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AGRONOMIC PERFORMANCE OF CANOLA HYBRIDS CULTIVATED IN A LOW ALTITUDE REGION IN SOUTHERN BRAZIL

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ABSTRACT - The area occupied by crops has expanded in recent years in the central region of Rio Grande do Sul, Brazil and the search for alternative winter crops to integrate the productive system is relevant given the idleness of the areas at this time and the lower risk of frost losses that occur in most grain-producing regions. In this sense, the objective of this research was to evaluate the agronomic performance of eight canola hybrids (Hyola 61, Hyola 50, Hyola 433, Hyola 571CL, Hyola 575CL, Diamond, ALHT B4, and ALHT M6), cultivated in low altitude areas, in the Central region of Rio Grande do Sul (RS). The experiment was conducted in 2017, in Santa Maria, RS, using a randomized block design with four replicates. Canola hybrids show variability regarding the morphological components and grain production. The environmental condition and low altitude of the region of Santa Maria do not compromise the productive potential of the canola crop, obtaining grain productivity superior to the state and national averages. Therefore, canola crop can be inserted in the central region of Rio Grande do Sul if adequate agronomic management is performed. The cultivars Hyola 50, Hyola 571CL, Hyola 433, Hyola 575CL, Diamond, and Hyola 61 present the highest grain productivity.
Keywords: *Brassica napus* L., cultivar cycle, grain production systems, morphological components.

DESEMPENHO AGRONÔMICO DE HÍBRIDOS DE CANOLA CULTIVADOS EM REGIÃO DE BAIXA ALTITUDE NO SUL DO BRASIL

RESUMO - A área de cultivo agrícola vem aumentando nos últimos anos na região central do Rio Grande do Sul e a busca por alternativas de cultivos de inverno para integrarem o sistema produtivo é relevante, dada a ociosidade das áreas e o menor risco de geadas que em outras regiões produtoras de canola. Neste sentido, o objetivo desta pesquisa foi avaliar o desempenho agronômico de oito híbridos de canola (Hyola 61, Hyola 50, Hyola 433, Hyola 571CL, Hyola 575CL, Diamond, ALHT B4 e ALHT M6), cultivados em local de baixa altitude, na região Central do Estado do Rio Grande do Sul, Brasil. O experimento foi conduzido em 2017, no município de Santa Maria, RS, utilizando o delineamento experimental de blocos ao acaso, com quatro repetições. Os híbridos de canola apresentam variabilidade quanto aos componentes morfológicos e produção de grãos. As condições ambientais e a baixa altitude da região de Santa Maria não comprometem o potencial produtivo da cultura da canola, obtendo produtividade de grãos superior às médias estaduais e nacionais. Portanto, a cultura da canola pode ser inserida na região central do Rio Grande do Sul se for realizado um manejo agronômico adequado.
Palavras-chave: *Brassica napus* L., ciclo de cultivares, sistemas de produção de grãos, componentes morfológicos.

INTRODUCTION

Canola (*Brassica napus* L.) is the third most important oilseed produced globally (KIRKEGAARD et al., 2016) and the world production in the 2017/2018 harvest was of approximately 74 million tons, an increase of 7.5% over the previous harvest (USDA, 2019). In Brazil, the area sown with canola in 2017 was of 48.1 thousand hectares, of which the state of Rio Grande do Sul accounted for 90%. The average Brazilian productivity in 2017 was of only 840 kg ha^{-1} (CONAB, 2017).

It is essential to consider altitude when choosing the crops to be implanted in a given region due to its influence on weather and geophysical phenomena. Körner (2007) describes that the available surface of a terrain tends to be larger in lower altitudes than in high altitude locations. This statement is consistent with the hypothesis formulated by Durães (2007), where low tropical regions shelter wide areas of the Brazilian territory and are described as low altitude, ranging from 0 to 700 m above sea level. Furthermore, there are four other atmospheric changes associated with low altitude when compared to high altitude: (i) increase in total atmospheric pressure and partial pressure of atmospheric gases; (ii) increase of air temperature, with implications on ambient humidity and lower risk of frost damages; (iii) lower solar radiation under clear skies, and (iv) lower fraction of ultraviolet radiation (UVB) indices (KÖRNER, 2007).

Comparative studies on environment x genotype x management interaction have reported significant effects on the expression of the characteristics of each cultivar. In

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this sense, local studies on the agronomic performance of canola cultivars, such as those performed in the high-rainfall zone of Australia (SPRAGUE et al., 2015), in the semiarid region of Italy (LICATA et al., 2018), in the Great Plains of the United States (JOHNSON; HANSON, 2003), in Canadian Prairies (MORRISON et al., 2016) or in Southern Brazil (LIMA et al., 2017) have demonstrated that genotypic differences are important for cultivar adaptation to specific cultivation environments (ZHANG et al., 2013).

Studying the agronomic performance of canola cultivars in new regions with lower risk of frost damages, helps understanding and decision-making in crop management, also assisting in identifying cultivars adapted to the cultivating region and in studying the viability of cultivation within the production system. The objective of this research was to evaluate the genetic variability and agronomic performance of eight canola hybrids, cultivated in a low altitude area in the central region of Rio Grande do Sul, Brazil.

MATERIALS AND METHODS

The experiment was conducted in 2017, in Santa Maria, Rio Grande do Sul, Brazil (29º41'02.31 S, 53º43'57.63 W), in an experimental area with an altitude of 117 m. According to the Köppen classification, the climate of the region is *Cfa*, humid subtropical, with hot summers and undefined dry season (HELDWEIN et al., 2009). The soil is classified as Paleudalf is characterized as an undulating plain with good drainage.

The experimental was conducted in a randomized block design with four replicates. The experimental unit consisted of five rows of 3.5 m of length and spacing of 0.45 m, totalizing an area of 7.87 m^2, with eight treatments, using hybrids Hyola 61, Hyola 50, Hyola 433, Hyola 571CL, Hyola 575CL, Diamond, ALHT B4, and ALHT M6. The assay cultivars are representative for the crop since they correspond to most cultivars available for cultivation in Brazil.

Sowing was conducted on May 10th, 2017, according to the sowing period indicated by Tomm et al. (2009). The emergence occurred eight days after sowing, after which thinning was performed to adjust plant density to 40 plants m^{-2}. Sowing fertilization was performed mechanically in the furrow, using a dose of 400 kg ha^{-1} of formula 05-20-20. The commercial urea (45% N) was applied at a dose of 50 kg ha^{-1} of N in a phase when the plants presented four true expanded leaves, according to the recommendation of the Soil Chemistry and Fertility Commission - RS/SC (CQFS, 2016) regarding the supply of cover nitrogen. When the plants presented six true expanded leaves, new cover fertilization of nitrogen was performed using ammonium sulfate (21% N and 24% S) at the dose of 20 kg N ha^{-1}.

During the crop cycle in the experiment, the duration of the subperiods days from emergence to the beginning of flowering (DEBF), duration of the flowering period, i.e., days from the beginning of flowering to end of flowering (DBFEF), and days from emergence to physiological maturation (DEPM) was evaluated. The phenological observations used to quantify the subperiod duration performed were: date of emergence (date when 50% of the seedlings in the plot emerged); beginning of flowering (date when 50% of the plants had at least one flower); end of flowering (date when no more flowers remained, apart from atypical plants); date of maturity (date when 50% of the seeds changed to a dark color on the siliques located in the middle of the main raceme of the plants).

The experiment was manually harvested in the three central rows of each plot, leaving a border of 0.75 m on each side of each sowing row, totalizing a plot area of 2.7 m^2. Subsequently, the plot was tracked and the grain productivity in kg ha^{-1} (PROD) was quantified by measuring the grain mass per plot and adjusting for the humidity of 13%.

Six representative plants were collected from each plot to evaluate the morphological characters grain yield components, such as plant height (PH in cm), height of insertion of the last silique (HILS in cm), number of primary branches (NPB), number of secondary branches (NSB), length of the siliques located in the inferior part of the plant (LSI in cm), length of the siliques located in the superior part of the plant (LSS in cm), total number of siliques per plant (TNS), number of grains per silique in the inferior part of the plant (NGSI), and number of grains per silique in the superior part of the plant (NGSS).

Daily meteorological data was collected from the website of automatic and conventional meteorological stations of the National Meteorology Institute (INMET) to conduct a detailed analysis of the cultivation environment. The respective meteorological stations are located at the coordinates 29º72'S and 53º72'W, approximately 1,000 m from the experimental area. All variables evaluated were subjected to analysis of variance, comparing the treatment means by the Scott-Knott test at 5% of significance ($p > 0.05$). The statistical analyses were performed with the aid of Software Genes (CRUZ, 2013).

RESULTS AND DISCUSSION

The total rainfall during cultivation was of 799.10 mm (Figure 1), which represents 60% more irrigation then required by the crop. During experimentation, irregular periods of rainfall occurred with an excess of rainfall (for 30 days after sowing and from 90 to 100 days after sowing) and water restriction between 30 to 60 days after sowing (Figure 1A). Although there were periods of water deficiency, these were not very intense due that more than 80% of the water requirement of the reference surface (grass) was met (Figure 1B). Under conditions of water excess, the porous space of the soil is predominantly saturated by water, reducing soil aeration and, consequently, the oxygen available to plants.

Fochesatto et al. (2014) add that extreme air temperatures and water deficiency and excess change the thermal requirement of the canola. The increase or decrease of the thermal requirement will depend on the subperiod of the crop development, as well as its intensity and duration. In this sense, studying the positioning of canola cultivars in specific regions is relevant, given that, besides evaluating the agronomic performance of cultivars, research on crop positioning also helps planning the production system, avoiding the delay of sowing summer crops.

The maximum and minimum daily temperatures fluctuated during the study period, with the average daily air temperature between sowing and harvesting of 16.45ºC (Figure 1B), remaining within the range recommended by Tomm et al. (2009), which corresponds to 13-22ºC for the growing season. The average daily temperatures that occurred in the germination and emergence periods were superior to 10ºC, remaining within the recommended range for fast germination and good root growth.

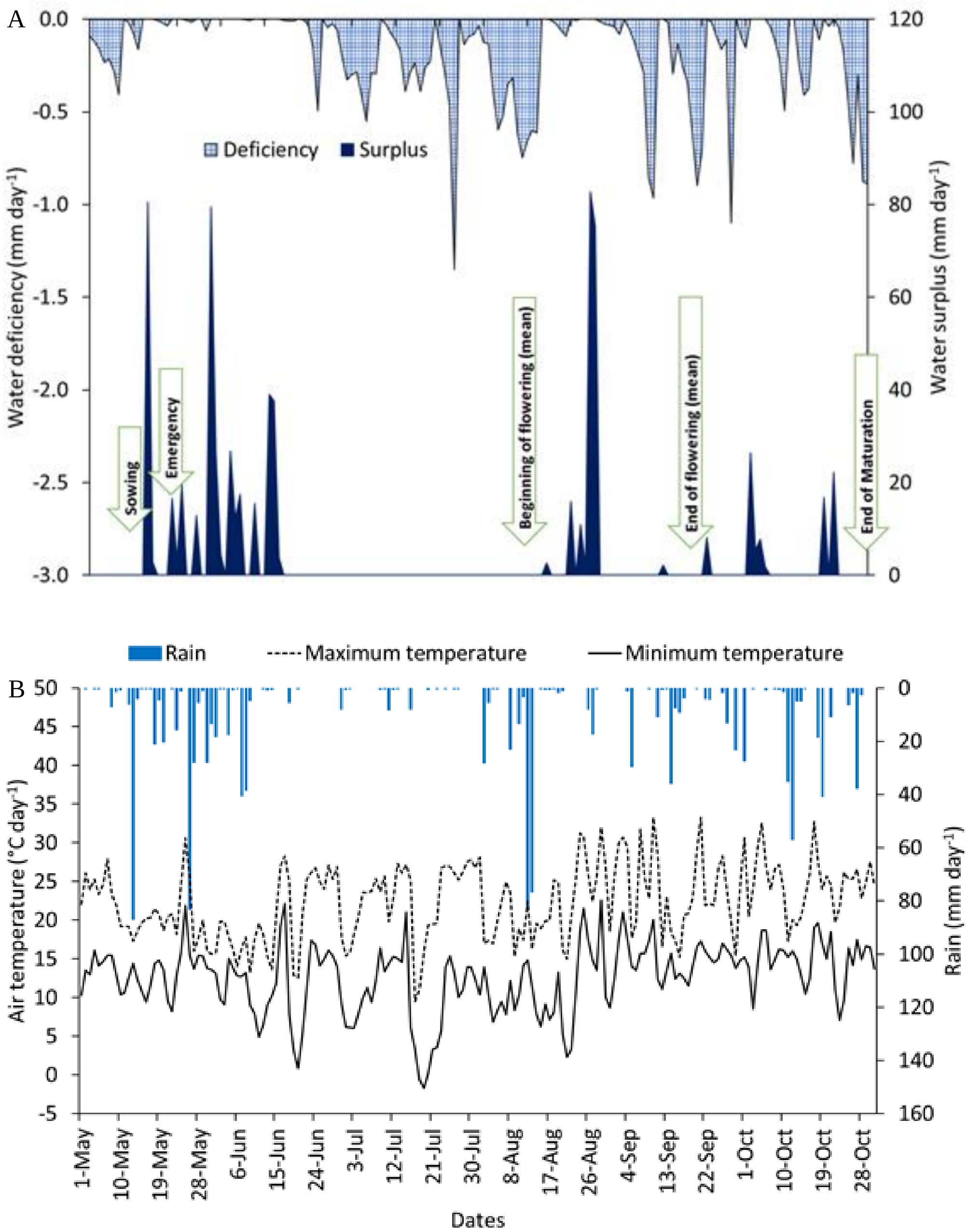

FIGURE 1 - A: Maximum and minimum temperatures, global solar radiation, and rainfall during the experimentation period, conducted between May 1st to November 10th, 2017. B: Daily water deficit and surplus obtained from sequential water balance for the grassy surface, with available water content equal to 75 mm, recorded in Santa Maria, RS, Brazil, from May 1st to November 10th, 2017.

Luz et al. (2012) found the base temperatures of 0.3ºC, 9.9ºC, and 7.9ºC for the subperiods of emergence to the beginning of flowering, beginning of flowering to the end of flowering, and end of flowering to physiological maturity, respectively, for cultivar Hyola 433. However, air temperature fluctuated during the study period in ranges below 0.3ºC and above 27ºC, given that temperatures below the base temperature delay plant growth and high temperatures (above 27ºC) cause the abortion of flowers and siliques in early formation (MORRISON; STEWART, 2002; TOMM et al., 2009). Therefore, these thermal oscillations associated with water condition and lack of solar radiation may have influenced the vegetative and reproductive development of the cultivars due to the direct and indirect influence that air temperature has on plant development and growth.

Lower altitude regions are warmer when compared to high altitude due to denser air having the ability to accumulate heat. Nwogha et al. (2019) reported that an increase in night/day temperature resulted in an increase in plant height, in the number of leaves, and leaf area of canola plants. Therefore, due to the severe winter weather that affected most of the southern Brazilian territory, such as frost in the flowering season, the Santa Maria region had reduced productivity losses due to its low altitude. This can be observed when comparing the productivity of Hyola 50 hybrid with the productivity of the state of Rio Grande do Sul in 2017 (CONAB, 2017), where Hyola 50 presented productivity 49% higher than the RS average.

According to the classification, low coefficients of variation were found for the variables DEPM (0.66%), DEBF (1.89%), PH (2.93%), LSS (3.49%), LSI (3.72%), HILS (3.84%), NGSS (5.39%), NGSI (5.81%), DBFEF (6.55%), HIFS (6.98%), and NPB (9.82%), while average CVs were found for PROD (13.03%) and TNS (14.51%), and high CV occurred for NSB (25.34%).

TABLE 1 - Mean values for duration in days of the phenological subperiods in days and morphological components.

Hybrids	DEBF	DBFEF	DEPM	PH	HIFS	HILS	NPB
Hyola 61	74.50 c*	33.50 b	132.75 c	101.07 e	54.59 c	98.02 e	3.30 c
Hyola 50	78.75 b	32.50 b	135.25 b	123.54 b	76.11 b	118.62 b	2.92 d
Hyola 433	70.25 d	35.00 b	130.25 d	108.94 d	59.98 c	105.37 d	3.25 c
Hyola 571CL	69.25 d	32.00 b	126.75 e	115.48 c	58.66 c	113.13 c	3.52 c
Hyola 575CL	69.50 d	30.75 b	126.00 e	109.52 d	58.19 c	107.02 d	3.42 c
Diamond	61.25 e	38.25 a	123.75 f	109.20 d	55.60 c	108.82 d	4.04 b
ALHT B4	78.25 b	33.75 b	131.50 c	125.29 b	74.27 b	120.86 b	2.58 d
ALHT M6	95.50 a	24.75 c	144.00 a	146.04 a	103.52 a	143.82 a	5.21 a
CV(%)	1.89	6.55	0.66	2.93	6.98	3.84	9.82
Hybrids	NSB	LSI	LSS	TNS	NGSI	NGSS	PROD
Hyola 61	2.46 b	7.02 a	6.16 b	114.37 b	14.08 b	12.54 c	1384.63 a
Hyola 50	3.25 b	6.79 a	6.52 b	116.5 b	14.31 b	15.22 b	1620.47 a
Hyola 433	6.71 a	6.49 b	6.36 b	132.67 b	12.61 c	14.25 c	1489.26 a
Hyola 571CL	6.06 a	6.38 b	6.32 b	169.15 a	10.27 d	13.09 c	1616.49 a
Hyola 575CL	5.17 a	6.16 b	6.26 b	133.41 b	10.46 d	12.76 c	1451.77 a
Diamond	6.83 a	7.14 a	6.28 b	133.66 b	17.32 a	16.30 b	1423.69 a
ALHT B4	2.96 b	6.94 a	6.88 a	98.25 b	16.67 a	17.51 a	1168.09 b
ALHT M6	2.46 b	6.52 b	6.25 b	132.08 b	13.56 b	13.41 c	1153.25 b
CV(%)	25.34	3.72	3.49	14.51	5.81	5.39	13.03

*Means followed by the same letter in the column do not differ by the Scott-Knott test at 5% of significance. DEBF = emergence to the beginning of flowering, DBFEF = beginning to end of flowering, DEPM = emergence to physiological maturation of the eight canola hybrids, PH = mean values in centimeters for the morphological parameters of plant height, HIFS = height of insertion of the first silique, HILS = height of insertion of the last silique, NPB = number of primary branches, NSB = number of secondary branches, LSI = length of the silique located in the inferior part of the plant (cm), LSS = length of the silique located in the superior part of the plant (cm), TNS = mean values for the productivity components of total number of siliques, NGSI = number of grains per silique located in the inferior part of the plant, NGSS = number of grains per silique located in the superior part of the plant, PROD = productivity (kg ha^{-1}).

Regarding the duration of subperiods in days for the canola hybrids (Table 1), the ALHT M6 genotype of the DEBF variable required the longest time to begin flowering, unlike the Diamond genotype, which was the most premature. In contrast, the ALHT M6 genotype of the DBFEF variable presented its shortest subperiod, differing from Diamond, which had the longest flowering period among all others. The cycle of cultivar ALHT M6 was the longest with 144 days while Diamond was the shortest with 123.75 days (variable DEPM). Similar results were found by Caraffa et al. (2017), in which the Diamond cultivar was the shortest with 100 days and the ALHT M6 genotype was the longest with 135 days. Studies conducted in South Africa also indicated the Diamond hybrid as presenting a short cycle (LOMBARD et al., 2019). This reduction in the crop cycle can be considered an advantage for planning the production system since the shorter canola cultivation cycle does not delay the cultivation the soybean crop in a canola and soybean cultivation system. The mean DEPM variable presented a result similar to the one found by Arrúa et al. (2017) in an experiment conducted in the state of Paraná, reporting a hybrid cycle average of 133 days.

The increase in the crop cycle compared to the cultivation in Três de Maio (RS) (CARAFFA et al., 2017) may be associated with the period of cloud cover and lower solar radiation, associated with different weather conditions between regions and years of the experiment. According to Diepenbrock (2000), the interception of solar radiation is the most important and limiting factor to plant growth rates in early stages of development and grain maturation. This demonstrates the importance of early sowing within the period recommended by the agroclimatic zoning of the crop, especially to not delay the preferred sowing season of summer crops.

Cultivar ALHT M6 obtained the highest values for the variables PH, HIFS, and HILS of the morphological components (146.04 cm, 103.52 cm, and 143.82 cm, respectively), contrasting with cultivar Hyola 61 which obtained the lowest values for variables PH and HILS, and the cultivars Hyola 433, Hyola 571CL, Hyola 575CL, Hyola 61, and Diamond which obtained lower values for HIFS.

For the NPB and NSB variables, also established as morphological components of the crop, cultivar ALHT M6 presented the largest number for NPB (5.21), differing from the cultivars ALHT B4, which presented an average NPB (2.56). For NSB, cultivars Diamond (6.83), Hyola 433 (6.71), Hyola 571CL (6.06), and Hyola 575CL (5.17) presented the highest numbers, demonstrating the potential to develop branches. The number of branches is a result of combinations of the genetics of each cultivar and the environmental conditions in which they are inserted (ASSEFA et al., 2014), causing a positive relationship between a higher number of branches and a higher number of siliques per plant and, consequently, higher productivity (ROSSETTO et al., 1998; SADAT et al., 2010; BANDEIRA et al., 2013).

For the LSI variable, cultivars Diamond (7.14 cm), Hyola 61 (7.02 cm), ALHT B4 (6.94 cm), and Hyola 50 (6.79 cm) presented the highest averages, statistically differing from the other genotypes. Hybrid ALHT B4 was statistically different from all the others for LSS, presenting a higher value (6.88 cm), thus considered the hybrid with the largest sized siliques, regardless of the position of the silique on the plant. Similar lengths of silique in spring canola hybrids were found by Amirnia et al. (2013) in Iran and Cai et al. (2013) in China, ranging from 4.8 to 6.8 cm. No studies comparing the lengths of siliques located at the top and bottom of the plant were found, highlighting the importance of this work regarding this characterization.

For the productivity components, hybrid Hyola 571CL presented the highest value of TNS, producing an average of 169.15 siliques per plant. A similar result was reported by Arrúa et al. (2017), who found the highest number of siliques per plant for the Hyola 571CL hybrid, producing 228 siliques. Hybrid ALHT B4 obtained the highest value of NDSS (17.51 grains per silica), and hybrids ALHT B4 (16.67 grains per silica) and Diamond (17.32 grains) differed from all others with the highest values for NGSI. Arrúa et al. (2017) found an average of 17.9 grains per silique, with no statistical difference between hybrids. In the present research, a close relationship between the length of silique and the number of grains per silique was identified, where hybrids with higher values for variables LSS (ALHT B4) and LSI (ALHT B4, Diamond, Hyola 61, and Hyola 50) presented higher NGSS (ALHT B4) and NGSI (ALHT B4 and Diamond), demonstrating that the environment conditions that occurred from flowering to grain maturation were not harmful to the plants because they were of low intensity, considering that the flowering of the canola crop begins at the bottom of the plant and ends at the top. Due to the uniformity of the data, the plants were not harmed by grain abortion or week grains. No studies comparing the number of grains per silique located at the top of the plant with the number of grains per silique located at the bottom were found, highlighting the importance of this characterization for the literature.

Cultivar Hyola 50 achieved the highest grain productivity, producing 1620.47 kg ha^{-1}. However, this value did not differ statistically from cultivars Hyola 571CL (1616.49 kg ha^{-1}), Hyola 433 (1489.26 kg ha^{-1}), Hyola 575CL (1451.77 kg ha^{-1}), Diamond (1423,69 kg ha-^{1}), and Hyola 61 (1384.63 kg ha^{-1}). Cultivars ALHT B4 (1168.09 kg ha^{-1}) and ALHT M6 (1153.25 kg ha^{-1}) formed the second group. The difference in productivity between the most (Hyola 50) and least productive hybrid (ALHT M6) was of 467 kg ha^{-1}, highlighting the importance of studies on cultivar placement.

The experiment average (1,413.46 kg ha^{-1}) was higher than the averages found by Caraffa et al. (2017) in Três de Maio (Rio Grande do Sul State) and by Lima et al. (2017) in Maringá (Paraná State), with respective values of 1,076 kg ha^{-1} and 1,081.01 kg ha^{-1}. Caraffa et al. (2017) found that Diamond was the most productive cultivar while the least productive was ALHT M6, corroborating the results obtained in the present study, where the Diamond cultivar was present in the most productive group and ALHT M6 in the least. Pereira et al. (2016) compared different sowing dates and identified differences between the cultivars regarding grain production, presenting loss of productivity when sowing was performed later, within the recommended period, demonstrating that the sowing date can also influence canola grain productivity and recommends that sowing be performed at the beginning of the recommended period to avoid delaying the preferred time of summer crops.

In addition to a broad characterization of the evaluated cultivars, a great variability between cultivars was proven to exist with differences regarding the beginning and end of flowering between cultivars, enabling lower risks of loss of productive potential during periods of water deficit and frost during flowering. Cultivating canola in the central region of Rio Grande do Sul after soybean cultivation is viable because grain production has exceeded state and national averages and may become an economical alternative for winter cultivation in the central region of Rio Grande do Sul.

CONCLUSIONS

Canola hybrids show variability regarding the morphological components and grain production.

The environmental condition and low altitude of the region of Santa Maria do not compromise the productive potential of the canola crop, obtaining grain productivity superior to the state and national averages. Therefore, canola crop can be inserted in the central region of Rio Grande do Sul if adequate agronomic management is performed.

The cultivars Hyola 50, Hyola 571CL, Hyola 433, Hyola 575CL, Diamond, and Hyola 61 present the highest grain productivity.

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