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MAXIMIZING RAPESEED YIELD AND QUALITY THROUGH ADJUSTMENTS IN SOWING DATE AND ROW SPACING

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Abstract

To explore optimal agronomic practices for maximizing rapeseed productivity and quality under specific environmental conditions, a field experiment was conducted during the 2022-2023 agricultural year in Jucu, Cluj County. The study aimed to evaluate the effects of two critical factors influencing crop performance (sowing date and row spacing) on the yield and quality of the rapeseed hybrid PT 275. Using a randomized split-plot design with three replications, the experiment tested three sowing dates (August 20, August 30, and September 10) and three row spacings (25 cm, 37.5 cm, and 50 cm). Yield data and quality indicators were assessed at the end of the growing season to determine the influence of the experimental variables, using standardized laboratory methods. The results revealed that sowing date significantly impacted yield, with August 30 emerging as the most favorable, achieving the highest yield of 3900 kg/ha, while narrower row spacings (25 cm and 37.5 cm) significantly outperformed wider spacing (50 cm). Delayed sowing (September 10) increased oil content but reduced yield, highlighting a trade-off between productivity and quality. While the genetic characteristics of the hybrid were the primary determinant of quality, the study highlighted significant variations in quality indicators associated with the technological factors examined. These findings provide actionable insights for optimizing rapeseed cultivation under temperate continental climates.

***Key words**: rapeseed, row spacings, sowing date, seed quality, yield optimization.*

INTRODUCTION

Rapeseed (*Brassica napus* L.) is the third-most cultivated oilseed crop globally, valued for its versatile applications in the edible oil production, protein sources (Raboanatahiry et al., 2021) and biodiesel (Wang and Yin, 2014). It has emerged as a significant crop in Romania in recent years, occupying approximately one-third of the total oilseed crop area (Ion et al., 2024) and is highly valued by apiarists. Additionally, rapeseed is extensively studied for its medicinal properties, including its anti-inflammatory, antiviral, antidiabetic, anticancer, and antioxidant effects (Tileuberdi et al., 2022).
As with other species, rapeseed productivity is influenced not only by genetic factors but also by variations in environmental conditions such as climatic factors (temperature, precipitation, photoperiod duration and abiotic stress), soil type and agricultural practices including sowing time, pest, weed, and disease management (Rajković et al., 2022; Wu et al., 2020). Crop yield losses can range between 3% and 73% due to these factors (Lipianu et al., 2023).
In the context of climate change, rapeseed sowing protocols are continuously adjusted, to maximize both yield and quality (Wang et al., 2011). Identifying the optimal sowing time is a crucial step to ensuring high and stable yields, as significant deviations in temperature and water availability can negatively impact crop production (Turhan et al., 2011). When agronomic practices are implemented appropriately and field conditions are ideal, temperature and soil moisture are the primary factors that govern seed germination and seedling emergence (Marjanović-Jeromela et al., 2019).
For optimal rapeseed development, it is critical to sow at the appropriate time, as spring climatic conditions can strongly influence crop performance. Early-flowering plants risk frost damage, while late-flowering plants are more

susceptible to heat stress and water deficit (Butkevičienė et al., 2021). Delayed sowing can substantially reduce the number of primary branches and flowers per plant (Balodis and Gaile, 2016), resulting in lower yields and compromised seed quality. Seed filling is particularly vulnerable to environmental stressors, especially temperature and precipitation patterns (Rajković et al., 2022).

The optimal inter-row spacing used for most cultivated species is not only intended to maximize yields but also to facilitate weed control. Weeds present an inherent challenge in crop production and therefore, row spacing is often adjusted to enable mechanical weed control, sometimes prioritizing this over yield optimization (Grimes et al., 2019).

Rapeseed oil is crucial for human nutrition due to its high unsaturated fatty acid content (Karunarathna et al., 2020). As a result, improving seed yield and oil production remains a key objective for rapeseed growers worldwide (Ren et al., 2022).

Studying the carotenoid content in rapeseeds, despite its relative low levels, offers potential for genetic improvements and breeding strategies to increase carotenoid concentrations, enhancing the nutritional value of rapeseed oil and animal feed; as the demand for natural carotenoids rises, rapeseeds could become a more sustainable source, providing an eco-friendly alternative to synthetic carotenoids. (Franke et al., 2010; Gao et al., 2007).

In the context of climate change and the specific agronomic requirements of autumn rapeseed cultivation, this study primarily aimed to evaluate the impact of sowing time and row spacing on yield and some quality parameters of the PT 275 hybrid under temperate continental conditions; the findings aim to refine agronomic protocols for climate-resilient rapeseed production.

MATERIALS AND METHODS

The trial was conducted in 2022-2023 agricultural year, at the Jucu VEGETAL farm (46°51′N, 23°48′E, part of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca (Figure 1), on a slightly acidic, humus-rich, argic-stagnic feoziom soil, with high fertility levels except for phosphorus. The experimental design followed a split-plot design with 3 replications (Figure 2).

Figure 1. Aspect from experimental field (original)

Figure 2. Experimental field design (original)

The experimental factors and their graduations are as follows:

- Factor S – sowing date with 3 levels:
  - S1 – August 20 (control);
  - S2 – August 30;
  - S3 – September 10.
- Factor D – row spacing with 3 levels:
  - D1 – 25 cm (control);
  - D2 – 37.5 cm;
  - D3 – 50 cm.

Two technological factors were evaluated: three sowing dates (S) and three row spacing distances (D). Yield for each experimental variant was determined using the following formula: average number of plants per square meter, multiplied by the average number of siliques per plant, multiplied by the average number of seeds per silique, and by the 1000-seed weight (TKW), all divided by 100 (Buzdugan and Năstase, 2013).

Representative samples from each variant were collected for assessing the several quality issues: the determination of fat content was accomplished using Soxhlet extraction, protein content by Kjeldahl method with mineralization in a Turbotherm TT 265 unit (Gerhardt, Koenigswinter, Germany), ash content by

heating at 550°C for 5 hours in a Nabertherm B180 (Nabertherm GmbH, Lilienthal, Germany) muffle furnace and total carotenoids through VIS spectrophotometry using a UV/VIS T80+ (PG Instruments Ltd, Leicestershire, UK) instrument (Latimer, 2012).
Data analysis was performed using Past4 for cluster analysis, visualized through heatmaps. Technological variants were characterized and assessed using the Bray-Curtis distance, incorporating the minimum and maximum values obtained from descriptive statistical analysis. This approach enabled the graphical representation of experimental results through a color gradient, with dark blue indicating lower values and red representing higher values.

RESULTS AND DISCUSSIONS

Rapeseed's temperature requirements for seed and oil production are high, ranging from 2,100-2,500°C for autumn genotypes. During the study period (August 2022 - July 2023), at Jucu Herghelie, Cluj-Napoca County, the sum of precipitation was 642.47 mm, and the average temperature recorded in the 2022-2023 agricultural year was 11.37°C, with a positive deviation of 1.37°C compared to the 50-year multi-annual average (Figure 3).

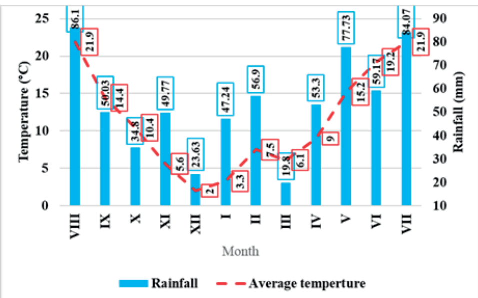

Figure 3. Thermal and Precipitation Regime at Jucu from August 2022 to July 2023

The yield of the PT 275 rapeseed hybrid ranged between 3,297 kg/ha and 4,053 kg/ha. The lowest yield occurred under late sowing (September 10), with a row spacing of 50 cm, underscoring the critical role of timely field preparation for autumn rapeseed (Suveț et al., 2021). Delaying field operations until the end of August results in yield losses of up to 794 kg/ha, losses that can be avoided by sowing the crop at the optimal time under suitable conditions. Conversely, the highest yield of 4,053 kg/ha was recorded when the crop was planted at the optimal time (August 20) and 25 cm row spacing. Overall, the results indicate a reduction in yield associated with delayed sowing and increased row spacing (Figure 4). These results align with studies showing that climatic factors during flowering directly impact rapeseed branching, pod formation and seed yield (Ozer, 2003).

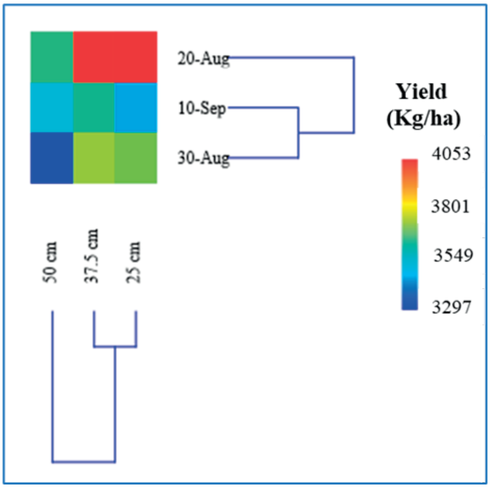

Figure 4. Yield of the PT 275 rapeseed hybrid by sowing date and row spacing

The oil content exhibited considerable variation throughout the experiment (4.5%). Higher oil content values were recorded in the variants where the rapeseed was sown later, specifically on September 10, with a row spacing of 50 cm, as well as on August 30, with a row spacing of 25 cm. These suggest that delayed sowing enhances oil accumulation in seeds, as air temperature, radiation, and precipitation during the flowering period generally play a significant role in determining the oil content of rapeseed seeds (Faraji, 2012). In terms of row spacing, the results showed greater variability. Although the highest average oil content was not observed at the 37.5 cm row spacing, this spacing consistently produced good results. The highest and lowest oil content values in the experiment were obtained at the other two row spacings, each associated with different sowing dates. Kirkegaard et al. (2016) found in their studies that as the sowing date was delayed, stress caused by low temperatures and other factors reduced rapeseed yield and oil content. Precipitation around the August 20 sowing date ensured rapid and uniform emergence, while later dates faced drought, causing uneven emergence and negatively development of plants impacting yield and quality. These findings highlight the importance of both sowing time and row spacing as agronomic practices that can influence the oil content of rapeseed, and they suggest that further research could explore the underlying mechanisms driving these responses.

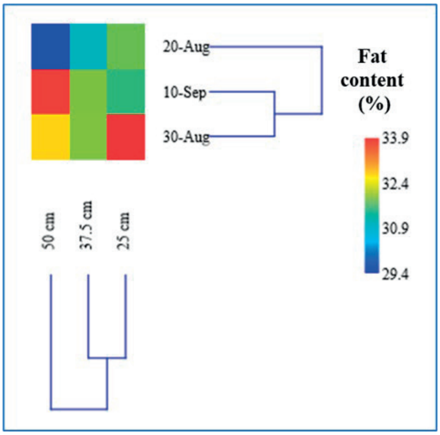

Figure 5. Fat content of the PT 275 rapeseed hybrid by sowing date and row spacing

The protein content ranged from 15.3% to 16.5%, with the lowest value under optimal sowing (August 20, 37.5 cm row spacing), and the highest under late sowing (September 10, 37.5 cm spacing). This divergent response at identical spacing suggests a non-linear response of protein synthesis to the combined effects of sowing date and plant density (Șuveț et al., 2024). These results suggest that the protein content is influenced by the interaction between these two agronomic factors, with both the minimum and maximum values occurring at a row spacing of 37.5 cm (Figure 6). Research conducted by Yang (2003) showed that early-sown rapeseed had higher protein, fat, and trace element content compared to late-sown rapeseed.

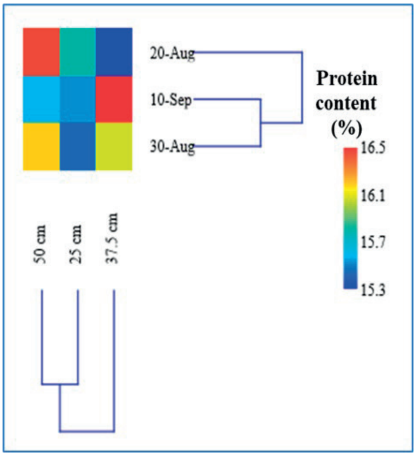

Figure 6. Protein content of the PT 275 rapeseed hybrid by sowing date and row spacing

A notable increase in ash content was observed when rapeseed sowing was delayed until August 30. In this experimental variant, the highest ash content of 3.57% was recorded when rapeseed was sown at a row spacing of 50 cm, while the other two row spacings also produced average or even favorable ash content values. In contrast, optimal sowing (August 20) consistently yielded the lowest ash content, regardless of the row spacing. This trend may reflect that sowing date plays a significant role in influencing ash accumulation, with delayed sowing tending to increase ash content in rapeseed (Figure 7).

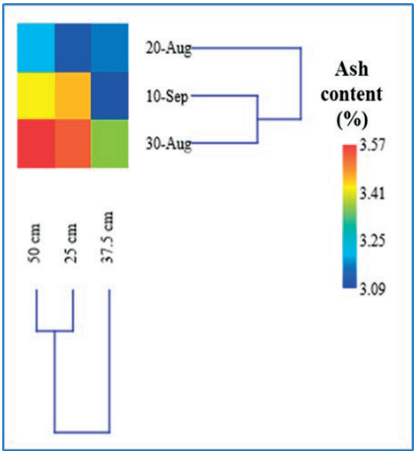

Figure 7. Ash content of the PT 275 rapeseed hybrid by sowing date and row spacing

The total carotenoid content was significantly influenced by both the sowing date and the row spacing, as illustrated in Figure 8. Across all row spacing variations, the highest average carotenoid levels were observed when the rapeseed was sown on September 10. In contrast, for the other two sowing dates, the lowest carotenoid values were recorded at a row spacing of 37.5 cm. The highest carotenoid content (21 mg/kg), was found when sowing occurred on August 30 at a row spacing of 25 cm. For the 50 cm row spacing, carotenoid values remained relatively consistent, showing similar results regardless of the sowing date. These findings suggest that both sowing time and row spacing affect carotenoid content, although their interaction patterns are not linear and warrant further investigation (Figure 8).
Small improvements in carotenoid content could have a significant impact on crop value and market competitiveness; additionally, research into rapeseed carotenoids provides valuable insights into plant metabolism and offers broader benefits for crop improvement and addressing global nutritional needs (Ning et al., 2024; SzydłOwska-Czerniak, 2013). Carotenoids, primarily β-carotene and xanthophylls in rapeseed seeds, showed pronounced sensitivity to agronomic practices (Shen et al., 2023).

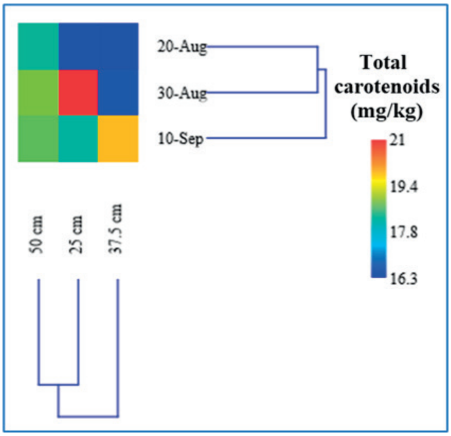

Figure 8. Total carotenoids content of the PT 275 rapeseed hybrid by sowing date and row spacing

An important factor is identifying technological solutions that can enhance both production and oil yield. A key inverse relationship emerged between oil content and yield: delayed sowing increased oil content but reduced yield (Figure 9).
When calculating the amount of oil obtained per hectare based on yield, it becomes evident that, on average, the hybrid in question yielded 1175 kg of oil per hectare. The highest yield of 1210 kg/ha was achieved when the rapeseed was sown on August 20, which corresponds to the optimal sowing period. As expected, the relationship between yield and oil production in this case appears to reverse and take on a positive correlation. An increase in production is linked to a corresponding rise in the amount of oil obtained per hectare.

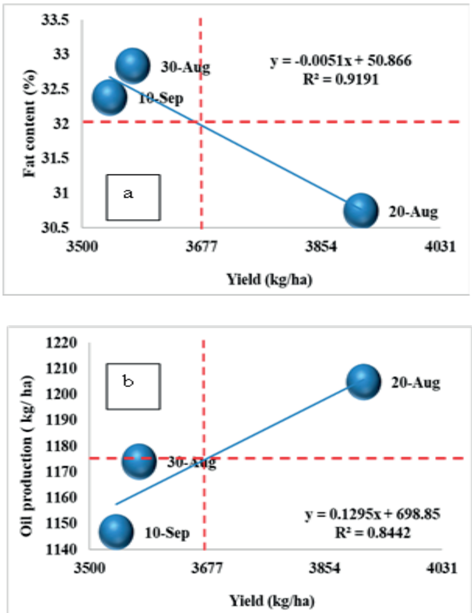

Figure 9. Relationship between yield vs. oil content (a) and yield vs. oil production per hectare in the PT 275 rapeseed hybrid sown on three different dates

When studying the relationship between production and oil content, as well as the correlation between production and total oil yield based on row spacing, a strong positive correlation emerges in both cases. The most favorable results are observed when the distance between rows was 25 cm. In both instances, this row spacing leads to the highest values for both production and oil yield, suggesting that optimal row spacing plays a crucial role in enhancing both the quantity of the harvested product and the amount of oil obtained per hectare. By adjusting the row distance to 25 cm, it is possible to maximize the benefits in terms of both oil content and overall yield (Figure 10).

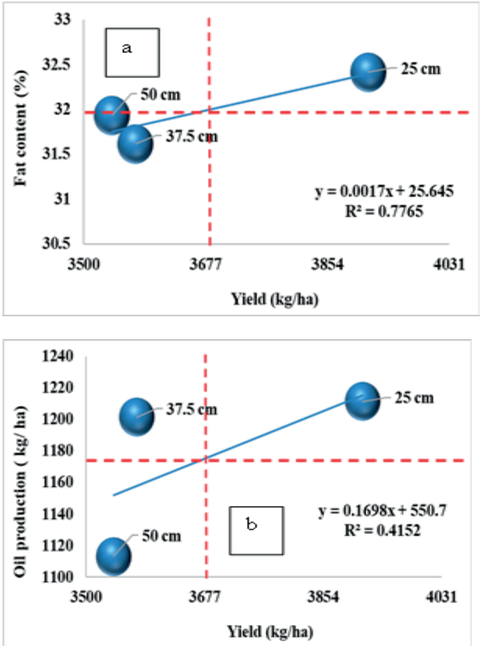

Figure 10. Impact of row spacing on yield, oil content and oil production per hectare in the PT 275 rapeseed hybrid sown on three different dates

CONCLUSIONS

This study emphasizes the importance of both sowing date and row spacing as key agronomic factors influencing various quality parameters and yields in rapeseed. Further multi-year trials and molecular analysis are needed to validate the repeatability of quality traits under variable climatic conditions.

The results highlight that optimizing these practices can improve oil content, protein levels, ash content, and carotenoid accumulation, ultimately leading to more productive and higher-quality rapeseed crops.

The yield of the PT 275 rapeseed hybrid showed a clear relationship with both sowing time and row spacing.

Optimal sowing (August 20) and 25 cm row spacing maximized yield (4,053 kg/ha) and oil production (1,210 kg/ha), while delayed sowing (September 10) reduced yield, emphasizing the importance of timely sowing in maximizing crop productivity. The oil content of rapeseed varied significantly across different sowing dates and row spacings, with the highest values recorded in delayed sowing, specifically on September 10 and August 30, at varying row spacings, highlighting that delayed sowing may increase oil content. Furthermore, row spacing played an important role, with the 37.5 cm consistently producing good results, although the highest and lowest oil content values were observed at the other row spacings.

The protein content of rapeseed showed a range of 15.3% to 16.5%, with the highest protein content observed in the variant sown on September 10, at a row spacing of 37.5 cm.

A significant increase in ash content was observed when sowing was delayed until August 30, particularly at a row spacing of 50 cm. The highest ash content of 3.57% was recorded in this variant. In contrast, sowing at the optimal time (August 20) consistently resulted in the lowest ash content, regardless of row spacing.

The total carotenoid content was also influenced by sowing date and row spacing, with the highest carotenoid levels observed when sowing occurred on September 10. However, the highest carotenoid content of 21 mg/kg was recorded when sowing took place on August 30 at a row spacing of 25 cm. This suggests that both sowing time and spatial arrangements interact to affect carotenoid accumulation in rapeseed. These findings underscore the need for adaptive agronomic practices to optimize rapeseed productivity and nutritional value under changing climatic conditions. Further research is needed to explore the underlying mechanisms and refine these agronomic strategies.

Sowing rapeseed on August 20 yields the highest production, though it may result in slightly lower oil content (%).

Delaying sowing increases oil content but reduces overall yield, making it less efficient for maximizing total oil production per hectare Despite the reduced yield from delayed sowing, when considering oil yield per hectare, it becomes clear that higher yields correspond to greater oil production. On average, the rapeseed hybrid yielded 1175 kg of oil per hectare, with the highest oil yield observed at the optimal sowing date of August 20, an increasing yield being positive correlated with increased oil per hectare.

A 25 cm row spacing yields the best results, improving both yield and oil content, highlighting the significance of optimizing row distance in rapeseed cultivation.

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