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RESPONSE OF WHITE MUSTARD (*SINAPIS ALBA* L.) TO SOWING DATE AND CROP MANAGEMENT UNDER WATER STRESS CONDITIONS

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Abstract. *White mustard (Sinapis alba L.) is considered a suitable alternative crop for agricultural systems increasingly affected by climatic variability, due to its short growing season and efficient use of soil resources. The aim of this study was to assess the influence of sowing date, crop density and fertilization level on crop establishment, vegetative growth and seed yield of white mustard under the pedoclimatic conditions of the Dobrogea region, in the Mereni area, Constanța County, during the 2024–2025 agricultural year, characterized by severe water deficit. The experiment was conducted under a minimum tillage system on a typical vermic chernozem soil, with winter vetch as the preceding crop. A total of 24 experimental variants were tested, resulting from the combination of four sowing dates (24 February, 1 March, 6 March and 11 March 2025), two row spacings (12.5 and 25 cm) and three mineral fertilization levels (N40P40, N60P60 and N80P80). The evaluated parameters included plant density at emergence, plant height, average number of siliques per plant, average seed weight per plant and seed yield. The results revealed clear differences among sowing dates, mainly driven by soil water availability during early growth stages. The third sowing date (6 March 2025) provided the most favorable conditions for crop establishment and yield formation. Despite a high number of siliques per plant, the severe precipitation deficit during March–April and the lack of rainfall in June negatively affected seed filling. The highest performance was obtained for the variant sown on 6 March 2025, at 25 cm row spacing and with the N80P80 fertilization level, which recorded an average seed weight of 6.8 g plant^{-1} and a maximum seed yield of 2134 kg ha^{-1}. The study provides updated experimental data supporting the optimization of white mustard cultivation technology under limiting climatic conditions specific to south-eastern Romania.*

Keywords: *Sinapis alba L., sowing date, crop density, mineral fertilization, seed yield, climatic conditions.*

INTRODUCTION

In the current context of European and national agriculture, climate change represents one of the main limiting factors affecting the stability of agricultural production, particularly in regions characterized by pronounced water deficit. The increasing frequency of drought periods, associated with high temperatures and uneven precipitation distribution, requires a reassessment of crop structure and the adaptation of cultivation technologies to the new pedoclimatic conditions (PRĂVĂLIE ET AL., 2014; STANCIU, 2024). In this context, crops with a short vegetation period, sown early and capable of efficiently exploiting soil water reserves accumulated during the cold season, gain strategic importance.

White mustard (*Sinapis alba* L.) belongs to this category of crops, being characterized by a relatively short growing cycle, high ecological plasticity and a strong ability to adapt to abiotic stress conditions. Recent studies highlight the increasing interest in this species both for seed production and for alternative uses (oil production, fodder, melliferous crop and cover crop), especially within agricultural systems oriented toward sustainability (MITROVIĆ ET AL., 2020; MATIN ET AL., 2025; QUINTANA-ESTERAS ET AL., 2025). Moreover, biological interactions between Sinapis alba seeds and other cultivated or spontaneous species indicate an allelopathic potential that may influence germination processes and crop establishment, as demonstrated by the results reported by MARINOV-SERAFIMOV ET AL. (2018) in studies on allelopathic effects between *Sorghum vulgare* and *Sinapis alba*.

In arid and semi-arid regions such as Dobrogea, characterized by an excessive continental climate, white mustard shows considerable agronomic potential due to its ability to efficiently utilize limited water and nutrient resources. Climatic analyses conducted for this region indicate a pronounced increasing trend in water deficit during the spring–summer period, which directly affects late-sown crops (PRĂVĂLIE ET AL., 2014). Under these conditions, early sowing and the adoption of conservative soil tillage systems become key elements for stabilizing crop yields. Reduced tillage systems, such as minimum tillage, are increasingly recommended in regions with high climatic risk, due to their role in conserving soil moisture, maintaining soil structure and reducing evaporation losses. The integration of short-cycle crops such as Sinapis alba into such systems may contribute to improved resource use efficiency and enhanced adaptation of agricultural systems to current climatic conditions (DRĂGAN ET AL., 2022; QUINTANA-ESTERAS ET AL., 2025).

Mineral fertilization, particularly with nitrogen and phosphorus, represents a decisive factor in achieving the productive potential of white mustard crops. Recent research indicates that crop response to nitrogen fertilization is strongly influenced by applied dose levels, plant density and pedoclimatic conditions, with significant differences observed among technological variants (HAQ ET AL., 2023; KOZERA ET AL., 2025). At the same time, sowing date directly affects growth and development dynamics, determining the extent to which available climatic resources are utilized during early growth stages. Under the specific pedoclimatic conditions of Southern Dobrogea, recent studies emphasize the potential of white mustard as a crop adapted to increased climatic variability and soil water constraints. Research conducted in conventional tillage systems in this region has shown that *Sinapis alba* exhibits good adaptability and yield stability; however, crop performance is strongly influenced by applied technological conditions, particularly sowing date and fertilization level (STROE AND PANAITESCU, 2025). These findings highlight the importance of adapting cultivation technology to regional specificity in order to optimally exploit the biological potential of the species. At the same time, most studies conducted in the Dobrogea region have been carried out under conventional soil tillage systems, while information regarding the performance of white mustard under conservative tillage systems remains limited. Given the current trend toward reduced soil disturbance, driven both by economic considerations and the need to conserve soil water resources, it is necessary to evaluate the performance of *Sinapis alba* under systems such as minimum tillage, which can significantly modify soil water and nutrient dynamics compared to conventional systems.

The interaction of sowing date, fertilization level and crop density within conservative tillage systems may generate crop responses different from those observed under conventional management. Therefore, extrapolation of results from conventional systems is not always appropriate, highlighting the need for studies addressing these interactions under local pedoclimatic conditions. Research conducted in Southern Dobrogea offers a relevant framework for improving the adaptation of white mustard to climate change and the transition toward sustainable agriculture. Although interest in Sinapis alba has increased, data regarding the combined effects of sowing date, fertilization and crop density under minimum tillage remain limited for south-eastern Romania. This gap supports the need to optimize cultivation practices for the specific conditions of Dobrogea. The present study evaluated the effects of sowing date, mineral fertilization (N40P40, N60P60, N80P80) and row spacing (12.5 and 25 cm) on the growth and yield of white mustard (*Sinapis alba* L., cv. Cezara) cultivated under minimum tillage on a typical vermic chernozem in south-eastern Romania.

MATERIAL AND METHODS

The research was conducted during the 2025 agricultural year, under field conditions, in the Mereni area, Constanța County, a region representative of south-eastern Romania from a pedoclimatic perspective. The soil on which the experiment was established was a typical vermic chernozem, characterized by a good level of natural fertility and a high capacity to support field crops. The preceding crop was winter vetch, a species known for its beneficial effects on soil structure and nitrogen regime, contributing to improved vegetation conditions for the subsequent crop. Soil tillage operations were carried out using a minimum tillage system, applied uniformly across all experimental variants, with the aim of conserving soil moisture and reducing mechanical disturbance of soil structure

The biological material used in the experiment was the white mustard (*Sinapis alba* L.) cultivar Cezara. The experiment was organized according to a factorial design, with sowing date, row spacing and mineral fertilization level as experimental factors. Four sowing dates, two row spacings (12.5 cm and 25 cm), corresponding to different crop densities, and three mineral fertilization levels (N40P40, N60P60 and N80P80) were studied. The combination of these three factors resulted in 24 distinct experimental variants, each variant being established on a 1 ha plot, with a total experimental area of 24 ha. Identical technological conditions were maintained for all variants with respect to the preceding crop, tillage system, weed, pest and disease control, as well as other crop management practices, ensuring that the observed differences could be attributed exclusively to the studied factors Plant density at emergence was determined in the field immediately after complete crop emergence using the metric frame method. For each experimental variant, three measurements were taken at different locations within the plot, and

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the results were expressed as plants per square meter. The values used in the analysis represent the arithmetic mean of the three determinations for each variant. Plant height was measured prior to harvest through direct field measurements using a measuring tape. For each experimental variant, ten adjacent plants were selected within each of three repetitions, resulting in a total sample of 30 plants per variant. The obtained values were statistically processed by calculating the arithmetic mean and were expressed in centimeters.

The average number of siliques per plant was determined at physiological maturity. For this purpose, three adjacent plants were harvested from three different locations within each plot, resulting in a sample of nine plants per variant. The total number of siliques was counted for each plant, and the final data were obtained by calculating the arithmetic mean, expressed as the number of siliques per plant.

The average seed weight per plant was determined after harvest in the Department of Crop Science laboratory of the faculty. Samples consisted of seeds collected from three adjacent plants for each variant, with the analyzed material ranging between 4,10 and 6,8 g. Measurements were performed using an analytical balance, and the results were reported relative to the number of analyzed plants and expressed as grams per plant. Seed yield was determined by harvesting a control area from each experimental plot. The harvested yield was weighed, and the obtained values were related to the harvested surface and extrapolated to one hectare. Final yield was expressed in kilograms per hectare, using the standard calculation formula for yield reporting per unit area. The experimental data were processed by calculating arithmetic means for each experimental variant, based on field and laboratory determinations. For the analyzed parameters: plant density at emergence, plant height, average number of siliques per plant, average seed weight per plant and seed yield: the values used in the analysis represent the mean of the measurements performed within each variant. Result interpretation was based on a comparative analysis of mean values, aimed at highlighting the influence of sowing date, row spacing and fertilization level on white mustard crop performance. Considering the large-plot experimental design, without independent plot replications, data analysis focused on identifying trends and relationships between the studied factors and analyzed parameters, without applying inferential statistical significance tests. This approach allows for the assessment of crop responses to different technological variants under real production conditions and ensures a realistic and accurate interpretation of the obtained results.

RESULTS AND DISCUSSIONS

Climatic conditions during the 2024-2025 agricultural year significantly influenced sowing management and crop development under minimum tillage. Air temperature and precipitation recorded during winter and the growing season were analyzed in relation to long-term averages (Figure 1). During the soil water accumulation period (November–December 2024), precipitation exceeded multiannual means (November: 56.6 mm, +40%; December: 92.8 mm, +173%), ensuring effective soil profile recharge and substantial water reserves for early sowing. Mean monthly temperatures were also above normal (+1.7°C in November; +3.3°C in

December), preventing persistent frost and supporting favorable soil thermal conditions. In January–February 2025, precipitation deficits became pronounced (–44% and –84%, respectively), although temperatures remained near or slightly above normal. Consequently, sowing (24 February–11 March) was scheduled to capitalize on accumulated soil moisture. The minimum tillage system contributed to moisture conservation by reducing evaporation losses. March was characterized by severe precipitation deficit (–79%) and markedly higher temperatures (+5.5°C), which accelerated crop emergence, particularly for early sowing dates. During April–May, thermal conditions were near normal, and precipitation partially recovered, especially in May, supporting vegetative growth and nutrient utilization. In June, at seed filling, extreme drought (–99.6%) combined with elevated temperatures (+4.3°C) intensified water stress and contributed to yield variability among experimental variants, depending on sowing date and efficiency of soil water use.

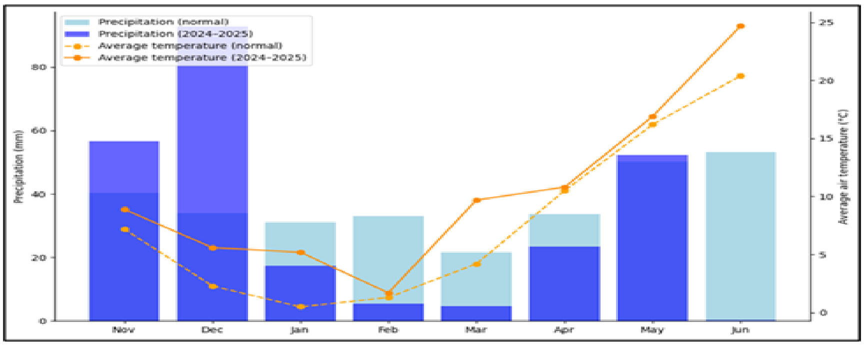

Figure 1. Thermal and precipitation regime during the 2024–2025 agricultural year compared to multiannual averages.

Plant density at emergence was a key indicator of white mustard establishment under the climatic conditions of the 2025 sowing period. Differences among sowing dates were mainly associated with the severe precipitation deficit in February–March and the soil's capacity to retain winter-accumulated moisture under minimum tillage. For the first sowing date (24 February), emergence density averaged 309 plants m^{-2} at 12.5 cm row spacing and 116 plants m^{-2} at 25 cm, indicating efficient use of soil water reserves. Similar or slightly higher values were recorded on 1 March (321 and 122 plants m^{-2}, respectively), suggesting adequate moisture for uniform emergence. The highest densities were observed for the 6 March sowing date (347 plants m^{-2} at 12.5 cm and 131 plants m^{-2} at 25 cm), likely due to the favorable thermal regime in March, which accelerated germination and emergence. In contrast, the 11 March sowing date recorded the lowest densities (approximately 295 and 111 plants m^{-2}), representing a 15–20% reduction compared to 6 March, primarily as a result of limited water availability in the upper soil layer.

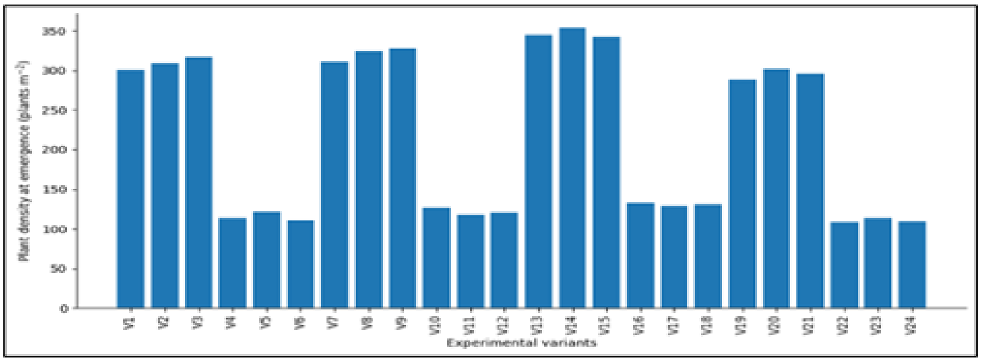

Figure 2. Plant density at emergence (plants m^{-2}) recorded for the 24 experimental variants of white mustard.

White mustard plant height was influenced by sowing date, crop density and fertilization level, in close relationship with the climatic conditions during the growing season. Mean plant height values recorded prior to harvest for the 24 experimental variants are presented in Figure 3. For the first sowing date (24 February 2025), plant height ranged between 119 and 126 cm, with an average value of approximately 122 cm. The more moderate growth observed under this sowing date can be associated with lower temperatures during the early growth stages, which temporarily limited vegetative development. In contrast, the second sowing date (1 March 2025) resulted in a significant increase in plant height, with values ranging from 128 to 143 cm and an average of approximately 136 cm. This response reflects the more favorable thermal conditions in March, which supported more intensive vegetative growth compared to the first sowing date. The highest plant height values were recorded for the third sowing date (6 March 2025), where plant height ranged between 130 and 159 cm, with an average of approximately 147 cm. These results can be attributed to the combined effect of higher spring temperatures and a longer effective growing period, which favored vegetative biomass accumulation. In contrast, the fourth sowing date (11 March 2025) resulted in reduced plant height values, ranging from 120 to 133 cm, with an average of around 127 cm. The reduction in vegetative growth under this sowing date is associated with later crop establishment and the pronounced precipitation deficit in March, which limited plant development during early growth stages.

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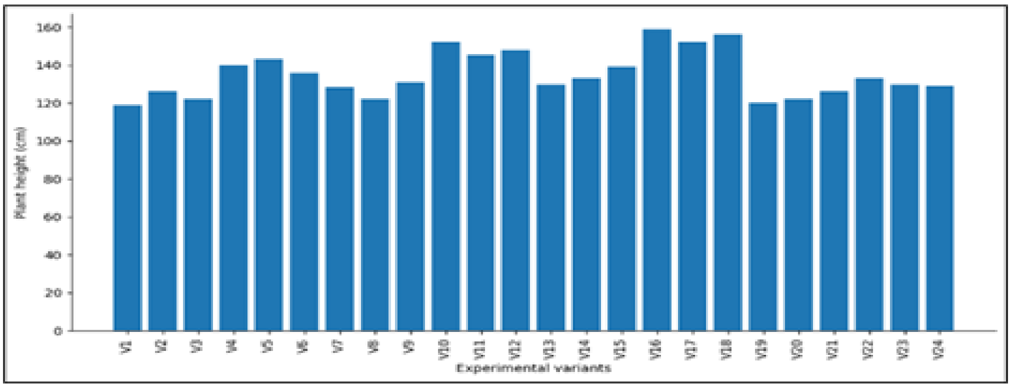

Figure 3. Variation of plant height (cm) in the 24 experimental variants of *Sinapis alba* L.

The average number of siliques per plant was significantly affected by sowing date and growing season conditions, reflecting the crop's capacity to use available water and nutrients during vegetative and reproductive stages (Figure 4).

For the 24 February sowing, values ranged from 128 to 136 siliques plant^{-1} (mean ≈133), indicating moderate yield component formation under cooler early-season conditions. The 1 March sowing produced higher values (138–173 siliques plant^{-1}; mean ≈159), associated with more favorable temperatures and an extended effective growing period. The highest values were recorded on 6 March (172–198 siliques plant^{-1}; mean ≈185), suggesting superior yield potential due to favorable thermal conditions and adequate soil moisture during inflorescence differentiation and silique formation. In contrast, the 11 March sowing showed lower values (120–146 siliques plant^{-1}; mean ≈133), mainly due to delayed establishment and increased spring water stress.

Despite the high silique number observed particularly for the 6 March sowing date, this potential was not fully translated into seed yield.The severe precipitation deficit recorded during March–April and the almost complete lack of rainfall during June negatively affected seed filling, leading to a high proportion of poorly developed or partially sterile siliques. In many cases, siliques contained a reduced number of seeds or seeds with low mass, while some remained completely empty. This phenomenon explains the discrepancy observed between the high number of siliques per plant and the final seed production and emphasizes the dominant role of water availability during the reproductive and seed-filling stages. The results indicate that under water-limited conditions, the number of siliques per plant alone is not a reliable predictor of final yield. Instead, the capacity of plants to sustain seed development under drought stress represents the critical factor determining productive performance, particularly in years characterized by pronounced climatic variability.

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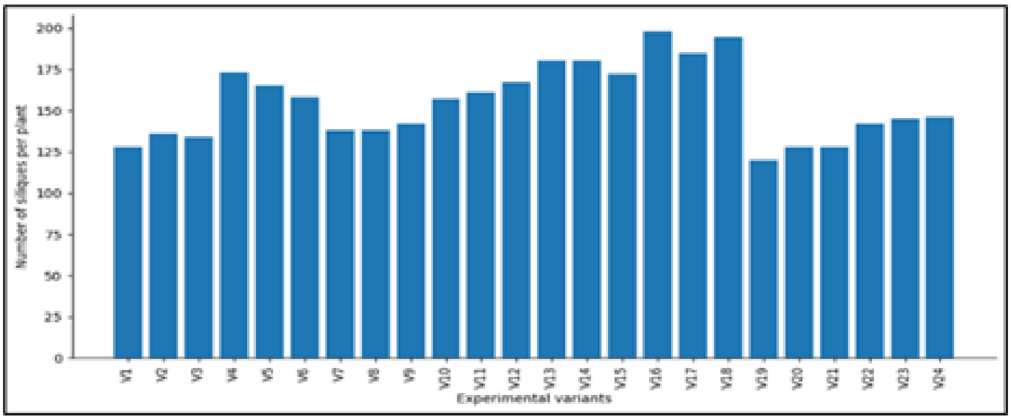

Figure 4. Average number of siliques per plant recorded for the 24 experimental variants of white mustard.

Although a high average number of siliques per plant was recorded, particularly for the third sowing date, this yield potential was not fully reflected in the obtained seed yields due to the influence of climatic factors acting during critical stages of crop development. Descriptive analysis revealed clear differences among sowing dates with respect to average seed weight per plant and seed yield (Table 1).

The third sowing date (6 March 2025) recorded the highest values for both average seed weight (6.51 g plant^{-1}) and seed yield (1992 kg ha^{-1}), which were considered the reference maximum (100%). Compared to this sowing date, seed yield obtained for the first sowing date (24 February 2025) was lower by approximately 16.2%, while average seed weight decreased by 17.2%, indicating an incomplete conversion of yield potential under less favorable climatic conditions. The severe precipitation deficit recorded during March and April resulted in significant losses of emerged plants and uneven silique development. A proportion of the formed siliques failed to develop completely, leading to reduced seed mass and, consequently, lower final yields. This effect was more pronounced for the fourth sowing date (11 March 2025), where average seed weight was approximately 27.5% lower than the maximum value, and seed yield decreased by about 16.5% relative to the reference. This explains the discrepancy between the high number of siliques per plant and the final seed yields obtained. Overall, the results confirm that under the climatic conditions of 2025, white mustard productivity was determined not only by silique formation capacity, but primarily by soil water availability during the critical stages of seed development, highlighting the importance of adapting cultivation technology to the specific climatic regime of the region.

Table 1.

Average seed weight per plant (g) and seed yield (kg ha⁻¹) recorded for the 24 experimental variants

Variant	Sowing date	Seed weight (g plant^{-1})	% of maximum	Seed yield (kg ha^{-1})	% of maximum
V1	24.02.2025	4,60	67,6	1514	70,9
V2	24.02.2025	5,00	73,5	1508	70,7
V3	24.02.2025	5,00	73,5	1540	72,2
V4	24.02.2025	5,40	79,4	1740	81,5
V5	24.02.2025	6,12	90,0	1832	85,8
V6	24.02.2025	6,22	91,5	1880	88,1
V7	01.03.2025	4,87	71,6	1578	73,9
V8	01.03.2025	4,93	72,5	1592	74,6
V9	01.03.2025	5,11	75,1	1608	75,4
V10	01.03.2025	5,83	85,7	1780	83,4
V11	01.03.2025	6,21	91,3	1822	85,4
V12	01.03.2025	6,35	93,4	1990	93,3
V13	06.03.2025	6,27	92,2	1880	88,1
V14	06.03.2025	6,30	92,6	1896	88,8
V15	06.03.2025	6,20	91,2	1844	86,4
V16	**06.03.2025**	**6,80**	**100,0**	**2134**	**100,0**
V17	06.03.2025	6,70	98,5	2090	97,9
V18	06.03.2025	6,80	100,0	2110	98,9
V19	11.03.2025	4,10	60,3	1489	69,8
V20	11.03.2025	4,30	63,2	1511	70,8
V21	11.03.2025	4,30	63,2	1532	71,8
V22	11.03.2025	4,92	72,4	1792	84,0
V23	11.03.2025	5,12	75,3	1812	84,9
V24	11.03.2025	5,60	82,4	1840	86,2

The results confirm that sowing date is a major determinant of white mustard productivity under the pedoclimatic conditions of Dobrogea. The high emergence density, plant height and number of siliques per plant recorded for the 6 March 2025 sowing indicate good adaptation to early spring sowing, enabling efficient use of winter-accumulated soil moisture. These findings are consistent with recent studies reporting a positive response of *Sinapis alba* to early sowing under moderate temperatures and adequate initial soil water availability (Haq et al., 2023; Kozera et al., 2025). However, a high number of siliques per plant did not ensure maximum seed yield under limited water availability during critical stages. The precipitation deficit in March–April reduced plant uniformity and increased post-emergence losses, while the extreme drought in June negatively affected seed filling, leading to partially or totally sterile siliques and poorly developed seeds. Similar responses under reproductive-stage drought stress have been reported in the literature (Kozera et al., 2025; Mykolaiko et al., 2025). Compared with conventional tillage systems previously reported for Dobrogea (Stroe and Panaitescu, 2025), minimum tillage improved soil moisture conservation and early growth stability. Nevertheless, drought during seed filling could not be fully mitigated, emphasizing that technological adaptation must integrate sowing date, crop density and fertilization in relation to annual climatic variability in south-eastern Romania.

CONCLUSIONS

The results obtained under the pedoclimatic conditions of the Mereni area, Constanța County, highlight that sowing date is a decisive factor for crop establishment and the expression of productive potential in white mustard (Sinapis alba L.), especially in years characterized by pronounced spring water deficit.

Sowing performed within the interval 24 February–11 March 2025 allowed effective utilization of soil water reserves accumulated during winter; however, clear differences were observed among sowing dates. Among these, the third sowing date (6 March 2025) proved to be the most favorable for white mustard cultivation, ensuring high emergence density, adequate vegetative development and superior values of yield components. Although the average number of siliques per plant was high, particularly for the third sowing date, final seed yield was strongly influenced by water availability during critical growth stages. The severe precipitation deficit during March–April and the almost complete absence of rainfall in June resulted in plant losses, uneven silique development and incomplete seed filling, leading to yield reductions in some experimental variants

The application of a minimum tillage system contributed to soil water conservation and stabilized growth processes during early vegetation stages; however, it could not fully compensate for the effects of severe drought stress during the seed-filling period. This finding emphasizes the need to adapt cultivation technology to the climatic characteristics of each agricultural year Under the climatic conditions of 2025, the most productive experimental variant was recorded for the third sowing date (6 March 2025), at 25 cm row spacing and a fertilization rate of N80P80 (variant V16), which achieved the highest average seed weight (6.8 g plant^{-1}) and the highest seed yield (2134 kg ha^{-1}). This technological combination can be recommended as an optimal option for white mustard cultivation under similar soil and climatic conditions in south-eastern Romania.

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