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Physiological quality of canola seeds under different sowing and harvesting times

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Abstract: To expand and implement the cultivation of canola in an agricultural production system, it is essential for the production and use of high-quality seeds. The objective of this research is to evaluate the germination of hybrid seed during different sowing and harvesting dates. The experiment was conducted at the experimental site and the Seed Laboratory of Federal University of Viçosa. The hybrids canola Hyola 432, 433, 401 and 61 were sown and harvest in different dates. After the seed processing, the seeds were evaluated for germination, first count of germination, speed of germination, time, and average velocity of germination. The experimental design was a randomized complete block 4 hybrids x 4 sowing times x 3 harvest times and with four replications. Data from qualitative factors were submitted to variance analysis and compared by Tukey's test and quantitatively factors were compared by regression analysis. To harvest seeds with high physiological quality it is necessary to sow between May and June and harvest after reaching physiological maturity until a maximum of 10 days. The seeds of Hyola 401 showed better seed quality, based on the results of all the variables studied, regardless of sowing and harvesting date.

Keywords: *Brassica napus*; germination; oilseeds; seed yield; tropicalization; vigor.

Introduction

Canola (*Brassica napus* L. var. Oleifera Moench), which belongs to the family *Brassicaceae*, has a grain with around 40% of oil and 34-38% of protein in the grain (So et al., 2021; Vastolo et al., 2022). This specie is the second most produced oilseed in the world (Tokel et al., 2021; USDA, 2024) for its oil that is extracted from the canola grains that later is produced for its high industrial and economic value as an edible oil and a feedstock for biodiesel production (Gularte et al., 2020). In Europe, this oil is the main feedstock for biodiesel production, contributing to the reduction of greenhouse gas emissions, therefore, constituting a promising alternative to make Brazilian agriculture more modern and sustainable.

To implement a canola crop in an agricultural production system, it is essential to have seeds with high physiological quality (Kourani et al., 2022). However, it is known that the quality of the seeds can be affected by several factors, among them are: harvest season (Colet et al., 2020), process of harvesting, drying, processing, storage (Lima et al., 2017; Leonardi et al., 2023), soil fertility, genetic factors and the cultural and climatic conditions throughout the development cycle of the plants (Garcia et al.,2016; Borges et al., 2023; Pimentel et al., 2024).

The genetic and physiological quality of seeds has great importance for improvement and adaptation of canola culture in new regions. The physiological seed quality is maximal at physiological maturity when the dry weight, germination, and vigor usually reached the maximum values. From this point, the physiological quality is either maintained or degenerated, in which occurs mainly from environmental conditions prior to harvesting. The canola seed maturation proceeds acropetally, starting from the lower branches and heads towards the upper main stem and side branches (Rosa et al., 2019), but may occur in the same plant pods not matured and, in extreme cases, even flowers (Zhang et al., 2021).

For canola seed, such as the case of other oilseeds, soybean for example (França Neto et al., 2007), harvesting is one of the most critical phases of the whole production process, as it can cause losses in quality and quantity of the seeds produced, which may reflect the intensity of deterioration impairing the vigor of them. Because of this, the harvest begins when the seeds begin to change from green to dark brown or black color (30 to 35% moisture), that is, when most of the seeds reached physiological maturity (Arinaitwe et al., 2023; Brown et al., 2023). Previously from Naghisharifi et al. 2024, the best time to harvest canola seeds is when 70% of the seeds are black.

The sowing season is another factor that directly influences physiological quality of seeds that will be harvested, because Brazilian regions have large climatic diversity. In tropical conditions, due to less variation of temperature and photoperiod, the distribution of rainfall is what generally determines the best time for planting crops, generally speaking. The most appropriate time for sowing canola is when the area has warmer temperatures during the night (Tomm, 2006; de Almeida et al., 2020; Rashid et al., 2020) and low rainfall at harvest time. Depending on weather conditions, the proper identification of harvest period of canola seed is very important in order to maintain the same vigor as the correct harvest period may be short (,).

In view of the limited information on management of canola seed production; for example, the small size of the seeds and the low

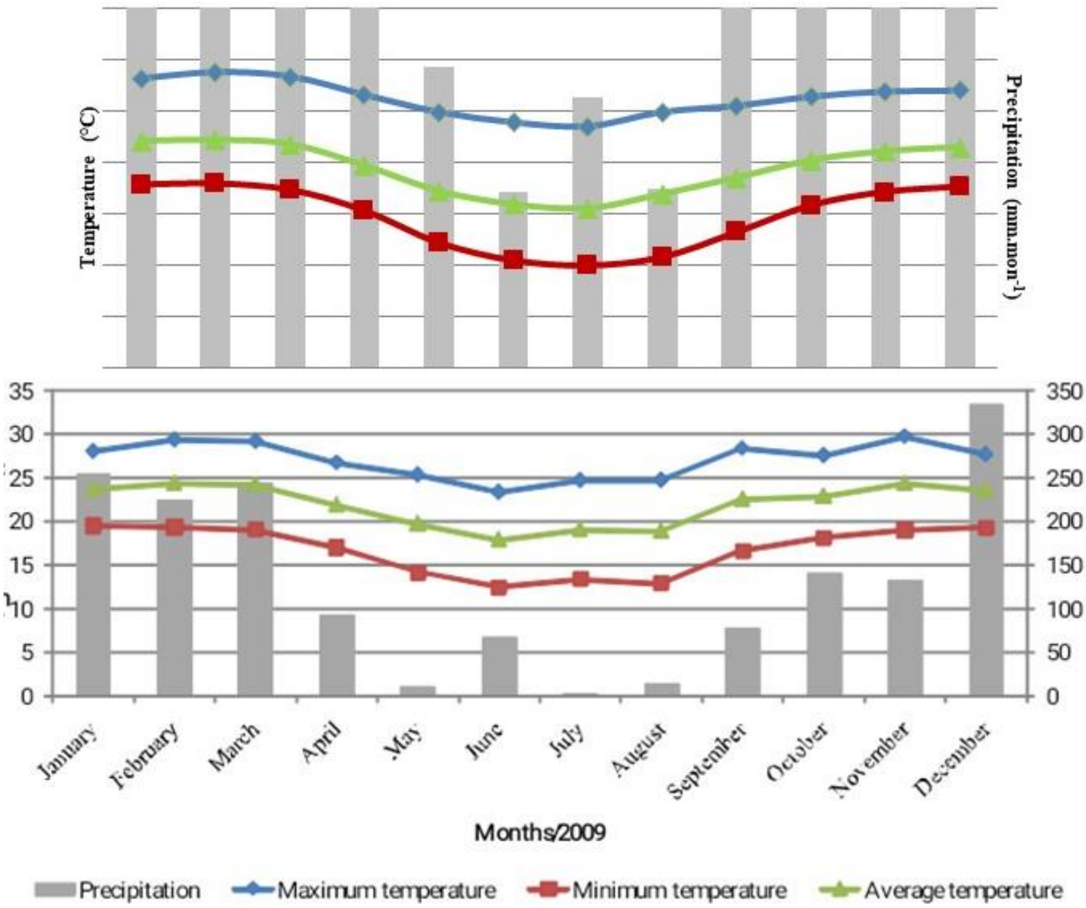

Figure 1. Precipitation and temperature data in Viçosa, MG, 2009.

seeding rate per hectare; information on the physiological quality of the seeds of this culture would be extremely useful to implement the growth and the adequate stand in the field. Thus, the aim of this study is to evaluate the physiological quality of seeds of four hybrids of canola in different dates of sowing and harvesting underagro-climatic conditions in Viçosa-MG, Brazil.

Results and Discussion

Seed germination quality - first count of germination (FCG)

The quality of seed germination is essential for the success of canola hybrid cultivars. The first germination count (FCG) stands out as an initial indicator of seed viability and vigor, directly influencing the productivity and quality of this crop (Boter et al., 2019).

There was interaction between the factors tested for all variables. For the first, second, and third sowing dates (05/26, 06/10 and 06/25), the variable first count of germination showed no differences between hybrid and harvest dates (Table 1), respectively. When comparing hybrids, it was generally observed that Hyola 401 had the highest absolute value for the first count of germination, regardless of sowing date and harvest date (Table 2). In the fourth sowing date (07/10), Hyola 401 showed a significant difference for the first count of germination when compared with the other hybrids (Table 1 and Fig. 2).

It was observed that, in general, Hyola 401 presented the highest FCG, regardless of the sowing time. However, in the fourth sowing season, this hybrid showed a significant difference in relation to the others (Table 1 and Fig. 2). These outcomes may be because of low vigor of the seeds in the fourth sowing date (07/10), due to climatic conditions in which it was harvested (Fig. 1). Furthermore, delays in sowing negatively impacted the FCG of all hybrids. This decline can be attributed to possible low seed vigor due to adverse weather conditions during harvest. In this sense, it is crucial to recognize other factors, such as weather conditions during the harvest period, in addition to observations based on a holistic approach to understanding the mechanisms underlying seed germination (Boter et al., 2019; D'hooghe et al., 2019).The hybrid Hyola 61 showed a significant reduction in the first count of germination and had a delayed harvest for the third and fourth period (06/25 and 07/10). In the Hyola 432, this reduction appeared only in the fourth time (07/10) and for PM, that can be explained by the fact that seeds tend to deteriorate in the field, consequently decreasing its physiological quality. Previously, Li (2023) reported that the harvesting of canola seeds should start at the physiological maturity of seeds, characterized by the change from green to dark brown or black color, when they are 30 to 35% of moisture. However, other studies have found that the best time to harvest canola seed with high vigor is up to 126 days after sowing (DAS), when the pods have higher proportion of colored straw and seeds with black color (Zandberg et al., 2022).. Observations suggest a possible deterioration of seeds in the field, affecting their physiological quality. However, the divergence between studies regarding the ideal harvest time highlights a gap in recommended practices. These findings highlight the need for a more comprehensive investigation and consideration of multiple factors to determine the optimal harvest time to maximize the quality and yield of canola crops Boter et al., 2019).

The Hyola 61 and Hyola 432 hybrids, with a reduction in the first germination count due to the delay in harvesting, suggest a possible deterioration of the seeds in the field. This is particularly evident for Hyola 61, which had its harvest delayed to the third and fourth periods, while in Hyola 432 this reduction occurred only in the fourth season (Table 1 and Fig. 2). These results highlight the sensitivity of seeds to the growing environment and late harvest. Furthermore, despite the reduction in all hybrids with the delay in sowing, Hyola 401 was less affected, suggesting greater genetic stability. These findings, taken together, highlight the importance of broader investigation and consideration of multiple factors in determining the ideal harvest

Table 1. First count of germination (%) of canola seeds in function hybrids, sowing dates and harvest times. Viçosa, Mines Gerais, UFV 2009.

Hybrids	Harvest dates	Sowing dates			
		05/26/2009	06/10/2009	06/25/2009	07/10/2009
Hyola 432	PM	99 Aa	94 Aa	96 Aa	79 Ca
	PM + 10	99 Aa	98 Aa	97 Aa	78 Ba
	PM + 20	97 Aa	98 Aa	91 ABa	66 Cb
Hyola 433	PM	95 Aa	100 Aa	96 Aa	87 BCa
	PM + 10	100 Aa	97 Aa	97 Aa	82 Ba
	PM + 20	100 Aa	100 Aa	93 ABa	84 Ba
Hyola 401	PM	100 Aa	100 Aa	99 Aa	97 Aa
	PM + 10	100 Aa	98 Aa	100 Aa	94 Aa
	PM + 20	100 Aa	99 Aa	99 Aa	97 Aa
Hyola 61	PM	96 Aa	99 Aa	96 ABa	94 ABa
	PM + 10	91 Aa	94 Aa	97 Aa	84 Bb
	PM + 20	92 Aa	96 Aa	89 Bb	84 Bb
CV			5.31		

Means in the column with the same uppercase letter are between hybrids within each harvest season, and the same lowercase letter are between harvest times of each hybrid, do not differ significantly by the Tukey's test ($p \leq 0.01$). PM=physiological maturity.

time, aiming to maximize the quality and yield of canola crops (Lechowska et al., 2019).

Germination test

Germination of canola seed did not differ significantly between the hybrid and harvest dates in the first, second, and third sowing dates (05/26, 06/10 and 06/25) (Table 2). The hybrid Hyola 401 seeds showed the highest germination values, averaging 100% between harvest times in the first three sowing dates (05/26, 06/10 and 06/25) (Table 2 and Fig. 3). In the fourth sowing date (07/10) this same material presented 97% of germination on average between harvest dates, indicating that their quality was maintained throughout the experiment. Even in the fourth sowing date (10/07), hybrids Hyola 432, 433, and 61 had an average germination of 76.85 and 91% between the time of harvest, which represents a reduction of approximately 22.12 and 6% in germination when compared with hybrid Hyola 401, respectively. These findings support the hypothesis that high-quality hybrids, such as Hyola 401, can maintain seed germination even under adverse conditions, highlighting their competitive advantage in canola crops (Pimentel et al., 2024).

These results confirm that the incorrect choice of sowing canola in culture may contribute to the harvest period to occur under conditions of high temperature and relative humidity, which are unfavorable for seed quality and promotes early deterioration (Sabbahi, et al., 2023). This deterioration causes reduction of seed germination, and the seeds that germinated would generate weak and small seedlings (Raboanatahiry et al., 2021). This can affect the initial development of canola (*Brassica napus* and *Brassica rapa*), especially when there is a reduction in seedling emergence and adequate stand, because it could reduce productivity (Kovaleski et al., 2019). Corroborating these findings, Malek et al. (2022) reported that seed germination is an important stage in plant life and directly influences plant development and survival in the field.

For the last two sowing dates (06/25 and 07/10), the hybrid Hyola 61 showed significant reduction in germination comparing harvest periods, where the average of the first harvest date (PM) resulted in 98% of germination, and the others (PM + 10 and PM + 20) resulted in 92%. Already, hybrid Hyola 432, in the last sowing date (10/07), showed the greatest reduction in germination among hybrids, especially for the last harvest (PM + 20), which meant a reduction of 24% on average in the other hybrids. The results highlight the consistency of Hyola 401 hybrid germination across different harvesting seasons. However, to strengthen interpretations, it would be beneficial to include additional analyses, such as growing conditions and environmental factors specific to each sowing period This more comprehensive approach would provide a more complete understanding of the determinants of canola germination and hybrid performance over time (Lima et al., 2017).

The effects of sowing dates on seed germination of canola in all hybrids were adjusted to a linear and quadratic model (Fig. 3). For all harvest dates and hybrids, it can be observed a tendency of decreasing in germination with the delay of sowing. Note also that hybrid Hyola 401 has a lower slope of the curves, demonstrating that it is less affected by later sowing date (Fig. 3). Seed germination, seedling emergence, and establishment of culture are important aspects of canola production (Petrie et al., 2020; Gong et al., 2022) and of other crops of agricultural production (Wang et al., 2023).

Based on the results of the study, it is recommended that future research further investigate the mechanisms underlying the lower sensitivity of hybrid Hyola 401 to seeding delay. Additionally, it would be beneficial to explore how other factors such as soil quality and climatic conditions, may interact with sowing times to influence canola seed germination. These more detailed investigations may provide valuable insights to optimize the production of canola and other agricultural crops. understanding the fundamental aspects of canola production, such as seed germination, seedling emergence and crop establishment (Righi et al., 2017).

Speed of germination index (SGI)

Comparing the hybrid, the delay of sowing (06/25 and 07/10) significantly decreased the germination rate of Hyola 432 and 433, regardless of the time of harvesting (Table 3). To Hyola 61, the delay of the harvest period (PM + 20 days), significantly reduced the rate of germination speed in all sowing dates. Previously, Hyola 401 was the hybrid that showed the best results for the germination speed index of seeds, regardless of the sowing date (Table 3 and Fig. 4). The stage of seed development at harvest influences both the yield and quality of canola seed (Elias and Copeland, 2001). However, the early harvest can result in low yield and low quality of the seeds, while late harvest can result in reduction of seed yield (Kovaleski et al., 2019; Bezerra et al., 2024).

For all hybrids, the rate of germination speed decreased with the delay of sowing date, regardless the harvest date (Table 3 and Fig. 4). The effects of sowing date on the germination speed index for all hybrids were adjusted to quadratic models (Fig. 4). For all harvest dates and. Moreover, it can be noticed that Hyola 401 has the lowest slopes of the lines for all harvest date compared to other hybrids, demonstrating that it was less affected by different sowing dates.

These results highlight the crucial importance of sowing and harvest timing in producing high-quality canola seeds. Understanding these patterns can guide more effective agricultural practices, maximizing both the yield and quality of canola seeds (Elahi et al., 2023; Sabbahi et al., 2023).

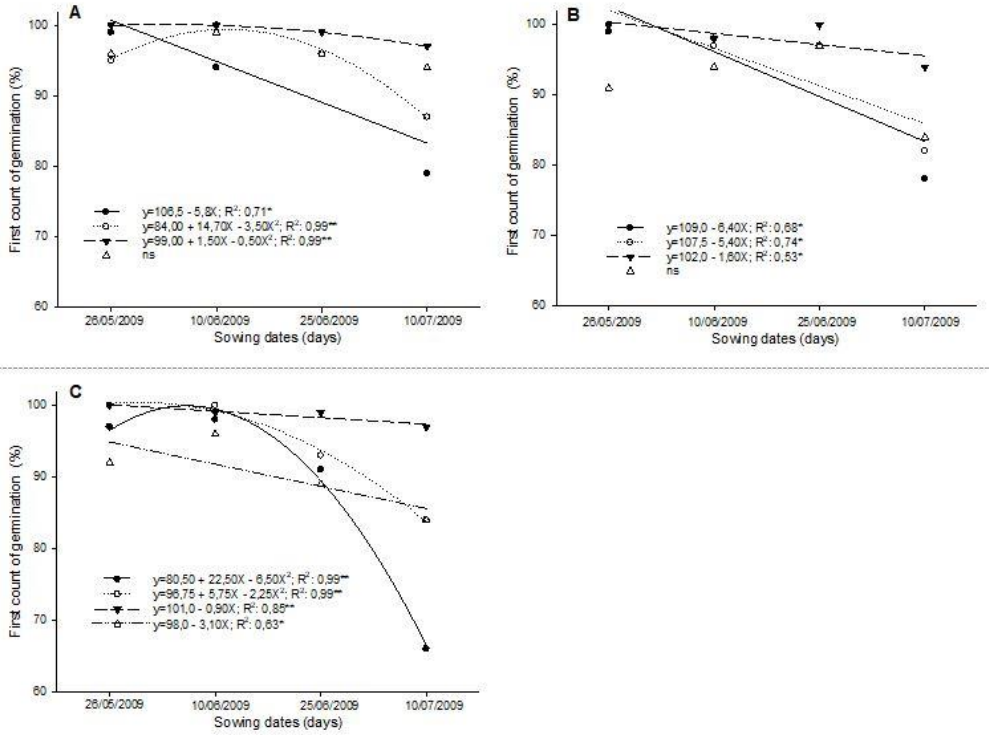

Figure 2. First count of germination of canola in functional hybrids (• Hyola432; O Hyola 433; ▾ Hyola401, and Δ Hyola61) and sowing dates at different harvest times (physiological maturity (PM) (A), PM + 10 days (B), PM + 20 days (C); Viçosa, MG, UFV, 2009 (R^2: coefficient of determination; * and ** Significant at $p \leq 0.15$ and 0.10, respectively ;ns not significant).

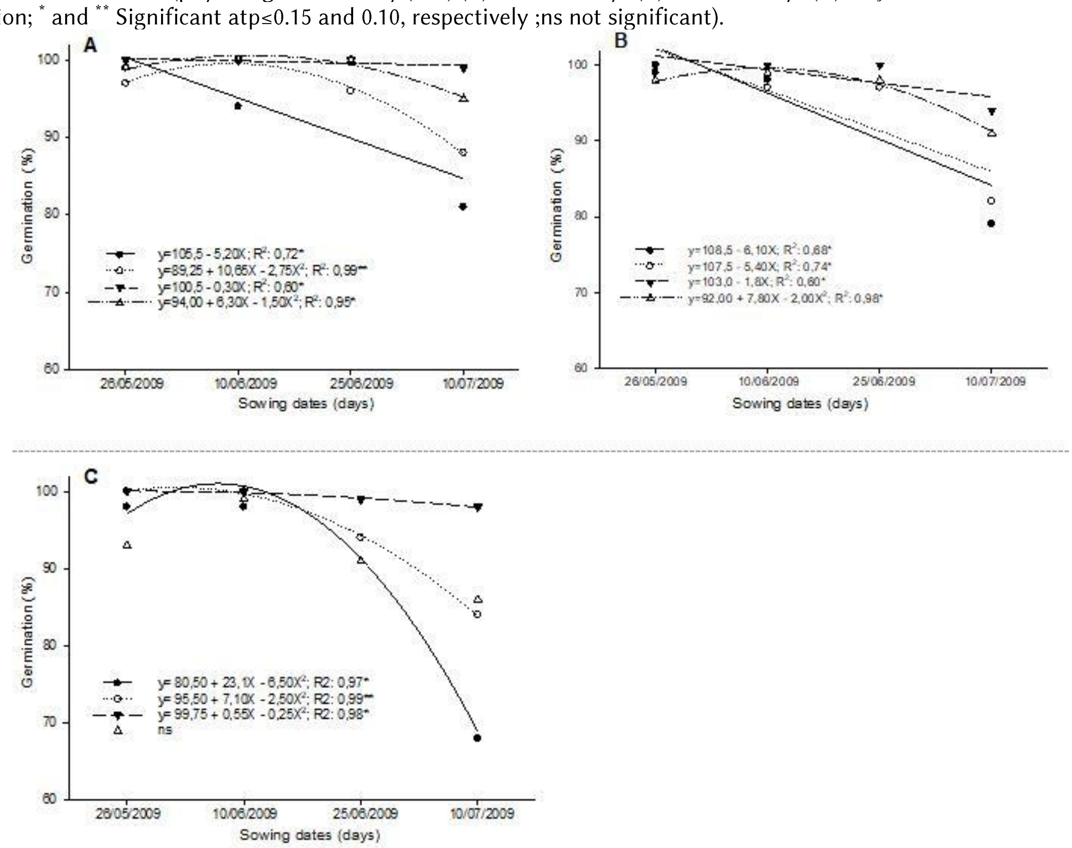

Fig 3. Germination of canola seed in function hybrids (•Hyola432; O Hyola 433; ▾Hyola401; Δ Hyola61) and sowing dates in different harvest times (Physiological Maturity (PM) (A), PM + 10 days (B), PM + 20 days (C); Viçosa, Minas Gerais, UFV, 2009 (R^2: coefficient of determination; * and ** Significant at $p \leq 0.15$ and 0.10, respectively; ns not significant).

Mean germination time (MGT)

Study results reveal that when comparing canola hybrids, both Hyola 61 and 433 consistently demonstrated higher germination values regardless of sowing and harvesting conditions (Table 4). This trend can be attributed to the lower germination speed observed in these materials, as indicated in Table 5, as well as the possible lower quality of the seeds. These findings suggest the importance of considering not only germination rate but also seed speed and quality when selecting canola hybrids to optimize crop performance.

Table 3. Germination speed index (GSI) of canola seeds in function hybrids, sowing dates and harvest times. Viçosa, Minas Gerais, UFV 2009.

Hybrids	Harvest dates	Sowing dates			
		05/26/2009	06/10/2009	06/25/2009	07/10/2009
Hyola 432	PM	15.71 Aa	14.86 Aa	15.00 Aab	12.33 Ba
	PM + 10	15.27 Aa	15.69 Aa	15.71 Aa	11.88 Ba
	PM + 20	15.74 Aa	15.68 Aa	14.16 Bb	11.45 Ca
Hyola 433	PM	14.15 Bb	14.89 Aa	15.14 Aa	13.07 Ba
	PM + 10	15.45 Aa	15.17 Aa	15.14 ABa	11.73 Bb
	PM + 20	15.04 ABab	15.45 ABa	14.38 ABa	12.62 BCab
Hyola 401	PM	15.03 ABa	15.79 Aa	15.88 Aa	15.05 Aa
	PM + 10	15.68 Aa	15.95 Aa	15.47 Aa	14.04 Aa
	PM + 20	16.13 Aa	16.05 Aa	15.52 Aa	14.44 Aa
Hyola 61	PM	14.11 Bab	15.16 Aab	14.88 Aa	14.68 Aa
	PM + 10	13.15 Bb	15.17 Aa	14.16 Bab	13.16 Ab
	PM + 20	14.32 Ba	14.01 Bb	13.64 Bb	12.82 Bb
CV			4.69		

Means in the column with the same uppercase letter are between hybrids within each harvest season, and the same lowercase letter are between harvest times of each hybrid, do not differ significantly by the Tukey test (p≤0.01). PM: physiological maturity.

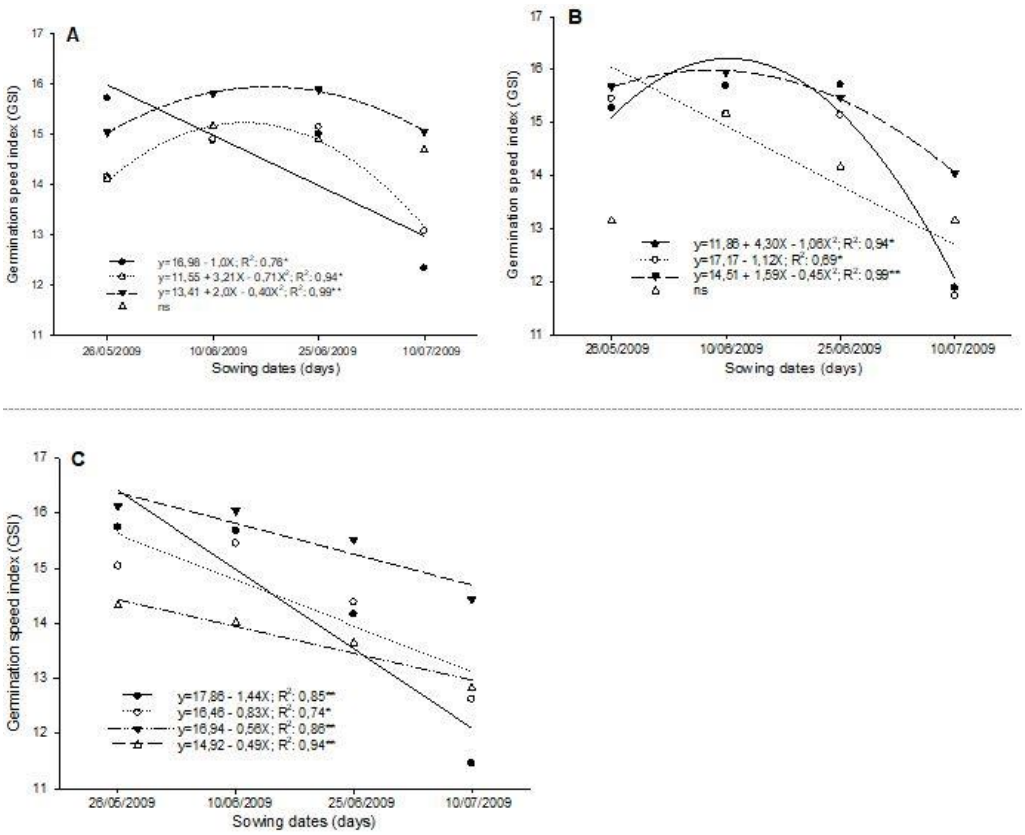

Figure 4. Germination speed index (GSI) of canola seed in function hybrids (• Hyola432; O Hyola433; ▾ Hyola401; Δ Hyola61) and sowing dates in different harvest times (physiological maturity (PM) (A), PM + 10 days (B),PM + 20 days (C);Viçosa-MG, UFV, 2009 (R^2: coefficient of determination; * and ** Significant at p≤0.15 and 0.10, respectively; ^{ns} Not significant).

The results of the study on canola hybrids, highlighting the superior performance of Hyola 61 and 433 in terms of germination, resonate with similar findings in other agronomic research. However, contradictorily, in some cases, hybrids with faster germination speed do not necessarily guarantee better productivity outcomes (Severino, 2021) For instance, recent studies in rice have shown that hybrids with slower germination speed may compensate for this disadvantage during plant growth, resulting in higher final yields (Fu et al., 2023). Thus, while the results of the canola study offer valuable insights, it is crucial to contextualize them within the broader landscape of agricultural research and consider the specific nuances of each crop and growing environment (Pimentel et al., 2024).

The effects of the sowing date on the average time of germination for all hybrids were set to a linear and quadratic model (Fig. 5). In general, for all harvest dates and hybrids, it can be observed an increasing trend on average germination of canola with the delay of sowing (Table 4 and Fig. 5).

Mean velocity of germination (MVG)

The variable average of seed germination for Hyola 61 was negatively affected in the first, second, and third sowing dates (05/26, 06/10 and 06/25), regardless of time of harvest (Table 5), respectively. For this same hybrid, the delay of the harvest dates (PM + 10 and PM + 20), decreased the average of germination speed. However, for the other hybrids, the average of germination speed was not significantly affected by different sowing dates and harvesting.

For all hybrids, in general, a reduction on average of germination speed was observed with the delay of sowing, regardless of the harvest period (Fig. 6). Furthermore, for all harvest dates and hybrids, was observed a tendency of reduction in the average time of germination with the delay of sowing date. For hybrid

Table 4. Mean germination time (MGT) of canola seeds in function hybrids, sowing dates and harvest times. Viçosa, Minas Gerais, UFV 2009.

Hybrids	Harvest dates	Sowing dates			
		05/26/2009	06/10/2009	06/25/2009	07/10/2009
Hyola 432	PM	3.20 Ca	3.22 Ba	3.26 Bab	3.56 Aa
	PM + 10	3.31 Ba	3.14 Ba	3.12 Bb	3.42 Ba
	PM + 20	3.13 BCa	3.16 Ba	3.40 Aa	3.46 Aa
Hyola 433	PM	3.54 ABa	3.44 Aa	3.25 Ba	3.46 Aab
	PM + 10	3.29 Ba	3.27Aba	3.27 Ba	3.65 Aa
	PM + 20	3.38 Aab	3.30Ba	3.34 Aa	3.43 Ab
Hyola 401	PM	3.40 BCa	3.21 Ba	3.21 Ba	3.35 Aa
	PM + 10	3.22 Bab	3.18 ABa	3.30Ba	3.44 Ba
	PM + 20	3.11 Cb	3.16 Ba	3.26 Aa	3.49 Aa
Hyola 61	PM	3.63 Ab	3.37 ABb	3.48 Aa	3.33 Ab
	PM + 10	3.85 Aa	3.36 Ab	3.58 Aa	3.62 ABa
	PM + 20	3.33 ABc	3.66 Aa	3.46 Aa	3.55 Aa
CV			3.38		

Means in the column with the same uppercase letter are between hybrids within each harvest season, and the same lowercase letter are between harvest times of each hybrid, do not differ significantly by the Tukey test (p≤0.01). PM=physiological maturity.

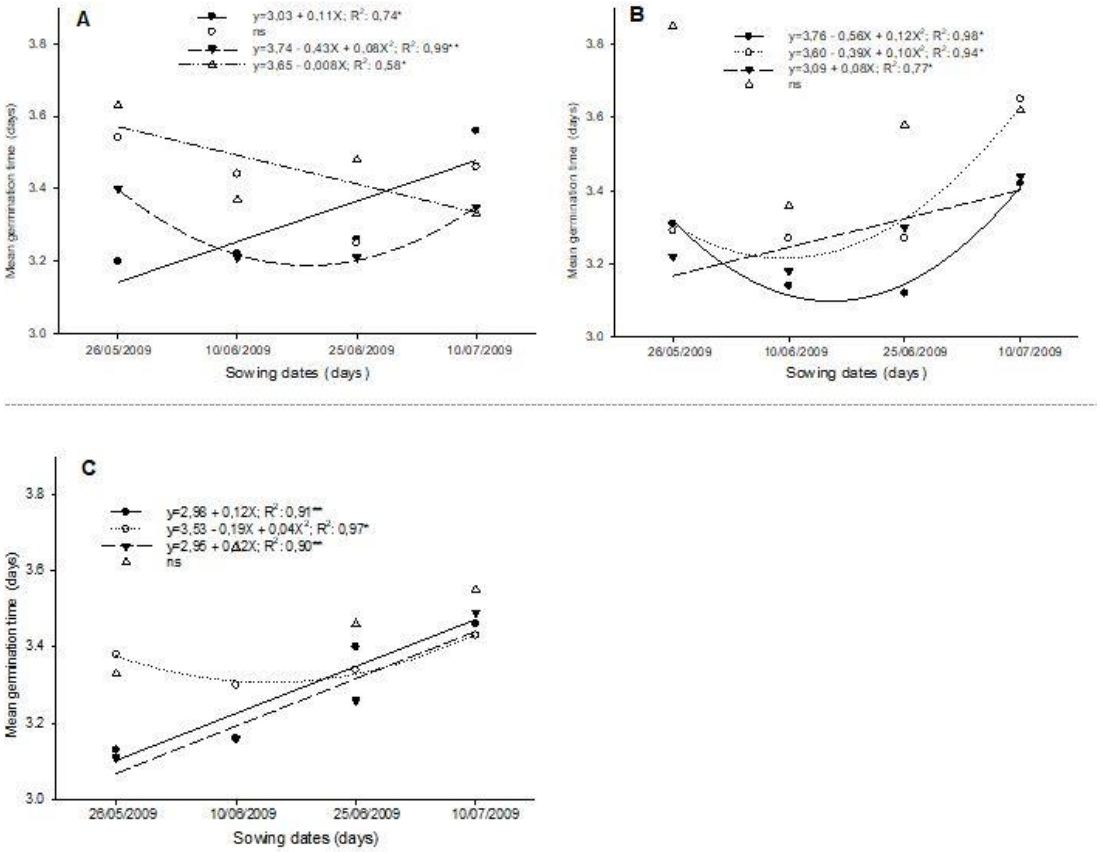

Figure 5. Mean germination time (MGT) of canola seed in function hybrids (• Hyola432; ○ Hyola433;▾ Hyola401; Δ Hyola61) and sowing dates in different harvest times (physiological maturity (PM) (A), PM + 10 days (B),PM + 20 days (C); Viçosa, Minas Gerais, UFV, 2009 (R^2: coefficient of determination; * and ** Significant at p≤0.15 and 0.10, respectively, ns not significant).

432, 433 and 401, the effects of sowing dates on the average of germination were set to the linear and quadratic model (Fig. 5). On the other hand, hybrid Hyola 61 did not adjust to any type of curve tested.

The results of the study highlight the sensitivity of the Hyola 61 hybrid to delay in sowing and harvesting, with significant reductions in germination and germination speed. This observation was verified by Stafen et al. (2018), which highlights the critical importance of sowing and harvesting on the quality of canola seeds. However, the resistance of other hybrids to these variations indicates the need for further investigation into the genetic and environmental factors that influence canola germination. provide valuable insights for developing more effective agricultural practices and maximizing canola crop yields.

Materials and Methods

Experimental area

This research was conducted in the experimental area of HortaVelha and the Seed Laboratory, Department of Plant Science at the Federal University of Viçosa (UFV), located in the state of Minas Gerais (MG). Viçosa is located at latitude 20°75'S, longitude 42°85'W and with an elevation of 690 meters (m). The climate is classified as a subtropical highland climate, with rainy summer and mild temperatures. In general, rainfall is concentrated in the months from October to March, with annual average of the 1,165 mm and the average annual temperature is 19.4°C (National Institute of Meteorology - INMET, 2012). Daily data of rainfall and temperature (maximum, average and minimum), were collected of automatic weather station located within 10 m of the experimental site (Fig. 1), and the climatic

Table 5. Mean velocity of germination (MVG) of canola seed of hybrids and sowing dates, Viçosa, MG, UFV 2009.

Hybrids	Harvest dates	Sowing dates 05/26/2009	06/10/2009	06/25/2009	07/10/2009
Hyola 432	PM	0.31 Aab	0.31 Aa	0.31 Aab	0.30 Aa
	PM + 10	0.31 Ab	0.32 Aa	0.32 Aa	0.30 Aa
	PM + 20	0.32 Aa	0.32 Aa	0.30ABb	0.29 Aa
Hyola 433	PM	0.28 BCb	0.29 Ba	0.31 Aa	0.29 Aab
	PM + 10	0.31 Aa	0.31 ABa	0.31 Aa	0.27 Ab
	PM + 20	0.30 Bab	0.30 Aa	0.30ABa	0.29 Aa
Hyola 401	PM	0.30ABb	0.31 Aa	0.31 Aa	0.30 Aa
	PM + 10	0.31 Aab	0.31 ABa	0.30 Aa	0.30 Aa
	PM + 20	0.32 Aa	0.32 Aa	0.31 Aa	0.29 Aa
Hyola 61	PM	0.28 Cb	0.30 ABa	0.29 Ba	0.30 Aa
	PM + 10	0.26 Bb	0.30Ba	0.28 Ba	0.28 Ab
	PM + 20	0.30Ba	0.27 Bb	0.29 Ba	0.28 Ab
CV			3.26		

Means in the column with the same uppercase letter are between hybrids within each harvest season, and the same lowercase letter are between harvest times of each hybrid, do not differ significantly by the Tukey test ($p \leq 0.01$). PM: physiological maturity.

data are from climatological normal of 1061 to 1900 (INMET, 2012).

Treatments and study design

The experiment consisted of forty-eight treatments, involving three factors: A) 4 sowing dates (05/26/09, 06/10/09, 06/25/09 and 07/10/09); B) 4 commercial hybrid Canola (Hyola432, 433, 401 and 61); and C) 3 harvest dates (Physiological Maturity (PM), PM + 10 days and PM + 20 days) (Assis et al., 2020; Aslam et al., 2021). The PM was defined as at least 50% of pods located in the middle third of the main racemes plants had seeds with a dark-brown color. The experimental design was a randomized complete block with four replications in a factorial split plot design (4×4×3). Each plot consisted of 17 rows 3 m long by 2.89 m wide, spaced at 0.17 m between rows, and subplots consisted of four rows in each plot. During the harvest time, we eliminated the two outer rows and 0.5 m from each end of the central lines and borders when sampling.

Traits measured and harvest

The plants of each treatment were harvested manually at ground level in each subplot. Afterwards, they were tied in bundles and placed to dry in the shade. Two to three weeks later, of bundles seeds were threshed manually, with processing carried out with the aid of sieves and a seed blower. Then, we determined the moisture content of the seeds by the oven method (Brasil, 2009). The following tests were performed to evaluate the physiological quality of the seeds:

Germination test: was performed with four samples of 50 seeds for each treatment and repeated occurrences. The seeds were sown in gerboxes containing two sheets of paper moistened with distilled water in amount equivalent to 2.5 times of the dry papermass. The gerboxes were kept in an incubator at 20±2°C (Brasil, 2009). Seedling counts were performed 5 and 7 days after sowing date and the results were expressed as a percentage of normal seedlings at the 7^{th} day (Brasil, 2009).

First count of germination (FCG): was conducted ~~along~~ with the germination test. For this one, we computed the number of normal seedlings 5 days after germination (Brasil, 2009).

Speed of germination index (SGI), Mean germination time (MGT) and Mean velocity of germination (MVG): number of normal seedlings were counted daily in the germination test and the rates were obtained as the following expression (Maguire, 1962):

$$GSI = \frac{G1}{D1} + \frac{G2}{D2} + \ldots + \frac{Gn}{Dn}$$

GSI = Germination Speed Index;

$G1$ = number of normal seedlings in the first count;

$D1$ = number of days to the first count;

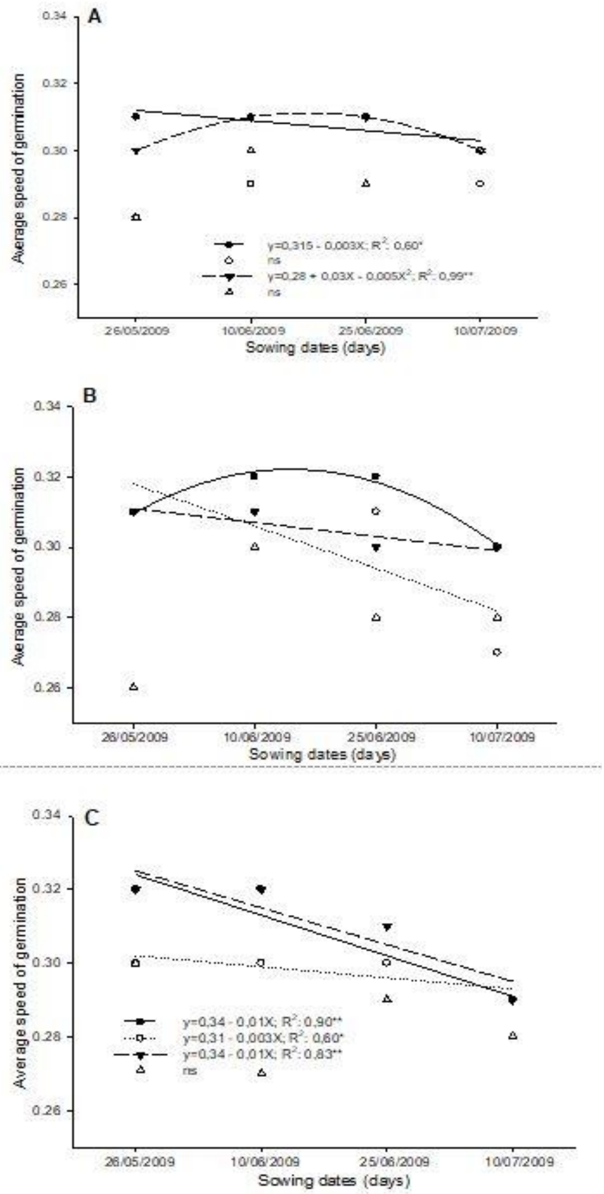

Figure 6. Average speed germination (MVG) of canola seed in function hybrids (• Hyola432; ° Hyola433; ▾ Hyola401; ∆ Hyola61) and sowing dates in different harvest times (physiological maturity (PM) (A), PM + 10 days (B), PM + 20 days (C); Viçosa - MG, UFV, 2009 (R^2: coefficient of determination; * and ** Significant at $p \leq 0.15$ and 0.10, respectively, ^{ns} not significant).

Gn= number of normal seedlings at last count;
Dn = number of days to the last count.

MGT also was calculated according to the formula cited by Labouriau and Valadares (1976): $MGT = \frac{\sum ni.ti}{\sum ni}$
MGT= mean germination time;
ni = number of germinated seeds in i-th day;
ti= time (days).

The calculation for VMG was performed according to the formula created by Labouriau and Valadares (1976): $MVG = \frac{1}{MGT}$
MVG = mean velocity of germination;
MGT = mean germination time.

Statistical analysis

The data, expressed in percentages, were subjected to analysis of variance and homoscedasticity, after that, it was transformed into arc sine (normal) to perform the variance analyzes. The means of the qualitative factors, when statistically significant, were compared using the Tukey's test at 1% probability ($p \leq 0.01$). The quantitative factor was assessed by regression, and the regression models were chosen based on the significance of the regression coefficients, adopting the significance levels of 10 and 15%and the biological phenomenon being described, and the coefficient of determination (R^2) (Adati et al., 2006). The data processed were performed with the SAS software (Delwiche and Slaughter, 2003) for the qualitative factors and Sigma Plot software for quantitative factor.

Conclusions

The region of Viçosa, Minas Gerais, has potential for canola production, but the timing of sowing and harvesting is crucial for seed quality. Hyola 401 is more tolerant to delayed harvesting than Hyola 61, which requires prompt harvest after physiological maturity. This study contributes to the optimization of canola cultivation in Brazil and provides insights for future research on seed vigor.

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Authors contribution

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