

Yield and Quality of Mustard Seeds Depending on the Use of Technology Elements

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Abstract

Due to its versatile uses, mustard is a valuable crop that is widely used for industrial purposes. That is why the improvement of agrotechnical methods of its cultivation in order to obtain high yields is practical importance. The aim of the research was to investigate how the application of diverse factors, including timing, and methods of sowing, affect the yield and quality of mustard seed in the Right-Bank Forest-Steppe of Ukraine. According to the research results, it was found that the yield of mustard depends on the growth and development of plants and the formation of elements of the crop structure – the number of pods per plant, the number of seeds per pod and the weight of 1000 seeds. This article discusses results in plant height in correlation to sowing period and row spacing. It was found that the timing and methods of sowing mustard significantly affect the biometric parameters of the crop and, accordingly, the seed yield. According to the results it was determined that in the conditions of the Right-Bank Forest-Steppe of Ukraine, the optimal time for sowing mustard is the early sowing period, which falls on the first and second quarter of April. In order to increase the yield of mustard, it is recommended to grow it with a row spacing of 45 cm at both sowing dates.

Keywords

Yield; Fertilizer; Germination Energy; Germination Rate; Weight of 1000 Seeds

Introduction

Growing oilseeds in Ukraine is one of the most promising and stable areas among the main sources of agriculturally-based

profitability (Kyryliuk, Tymushchuk and Kalchuk, 2019). Mustard occupies one of the leading places among oilseeds (Mykolaiko, 2024). It is a highly profitable horticultural crop with promising applications in the industrial sector (Syaranamual *et al.*, 2024; Tanwar and Goyal, 2021). Mustard seeds are widely used in the food industry for the production of spices and flour (Bolkhovitina, Chubakha and Shydakova-Kameniuksa, 2023; Kumar, Singh and Singh 2017). Due to its functional properties, it has become a valuable ingredient for baking, which has led to an increase in demand for its seeds (Zhang *et al.*, 2023). In addition, the plants are used in the production of green manure, raw materials for biofuels, and for soil reclamation. Additionally, they play an important role in the development of beekeeping and animal feed production (Baidala, Mirzoieva and Mirzoiev, 2023; Licataa *et al.*, 2024). Mustard plants are also one of the main components in the paint and varnish industry (Taj, Upadhyay and Sharma, 2024).

Sowing dates and optimal cultivation methods can have an effect on high yields and quality of mustard seeds of new high-yielding varieties such as Podolyanka, BINA Sarisha-9 and Japanese Sarisha (Kyryliuk, Tymushchuk and Kalchuk, 2019; Mehedi *et al.*, 2024). This research examines sowing dates, soil temperatures and factors involved in high yield of various mustard species. For example, very early sowing dates, mustard crops can become overgrown with weeds. On the other hand, later sowing dates can suffer from a moisture deficit which can reduce seed germination (Tereshchenko, 2001). Melnychuk *et al.*'s study found that sowing dates influenced the interphase periods of ontogenesis and the growing season of white mustard (*Sinapis alba*). These factors had a significant impact on the formation of the plant's generative and reproductive organs, the duration of interphase periods of their development, and the productivity of agrocenosis (Melnychuk, Sendetskyi, Lys and Stelmakh, 2024).

According to Kyrychenko and Rozhkov (Kyrychenko and Rozhkov, 2023), the density of plants and their uniform distribution over the area are important factors in the cultivation of mustard. It was found that the highest yield of Sarepta mustard (*Brassica juncea*) seeds was obtained at a seeding rate of 2.0 million seeds/ha, while the biometric parameters of an individual plant were higher in variants with a seeding rate of 1.5 million seeds/ha (Polyakov *et al.*, 2016). According to Zhernova (Zhernova, 2009), one of the main agrotechnical measures that affect the formation of biometric indicators, the number of pods per plant, is the sowing methods and seeding rates. In the conditions of the southern Steppe of Ukraine, the largest number of pods per plant was obtained with a row seeding method at a row spacing of 15 cm at a seeding rate of 1.0 million pcs/ha. With an increase in both the seeding rate and row spacing, the number of pods per plant decreased. At the same time, there was no significant difference in plant height. According to Chekhov and Zhernov (Chekhov and Zhernov, 2009), in the conditions of the southern Steppe of Ukraine, sowing dates and seeding rates significantly influenced the productivity of white mustard. The highest yield of 1.77 t/ha was obtained at the first sowing date, when the soil temperature was 2-4°C with a seeding rate of 2 million pieces/ha.

The study examined the influence of technology elements on the yield and seed quality of four varieties of white mustard (*Sinapis alba*) – Etalon, Pidpecherecka, Ariadna and Oslava and one variety of black mustard (*Brassica nigra*) Tsarivna Pivnoch. The aim of the research is to determine the factors influencing the formation of biometric parameters,

yield and quality of mustard seeds based on elements such as timing and methods of crop sowing in the Right-Bank Forest-Steppe of Ukraine.

Methodology

Study Area

This study was conducted at the experimental field of Pavlo Tychyna Uman State Pedagogical University, under the Ministry of Education and Science of Ukraine, during 2020-2023. This area is located in a zone of unstable moisture of the Right-Bank Forest-Steppe of Ukraine.

Research Framework

The framework of this research included two sowing factors (factor A): the first sowing date when the soil reached physical maturity (at an optimum humidity of 40 - 60 % total humidity) and soil temperature of +5...+7 °C, which falls on the first of April, the second at a soil temperature of +8...+9 °C, which falls on the third of April. The second factor considered in the research framework was two sowing methods (factor B): the usual row method with a row spacing of 15 cm and the second wide-row method with a row spacing of 45 cm. Sowing was carried out at a seeding rate of 1.5 million units/ha. In the experiment, 5 varieties were studied, the placement of which was systematic in blocks, where the variants were placed systematically in each block of 4 variants, and 4 replications of each variant were randomised.

Research Methods

Biometric parameters that affect seed yield (seed yield structure) – plant height, number of pods per plant and number of seeds per pod were determined according to the Methodology for variety testing of agricultural crops (Volkodav, 2000). Biometric parameters were determined in 20 plants of each replication by variant. Seed yield after primary cleaning was determined by weighing by plots from each replication. Average seed samples, germination energy, germination rate and weight of 1000 seeds were collected according to DSTU (DSTU 4138, 2002). Seed germination energy was determined by calculating the average percentage of full-grown seedlings to the number of sown seeds. A sample from each sample (replicate of each variant) was taken in small portions (spot samples) from different locations and after ensuring their homogeneity, mixed (pooled sample). Smaller samples were separated from the obtained amount of seeds by dividing them into 4 stages. At each stage, the sample was mixed and an average sample was formed, which was analysed for seed quality.

Soil and Weather Conditions

During the study period, weather conditions were close to the average long-term temperature rates, and the moisture availability varied by year. The growing seasons of 2020, 2022 and 2023 were characterised by moisture deficits, with precipitation deficits of 36.2, 114.2 and 50.3 mm, respectively, and only in 2021 was there a slight waterlogging, with precipitation 50.3 mm above the long-term average. The soil at the experimental site is a podzolic heavy

loamy black soil characterized by a lumpy-dusty structure with a low humus content of 3.31%. The reaction of the soil solution is neutral, pH 6.5–6.7. The content of mobile phosphorus compounds and potassium was of 80-130 mg/kg, which is average. That is, the soil and climatic conditions were favorable for the growth and development of mustard plants and the formation of yield and seed quality.

Statistical Analysis

The experimental data were statistically processed using analysis of variance and regression analyses according to the Fisher method (Fisher, 2006) and guidelines (Ehrmantraut, Prysiashniuk and Shevchenko, 2007). Statistical processing was performed using the Statistica 6 software.

Results

The yield of mustard depends on the growth and development of plants and the formation of the elements of the crop structure, the number of pods per plant, the number of seeds per pod and the weight of 1000 seeds. Factors such as structural elements and the state of plant development, their height, were found to also affect yield. The study showed that the height of plants is not determined by sowing methods, row spacing, but by sowing dates. On average, a significant increase in plant height was observed in the first sowing period, when the soil warmed up to a temperature of 6–7°C, compared to the second later period, regardless of row spacing. The expansion of row spacing to 45 cm provided a significant increase in plant height, both at the first and second sowing dates, which was 2.0 cm at the first sowing date, and 2.1 cm at the second – LSD₀₅ term and sowing method = 0.7 cm (Table 1).

Table 1: Biometric indices depending on sowing dates and methods (average of five varieties for 2021–2023)

Variant		Plant height, cm	Number of pods per plant, pcs.	Number of seeds per pod, pcs.
Sowing period	Sowing method			
I-II decade of April, t 6–7 °C	15	96.1	108.0	3.6
	45	98.1	101.5	3.7
III decade of April, t 8–9 °C	15	81.3	42.2	3.4
	45	83.4	35.4	3.5
LSD ₀₅ time and method of sowing		0.7	0.8	0.2

The determining factor for the formation of mustard productivity is the number of pods per plant, the number of seeds per pod and the weight of 1000 seeds. It was found that the number of pods per plant depended on both the period and the method of sowing mustard. Significantly more pods were formed during the first sowing period, regardless of the row spacing. While in the second term, depending on the sowing method, 35.4–42.2 pods were formed on the plant, in the first term there were significantly more pods – 101.5–108.0 pcs. or 2.6–2.9 times more. Sowing methods also influenced the formation of pods on the plant, but no significant difference in their number depending on the row spacing was found.

Literature reviews showed that the number of seeds per pod is the least variable element of white mustard yield. The number of seeds per pod in narrow-row and wide-row sowings was almost equal, respectively 3.1–3.3 and 3.3–3.5 pcs, which coincides with the findings of other researchers (Zhernova, 2009). According to Blashchuk and Tetereshchenko (Blashchuk and Tetereshchenko, 2017), the number of seeds per pod in narrow and widerow sowing was also close in range 4.8–5.3 and 4.7–5.2 pcs. Respectively. However they observed an increase by 0.1–0.2 pcs./pod at the lowest seeding rate (1.0 million pcs./ha).

It was found that crop structure contributed to the increase in mustard seed productivity (Table 2).

Table 2: Seed yield and quality depending on timing and sowing methods (average of 5 varieties for 2020–2023)

Variant		Yield, t/ha	Germination energy, %.	Germination rate, %	Weight of 1000 pieces, g
sowing period	sowing method				
I-II decade of April, t 6–7 °C	15	1.57	95	95	4.24
	45	1.51	94	95	4.29
III decade of April, t 8–9 °C	15	1.35	94	94	4.12
	45	1.09	94	95	4.21
LSD ₀₅ time and method of sowing		0.01	0.73	0.46	0.07

Since more pods were formed on the plant during the first sowing period, the seed yield was significantly higher – by 0.06 t/ha than during the second sowing period, regardless of sowing methods. Voloshchuk 's research (Voloshchuk, 2023) found that in the Carpathian region, under the conventional row sowing method of 15 cm and different seeding rates (1 and 1.5 million seedlings/ha), field germination remained largely unchanged, at 91.1% and 90.8%, respectively. According to this study with regards to seed quality, germination energy and seed germination, no significant changes were observed with respect to the size of crop structure elements or the sowing time of mustard. Additionally, no significant difference was found based on the sowing time. Furthermore, the weight of 1000 seeds in comparison with the weight of seeds per pod depended on both the term and method of sowing mustard. When sowing in the first (early) term, the weight of 1000 seeds was significantly higher than when sowing in the second (later) term regardless of the sowing method. Seeds grown with a 45 cm row spacing had higher weights (4.29 g in the first term, 4.21 g in the second term) rather than those grown with the narrow-row method (4.24 and 4.12 g). The difference was statistically significant with an LSD₀₅ of 0.07 g.

The study of the factors influencing the formation of crop yield revealed that the “sowing time” factor had the greatest impact accounting for 73.0%, while the “sowing method” factor had lesser influence at 19.4%. The influence of other factors and their interaction was minimal (Figure 1).

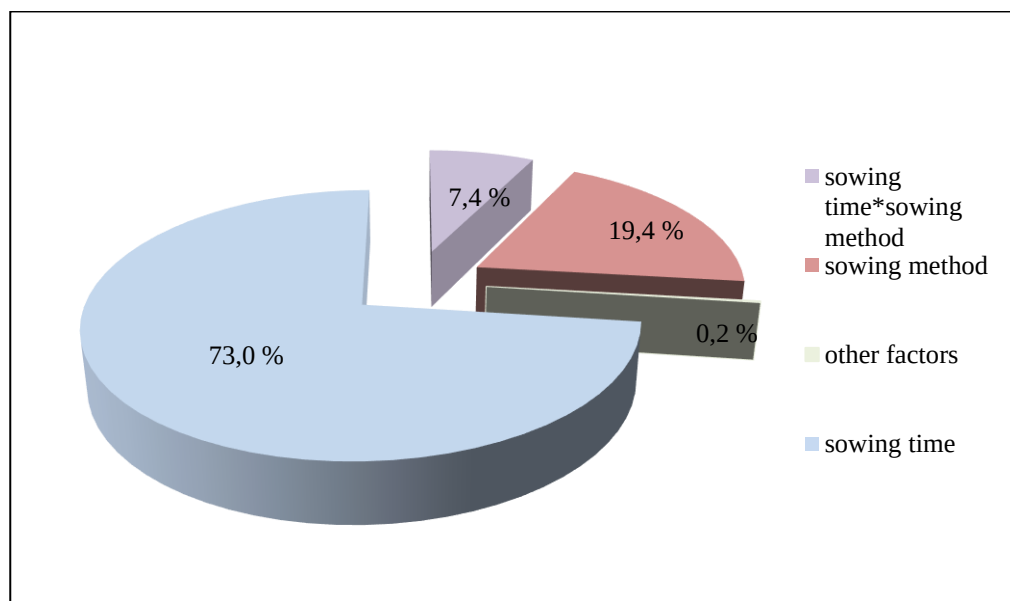
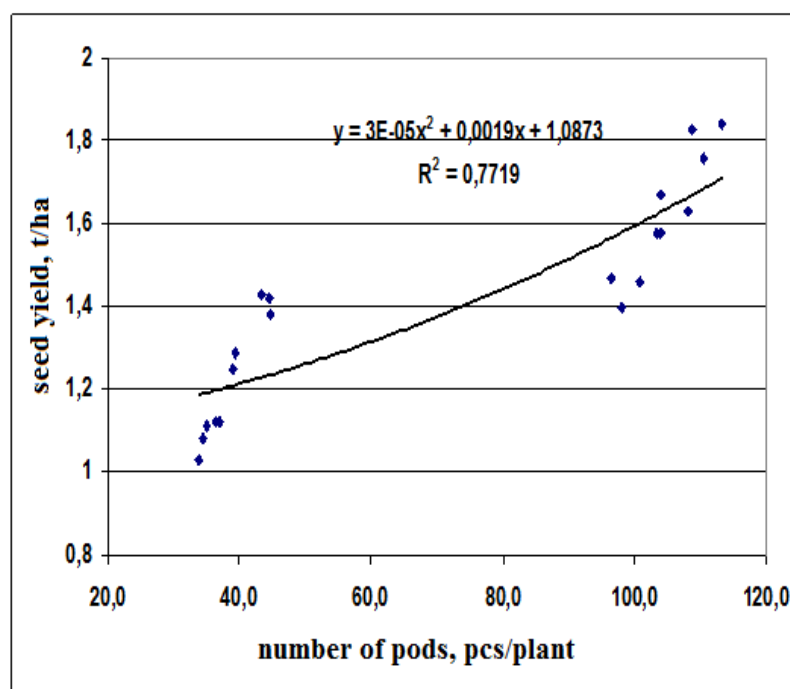


Figure 1: Influence of factors on seed yield depending on the timing and methods of sowing (average of 5 varieties, 2020–2023)

The correlation and regression analysis between seed yield and the number of pods per plant and the number of seeds per pod is represented by a second-order polynomial and the corresponding equations – $y = 3E-05x^2 + 0.0019x + 1.0872$ and $y = -1.2123x^2 + 9.1578x - 15.78$ (Figure 2).



A

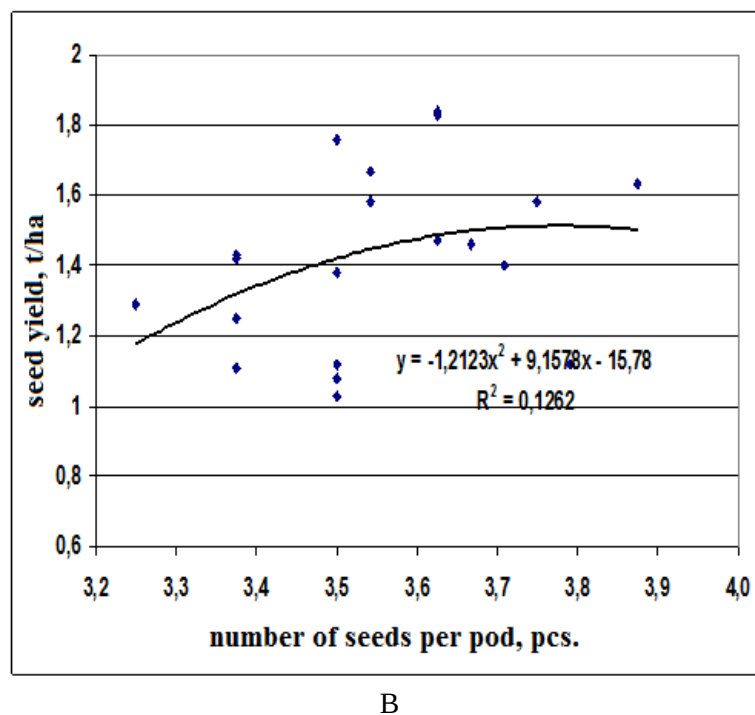


Figure 2: Correlation and regression between seed yield and number of pods per plant (average of 5 varieties for 2021-2023)

A strong correlation was found between the yield of mustard seeds and the number of pods per plant with a determination coefficient of $R^2 = 0.7719$ and a correlation coefficient of $r = 0.88$ (a). An average correlation was observed between the seed yield and the number of seeds per pod with a determination coefficient of $R^2 = 0.1262$ and a correlation coefficient of $r = 0.33$ (b).

Discussion

Mustard is one of the most important oilseeds crops grown for edible oil, vegetables, condiments, medicinal and bioprocessing purposes (Dhillon *et al.*, 2022; Tanwar and Goyal, 2021). It has been determined that the difference between its potential and realised yields is due to various factors (Dhillon *et al.*, 2022). Mustard tends to ripen (complete its life cycle) earlier, accumulating fewer heat units, which may be a prerequisite for the fact that earlier sowing dates increase its yield (Kayacetin *et al.*, 2019). Plants that consumed the optimum amount of heat and changed phenological phases in time produced more yield per unit area (Samota, Sharma and Paliwal, 2022).

It was experimentally determined that the sowing date significantly affects the number of days to harvest, plant height, number of pods, fresh feed yield and weight of mustard pods (Amiri *et al.*, 2025). The highest plant height (206.9 cm) and number of pods per shoot (10.5) were obtained when sowing mustard at earlier sowing dates. This suggests that plants sown early and on time are exposed to optimal temperature, moisture and day length for a longer time. In the conditions of the Precarpathian region, when sowing

mustard in the first term, when the soil reaches a warming temperature of 5-10 °C, the highest yields were obtained on average 1.9-2.1 t/ha and exceeded by 0.2-0.25 t/ha, 0.35-0.41 t/ha or by 10-22 and 15-25% the following later sowing terms (Melnychuk et al., 2024). In the Western Forest-Steppe, sowing in the early spring, when the soil warmed up to +3...+4 °C, yields of mustard seeds were highest, depending on the varietal characteristics, from 1.35 t/ha to 2.10 t/ha or more, respectively, by 0.45–0.69 t/ha compared to the later sowing period, when the soil warmed up to +7...+8 °C (Kozina, 2015). In the study of factors influencing the yield of mustard in the hot, humid continental climate of Turkey, it was found that the maximum seed yield of 1084 kg ha⁻¹ was found when sown on 15 March, while the lowest seed yield of 141 kg ha⁻¹ was determined on plants sown on 1 May during on both years of the study (Kayacetin, 2023).

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These results are consistent with the results of our research, where sowing earlier contributed to an increase in plant height by 14.7% and the number of pods by 66%. Given the different conditions of the research, it is necessary to take into account the units of heat consumption, which determines the timing of sowing mustard for different growing conditions. The study of this factor may become a prospect for further research in different soil and climatic conditions of Ukraine.

The planting pattern is another key factor for high yields and high profitability. Studies have shown that increasing the row spacing from 10 cm to 20 cm increased the number of pods and seed weight by 28% and 3%, respectively. At the same time, plant height decreased by 1.6 % with an increase in row spacing (Brar and Gill, 2021). According to our studies, the number of pods, decreased by 6.0-6.8 pcs, depending on the sowing date, which indicates the need for further research, taking into account other factors of influence.

Conclusion

On average, a significant increase in plant height was observed at the first sowing date. The height of plants in the first sowing period increased by 15.2% compared to the second later sowing period. Therefore, the optimal time for farmers is the early sowing of mustard, when the soil temperature at a depth of 10 cm is 6-7 °C, approximately in the first and second quarter of April. Widening the row spacing to 45 cm ensured an increase in plant height at the first and second sowing dates, reaching to 2.0 cm and 2.1 cm, respectively. There was no significant difference in germination energy and seed germination. The weight of 1000 seeds at the first (early) sowing date was higher and totaled 4.27 g, which in turn contributed to an increase in yield by 0.32 t/ha compared to the second (later) sowing date. It was determined that the influence of the factor 'sowing time' on crop yield was the most significant resulting in 73.0%. A strong correlation was found between the yield of mustard seeds and the number of pods per plant with a determination coefficient of $R^2 = 0.77$ and a correlation coefficient of $r = 0.88$.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5	Author 6	Author 7	Author 8	Author 9	Author 10
Conceived and designed the research or analysis	Yes	Yes	No	Yes	No	No	No	Yes	No	No
Collected the data	Yes	No	No	No	No	No	No	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	No	No	No	No	No	No	No
Critical revision of the article/paper	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	No	Yes	No	No	No	No	No	No	No
Supervision	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Project Administration	Yes	No	Yes	No	No	No	No	No	No	No
Funding Acquisition	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
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