw), with an average annual temperature of 21 °C, relative humidity of 68% and average annual rainfall of 1,668 mm. Average temperature during experiments was 21.2 °C, with total rainfall of 9.2 mm during experiment I and 403.5 mm during experiments II and III (figures 1 and 2).

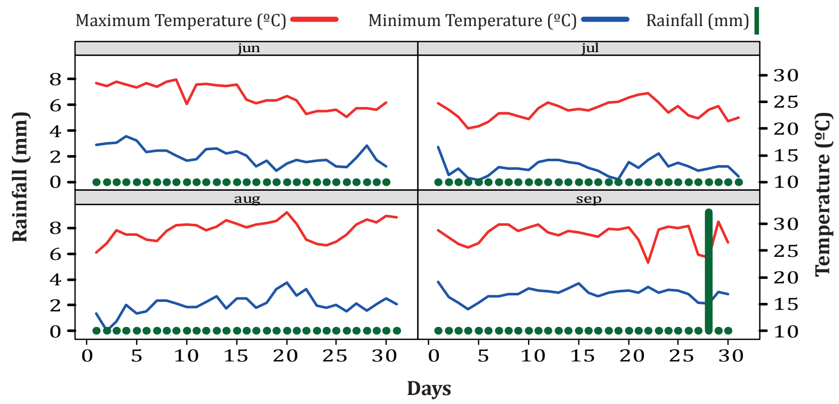

Figure 1. Precipitation and maximum/minimum temperatures during Experiment I. Brasília, DF, 2017.

Figura 1. Precipitación, temperatura máxima y mínima durante el experimento I de canola. Brasilia, DF, 2017.

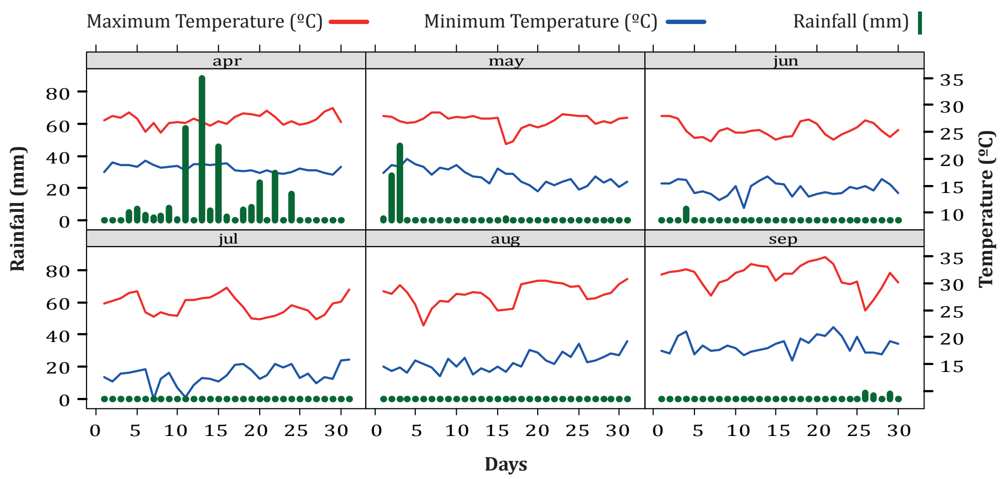

Figure 2. Precipitation and maximum/minimum temperatures during Experiments II and III. Brasília, DF, 2019.

Figura 2 Precipitación, temperatura máxima y mínima durante el experimento II y III de canola. Brasilia, DF, 2019.

The eight genotypes were distributed in a randomized block design (RBD) with four replications. In experiment I, each plot consisting of 16 lines, 5 m long and spaced 0.17 m, had a population density of 40 plants.m^{-2} and a total area of 656 m^2. Experiments II and III, consisted of plots with 8 lines, 5 m long, spaced 0.17 m, with a population density of 40 plants.m^{-2} and a total area of 450 m^2.

Seven agronomic traits were evaluated: i) number of days to flowering onset (NDF, days): number of days from sowing to flowering onset, in which 50% of the plants presented at least one flower; ii) cycle (CY, days): days from sowing to harvest; iii) pod length (PL, cm), average length of five random pods derived from five randomly chosen plants; iv) pod mass

(PM, g): average weigh of the randomly chosen pods with grains; v) number of grains per pod (NGP): average grains from five random pods; vi) mass of 1000 (thousand) grains (M1000G, g): weight of 1000 grains from five plants; vii) grain yield (PROD, $kg.ha^{-1}$): total grain weight in relation to plot area.

Statistical analysis

After checking normality and homoscedasticity by Shapiro-Wilk and Bartlett tests respectively, data were subjected to ANOVA ($p<0.05$). Mean comparison was assessed by Tukey test ($p<0.05$).

The following statistical model was used:

$$Y_{ijk} = m_k + H_i + B_k + A_j + HA_{ij} + e_{ijk}$$

where:

Yijk = effect of observing the hybrid i on repetition j in k environment (experiments);

m_k = general environment average in k environment;

H_i = hybrid effect;

B_k = block effect;

A_j = environmental effect;

HA_{ij} = interaction effect of hybrid i and environment j;

e_{ijk} = random error.

The following genetic parameters were estimated: quadratic genotypic component (Φ_g^2); quadratic component of the hybrid x environment interaction (Φ_{ga}^2); residual variance (σ_r^2); genotypic determination coefficient (R^2); intraclass correlation (r); genetic variation coefficient (CVg (%)) and CVg/CVe ratio. All analyses were performed with Genes software (4).

Results and discussion

Significant differences were detected for NDF, PL and NGP (table 1, page 24), indicating variability between hybrids. A similar result was previously detected by Zare and Sharafzadeh (2012) for the same traits.

Significant environmental variation for all traits, except PL, evidenced strong environmental influence. CY, PL and NGP showed significant differences for hybrid-environment interaction (HxE), indicating different environmental performance for all hybrids.

Heritability (H^2) constitutes the proportion of genetic variance in total phenotypic variance. It allows estimating genetic gains in selection cycles, and for fixed treatments, as in the present study, it represents a determination coefficient (R^2) (14). For NDF, H^2 resulted in 0.92, followed by 0.72 for PL, meaning that these traits are less influenced by the environment than the others. Other studies have also reported high R^2 magnitudes (above 0.89) for NDF (12, 15, 16). Meanwhile, NGP and M1000G presented intermediate R^2 (0.68 and 0.57, respectively), as previously found (9, 11). The lowest R^2 values detected in this study (less than 0.50), indicated a stronger environmental influence on those traits.

Regarding PL (table 2, page 24), ALHT B4 and Diamond hybrids did not significantly vary among environments. As for NGP, three of the eight genotypes (Hyola 50, Hyola 433 and Diamond) had significant environmental variation.

When analyzing within each environment, Diamond hybrid presented the shortest cycle in the three experiments (ranging from 102 to 114 days), being, however, not statistically different from the rest in Experiment I. In general, considering that canola varies from 107 to 166 days (6) these evaluated genotypes can be classified as short-cycle hybrids. Precocity may be associated with climatic conditions, such as high temperature (approximately 32.5 °C in experiment I and 33.5 °C in experiments II and III) and long photoperiod. Canola hybrids with a shorter cycle are vital for incorporating canola in crop rotation systems in Brazilian Cerrado, allowing the species to benefit from the end of rainy periods and reducing mechanized irrigation.

Table 1. ANOVA and genetic parameters for number of days to flowering onset (NDF); cycle (CY); pod length (PL); pod weight (PM); number of grains per pod (NGP); weight of 1000 (thousand) grains (M1000G) and grain yield (GY) in eight canola genotypes grown in Cerrado, Brazil.

Tabla 1. Análisis de varianza conjunta y parámetros genéticos de los experimentos para las características: número de días para iniciar la floración (NDF); ciclo (CY); longitud de la vaina (PL); masa de la vaina (PM); número de granos por vaina (NGP); peso de 1000 (mil) granos (M1000G) y rendimiento de grano (GY) en ocho genotipos de canola.

SV	DF	Medium squares						
		NDF	**CY**	**PL**	**PM**	**NGP**	**M1000G**	**GY**
Block	3	28.07	9.31	0.22	920.72	9.96	0.10	2,009,995.54
Hybrids	7	151.04**	210.66	1.16*	1,689.23	103.19*	0.19	772,174.77
Environments	2	7,044.66**	728.51**	0.10	203,947.91*	271.32**	2.41**	28,461,036.04**
HxE	14	12.92	76.26**	0.31*	929.78	32.74**	0.08	675,616.09
Residue	69	12.76	10.78	0.14	1640.02	12.42	0.11	553,632.35
Mean		50.14	120.58	5.48	83.24	20.94	3.26	23.93
CVe(%)		7.12	2.72	6.89	48.64	16.82	10.08	31.09
Φ_g^2		11.51	11.20	0.07	63.29	5.87	0.01	8,046.56
Φ_{ga}^2		0.03	14.32	0.04	0.00	4.45	0.00	26,683.94
σ_r^2		12.76	10.78	0.14	1,640.02	12.42	0.11	553,632.36
R^2		91.45	63.80	72.91	44.96	68.27	57.66	12.50
r		47.36	30.85	28.19	4.09	25.83	8.09	1.37
CVg(%)		6.77	2.78	4.86	9.56	11.57	2.90	3.75
CVg/CVe		0.95	1.02	0.71	0.20	0.68	0.29	0.12

Sources of Variation (SV); Degrees of Freedom (DF); Hybrid x Environment Interaction (HxE), Environmental Variation Coefficient (CVe(%)); Genotypic Quadratic Component (Φ_g^2); Quadratic Component of Genotype x Environment Interaction (Φ_{ga}^2); Residual Variance (σ_r^2); Genotypic coefficient of determination (R^2); Intraclass Correlation (r); Genetic Variation Coefficient (CVg(%)) and CVg/CVe ratio (CVg/CVe); **,* Significant at 1% ($p<0.01$) and 5% ($p<0.05$) probability, respectively.

Fuentes de variación (SV); Grados de libertad (DF); Interacción Genotipo x Ambiente (GxE), Coeficiente de Variación Ambiental (CVe (%)); Componente cuadrático genotípico (Φ_g^2); Componente cuadrático de la interacción genotipo x ambiente (Φ_{ga}^2); Varianza residual (σ_r^2); Coeficiente de determinación genotípico (R^2); Correlación intraclase (r); Coeficiente de variación genética (CVg (%)) y relación CVg / CVe (CVg / CVe); **, * Significativo al 1% ($p <0,01$) y al 5% ($p <0,05$) de probabilidad, respectivamente.

Table 2. Tukey media comparison test for the characteristics cycle (CY, days), pod length (PL, cm) and number of grains per pod (NGP) in eight canola genotypes in the three experiments.

Tabla 2. Prueba comparación de medias de Tukey para el ciclo de características (CY, días), longitud de vaina (PL, cm) y número de granos por vaina (NGP) en ocho genotipos de canola en los tres experimentos evaluados.

Genotypes	CY						PL						NGP					
	Exp. I		Exp. II		Exp. III		Exp. I		Exp. II		Exp. III		Exp. I		Exp. II		Exp. III	
Hyola 50	117.5	Ba	27.0	Abc	125.5	Aa	5.6	Aa	5.8	Aa	5.6	Aabc	21.5	Aa	27.7	Aa	21.8	Aab
Hyola 61	117.3	Ba	133.5	Aab	118.5	Bab	5.4	Aa	5.7	Aa	5.5	Aabc	17.9	Ba	24.3	Aa	21.6	Abab
Hyola 76	117.3	Ca	135.0	Aa	126.0	Ba	5.5	Aa	5.4	Aab	5.3	Abc	19.8	Aa	22.2	Aa	19.4	Aab
Hyola 433	117.0	Aa	120.5	Ac	117.3	Ab	5.5	Aa	5.6	Aab	5.0	Ac	19.5	Aa	25.1	Aa	8.7	Bc
Hyola 571	117.3	Aa	122.5	Ac	122.3	Aab	5.2	Aa	4.7	Ab	4.9	Ac	16.3	Aa	21.1	Aa	17.0	Abc
Hyola 575	117.0	Aa	122.8	Ac	118.5	Aab	5.2	Aa	5.3	Aab	5.3	Abc	15.4	Aa	20.7	Aa	17.1	Ab
ALHT B4	117.0	Ba	125.8	Abc	122.3	ABab	5.9	Aa	5.8	Aa	6.2	Aab	21.0	Aa	26.3	Aa	23.0	Aab
Diamond	114.0	Ba	120.5	Ac	102.0	Cc	5.8	Aba	5.1	ABab	6.3	Aa	21.6	Aa	27.1	Aa	26.9	Aa

Means followed by the same lowercase letters vertically and the same uppercase letters horizontally constitute a statistically homogeneous group.

Las medias seguidas de las mismas letras minúsculas verticalmente y las mismas letras mayúsculas horizontalmente constituyen un grupo estadísticamente homogéneo.

The NGP significantly varied across all three experiments, with the hybrids Diamond, Hyola 50, ALHT B4, Hyola 433, Hyola 76 and Hyola 61 exhibiting the highest number of grains. For this trait, Diamond presented the higher values in experiments II and III, agreeing with the 17-24 grains per pod, previously observed in different canola genotypes (5, 15).

Grain yield resulted promising (figure 3) since all averages resulted higher (above 1,500 $kg.ha^{-1}$) than the national grain yield average (1,429 $kg.ha^{-1}$) (2), expecting Hyola 571, Hyola 433, ALHT B4 and Hyola 50 hybrids, that resulted below the national average in Experiment III.

The Hyola 61 hybrid showed the highest grain yield (2,926 $kg.ha^{-1}$), followed by Diamond hybrid (2,816 $kg.ha^{-1}$) in experiment I. Hyola 61 had previously exhibited high grain yield stability under both water deficit and intense cold (6). Diamond also outstood in experiment II for grain yield (3,356 $kg.ha^{-1}$), surpassed only by Hyola 76 (4,179 $kg.ha^{-1}$) and Hyola 571 (3,930 $kg.ha^{-1}$). In experiment III, Diamond (1,977 $kg.ha^{-1}$) showed the highest grain yield, followed by Hyola 61 (1,821 $kg.ha^{-1}$) and Hyola 76 (1,637 $kg.ha^{-1}$).

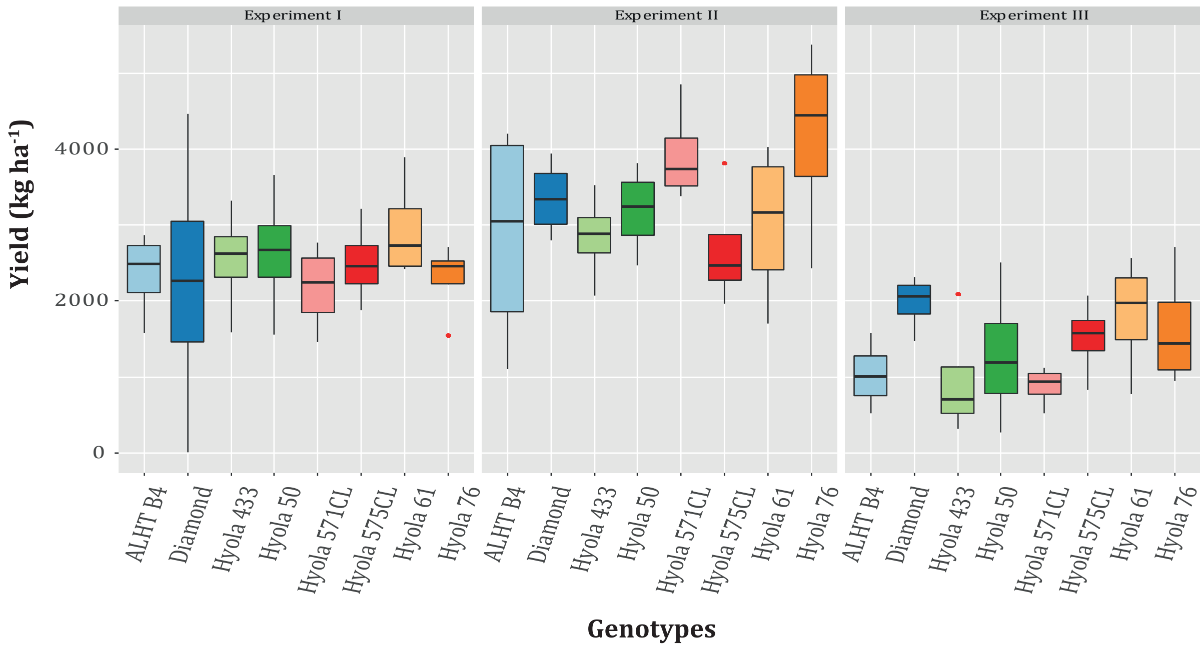

Figure 3. Boxplot from experiments I, II and III for grain yield in eight canola genotypes grown in Cerrado, Brazil.

Figura 3. Diagrama de caja de los experimentos I, II y III para el rendimiento de grano en ocho genotipos de canola cultivados en Cerrado, Brasil.

Conclusion

In summary, observing average estimates, we conclude that Hyola 61 and Hyola 76 outperformed with higher grain yield, followed by Diamond, with high production and shorter cycle. Due to these two key characteristics, Diamond can be considered the best option for crop rotation systems. Therefore, both hybrids constitute valuable alternatives for the Brazilian Cerrado.

References

1. Bassegio, D.; Zanotto, M. D. 2020. Growth, yield, and oil content of *Brassica* species under Brazilian tropical conditions. Brag. 79: 203-212.

2. Channaoui, S.; Idrissi, I. S. E.; Mazouz, H.; Nabloussi, A. 2019. Reaction of some rapeseed (*Brassica napus L.*) genotypes to different drought stress levels during germination and seedling growth stages. Oil. Crop. Lip. 26:1-23.

3. CONAB. 2020. Acompanhamento da safra brasileira de grãos: safra 2018/19. N° 6. Quarto levantamento. Brasília. Conab. 126 p.
4. Cruz, C. D. 2013. GENES - a software package for analysis in experimental statistics and quantitative genetics. Acta Scie. Agron. 35: 271-276.
5. Durán, X. A.; Ulloa, R. B.; Carrillo, J. A.; Contreas, J. L.; Bastidas, M. T. 2010. Evaluation of yield component traits of honeybee-pollinated (*Apis mellifera* L.) rapeseed canola (*Brassica napus L.*). Chil. Jour. Agric. Res. 70: 309-314.
6. Embrapa. 2014. Sistemas de produção do cultivo de canola - Sementes. https://www.spo.cnptia.embrapa.br (query data: 05/03/2021).
7. Estevez, R. L.; Chambo, A. P. S.; Barbosa, J. D.; Cruz, I. F. 2014. A Cultura da Canola (*Brassica napus* var. oleifera). Sci. Agr. Para. 13: 1-9.
8. Hussain, Z.; Khan, M. A.; Iqbal, F.; Raffi, M.; Hafeez, Y. 2019. Electrospun microbial-encapsulated composite-based plasticized seed coat for rhizosphere stabilization and sustainable production of canola (*Brassica napus L.*). Jour. Agric. Fo. Chem. 67: 5085-5095.
9. Khan, A. M.; Uddin, R.; Rahman, Z. U.; Din, I. U.; Muhammad, A.; Ali, Q.; Iqbal, N.; Zafar, A. 2019. Genetic variability and heritability for yield and yield associated traits among *Brassica napus* genotypes. Inter. Jour. Biosc. 14: 369-377.
10. Köppen, W.; Geiger, R. 1936. Das Geographische System der Klimate. Handbuch der Klimatologie.
11. Krüger, C. A. M. B.; Silva, J. A. G.; Medeiros, S. L. P.; Dalmago, G. A.; Sartori, C. O.; Schiavo, J. 2011. Arranjo de plantas na expressão dos componentes da produtividade de grãos de canola. Pesq. Agrop. Bras. 46: 1448-1453.
12. Laghari, K.; Baloch, M.; Sootaher, J. K.; Menghwar, K. K.; Kachi, M.; Kumbhar, Z. M. 2020. Correlation and heritability analysis in rapeseed (*Brassica napus L.*) genotypes. Pur. App. Bio. 9:507-516.
13. Panozzo, L. E.; Zuchi, F.; Silva, F. D.; Pinto, L. B.; Dias, D. C. F. S.; Barros, W. S.; Tomm, G. O. 2014. Evaluation of some hybrids of canola in function of sowing dates in Viçosa. MG. Brazil. Afric. Jour. of Agric. Res. 9: 2488-2494.
14. Yokomizo, G. K. I.; Vello, N. A. Coeficiente de determinação genotípica e de diversidade genética em topocruzamentos de soja tipo alimento com tipo grão. Pes. Agrop. Bra. 35: 2223-2228.
15. Young, L. W.; Wilen, R. W.; Bonham-Smith, P. C.; 2004. High temperature stress of *Brassica napus* during flower ingreduces micro-and megagametophyte fertility, induces fruit abortion, and disrupts seed production. Jour. Exp. Bot. 55: 485-495.
16. Zare, M.; Sharafzadeh, S. 2012. Genetic variability of some rapeseed (*Brassica napus L.*) cultivars in Southern Iran. Afric. Jour. Agric. Res. 7: 224-229.