

Seed productivity of mustard depending on varietal characteristics and application of mineral fertilizers

Irina Mykolaiko¹, Valentine Polishchuk², Anatolii Balabak², Volodymyr Doronin³ and Anna Brovdi^{2*}

¹ Pavlo Tychyna Uman State Pedagogical University, 20300 Uman, Cherkasy region, Ukraine

² Uman National University, 20300 Uman, Ukraine

³ Institute of Bioenergy Crops and Sugar Beets of NAAS, 03110 Kyiv, Ukraine

*Corresponding author: abrovdi@ukr.net

Abstract

Mykolaiko, I., Polishchuk, V., Balabak, A., Doronin, V. & Brovdi, A. (2026). Seed productivity of mustard depending on varietal characteristics and application of mineral fertilizers. *Bulg. J. Agric. Sci.*, 32(2), 299–305

The paper investigates the peculiarities of mustard seed yield and quality formation depending on the use of mineral fertilizers. It has been determined that the use of mineral fertilizers increase the yield structure, which contributed to the increase in the seed productivity of mustard. On average, seed yields increased significantly by 0.32–0.56 t/ha in the varieties with the application of mineral fertilizers, both as the main fertilizer and together with foliar fertilization, compared to the control without fertilizers. The introduction of phosphorus-potassium fertilizers in the main fertilizer provided a significant in the yield of mustard seeds of all varieties, which ranged from 0.14 t/ha (Tsarivna Pivnochi) to 0.27 t/ha (Oslava). With the main fertilizer and foliar feeding with nitrogen fertilizers, seed yields increased significantly compared to the control, and the addition of phosphorus-potassium fertilizers to the main fertilizer. The greatest influence on seed yield was the «fertilizer» factor, which accounted for 85.1%, while the influence of the «variety» factor was much lower. Thus, in order to increase the yield of mustard seeds when grown in the conditions of the Right-Bank Forest-Steppe, it is advisable to apply $P_{45}K_{45}$ as the main fertilizer, and to carry out two fertilizations with nitrogen fertilizers at a rate of N_{15} and in the rosette-stemming stage at a rate of N_{30} , which ensures high seed productivity of mustard.

Keywords: variety; yield; fertilization; germination energy; germination rate; weight of 1000 seeds

Introduction

Ukraine is among the top ten world leaders in mustard cultivation and ranks fourth in terms of crop production among oilseeds in the country, where mustard is next only to rapeseed, soybean and sunflower (Petrova, 2020; Mykolaiko, 2024). With the introduction of modern varieties capable of producing high seed yields, the maximum realization of the genetic, and biological potential of the crop by improving the elements of crop cultivation technology is of practical importance (Zhuykov, 2014), so the study of ways to increase the yield of mustard seeds is relevant.

One of the most effective elements of technology that increases mustard yields is the application of mineral fertilizers. Mustard responds well to fertilization, which can contribute to a significant increase in yield (Bulbul et al., 2022).

According to Blashchuk and Tereshenko (2014), under conditions of unstable moisture in the central Forest-Steppe zone of Ukraine, early sowing with a fertilizer dose of $N_{45}P_{45}K_{45}$ ensured the maximum yield of mustard seeds of the Talisman variety – 1.81 t/ha. In the conditions of the SE Research Farm “Chabany” on grey forest light loamy soils, on average for 2016 – 2018, the highest yield of white mustard seeds (2.58 t/ha) was obtained when applying min-

eral fertilizers at a dose of $N_{45}P_{60}K_{90}$, and feeding plants in the rosette stage with Tropical (1.0 kg/ha) (Hubenko and Liubchych, 2020). According to Saiko and Vyshnevskiy (2015), in the northern part of the Right-Bank Forest-Steppe of Ukraine, on grey forest soils of the experimental farm «Chabany», of the National Research Centre «Institute of Agriculture of NAAS», foliar feeding with Florine flowering stimulator against the background of mineral fertilizers at a dose of $N_{60}P_{60}K_{90}$, ensured the formation of high indicators of mustard yield structure elements, and formed a yield of 2.27 t/ha. In a stationary experiment on black earthy podzolic medium loamy soils of the Khmelnytskyi State Agricultural Experimental Station, against the background of mineral fertilizer, at a dose of $N_{60}P_{60}K_{60}$, the highest yield of white mustard of 2.06 t/ha was obtained under the shelf system of basic tillage. The same yield (2.05 t/ha) was provided by the flat-cutting system of basic tillage on the background of organic-mineral fertilizer (with the predecessor straw left in the field and the addition of $N_{30}P_{30}K_{30}$) (Kirilyuk et al., 2019). According to Hubenko and Liubchych (2020), the application of mineral fertilizers even in small amounts (60 kg/ha of P and 90 kg/ha of P) led to a significant increase in the yield of mustard seeds – by 0.84 t/ha.

In the conditions of the Ukrainian Steppe on the experimental field of the Institute of Oilseeds on ordinary heavy loamy black soil, the highest yield of the Prima variety (1.62 – 1.76 t/ha) and Zaporizhanka variety (1.49 – 1.64 t/ha) was formed by applying mineral fertilizers at a dose of $N_{100}P_{120}$ (Poliakov et al., 2016). Studies by Tomashova et al. (2012) found that in the Crimea, the highest yield of white mustard seeds – 2.03 t/ha – was obtained by sowing in the «February windows», against the background of fertilizer application in the autumn at a dose of $N_{60}P_{60}$.

Numerous studies on the effectiveness of mineral fertilizers for growing mustard seeds, conducted in different soil and climatic conditions of Ukraine, have shown their high efficiency both in small doses and in large doses. However, all studies were conducted with mineral fertilizers as the main fertilizer in combination with sowing dates and methods of basic tillage, mainly with one or two varieties. Therefore, the task of our research was to establish the patterns of yield formation and seed quality of five varieties of white and black mustard of different origin when phosphorus-potassium fertilizers were applied as the main fertilizer, and once and twice foliar fertilization with nitrogen fertilizers.

One of the main tasks that all agrotechnological measures for growing mustard seeds should be aimed at is the creation of favorable conditions for the growth and development of crop plants.

The aim of the study was to identify the peculiarities of

formation of yield and quality of mustard seeds depending on the use of mineral fertilizers.

Material and Methods

The study of the effectiveness of mineral fertilizers for the cultivation of mustard seeds was carried out at the experimental field of Pavlo Tychyna Uman State Pedagogical University of the Ministry of Education and Science of Ukraine during 2020–2023, which is located in the zone of unstable moisture of the Right-Bank Forest-Steppe of Ukraine. The effect of mineral fertilizers on the seed productivity of four varieties of white mustard – Etalon, Pidpecherecka, Ariadna and Oslava – and one variety of black mustard Tsarivna Pivnochi was studied.

The experimental design included 4 variants: 1) a control – no mineral fertilizer, 2) basic fertilization, with phosphorus-potassium fertilizer at a dose of $P_{45}K_{45}$ without fertilization, and 3) with a single fertilization with nitrogen fertilizer at a dose of N_{15} after germination, as well as 4) basic fertilization at a dose of $P_{45}K_{45}$, with two fertilizations with nitrogen fertilizer at a dose of N_{15} after germination, and one fertilization with nitrogen fertilizer at a dose of N_{30} during the rosette-stemming stage. Sowing was carried out using a conventional line method, with a seeding rate of 2 million seeds per ha.

Biometric parameters that affect seed yield (seed yield structure) – plant height, number of stems and pods per plant were determined according to the Methodology for variety testing of agricultural crops (Volkodav, 2000). Seed yield was determined by weighing the plots from each replication. Seed yield was determined in quadruplicate. Average seed sampling and seed quality – germination energy, germination rate and weight of 1000 seeds, were taken according to DSTU (National standard of Ukraine, 2002).

The reliability of the experimental data was assessed by the calculation-comparative method, using the analysis of variance according to the Fisher method (Fisher, 2006) and guidelines (Ehrmantraut et al., 2007).

The weather conditions during the years of research were close to the average long-term temperature regime, and differed in terms of moisture supply. The growing seasons of 2020, 2022, and 2023 were characterized by moisture deficits, and only in 2021 was there a slight waterlogging.

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 (according to the Chirikov method), and potassium is 80–130 mg/kg – average availability.

Results and Discussion

It is known that mustard requires primary, secondary and trace elements in sufficient quantities to increase yields (Jha et al., 2023). Wang et al. (2019) concluded that long-term balanced application of N, P and K significantly increased crop yields, and led to stable productivity of agricultural land. Traditionally, farmers prefer to increase nitrogen fertilizer application as it improves soil fertility and increases crop productivity (Nkoi et al., 2021; Zhang et al., 2022). Studies by Jankowski et al. (2020), have shown that nitrogen application at a rate of up to 80 kg/ha increased yields to 1.57 Mg ha⁻¹, and increased the weight of 1000 seeds to 8.12 g.

Our research has shown that the use of mineral fertilizers has increased the yield structure of all varieties compared to the control without fertilizers. The increase in yield structure indicators contributed to an increase in the seed productivity of mustard. On average, the seed yield of the varieties significantly increased with the introduction of mineral fertilizers compared to the control without fertilizers (Table 1).

The largest increase in yield was provided by the complex application of phosphorus-potassium fertilizers, with two foliar fertilizations with nitrogen fertilizers on the seedlings and in the rosette-stemming phase, which was 0.56 t/ha compared to the control. The application of only phosphorus-potassium fertilizers in the main fertilizer, and in the main fertilizer with a single nitrogen fertilization, also provided a significant increase in the yield of mustard seeds compared to the control, but its level was significantly lower than with two fertilization against the background of the main fertilizer.

As for the quality of seeds – germination energy and germination rate, the use of mineral fertilizers did not provide a significant increase in these indicators, they were at the level of control. At the same time, the weight of 1000 seeds on average for the varieties significantly increased, with a single foliar application against the background of the main fertilizer by 0.25 g, and twice – by 0.33 g, compared to the

control. When applying only the main fertilizer, a significant increase in the weight of 1000 seeds was not detected, only a tendency to increase it was observed.

Voloshchuk's research has shown that when applying mineral fertilizers at the rate of N₃₀P₃₀K₃₅ and additional fertilization, with ammonium nitrate at the rate of N₃₀ in the rosette stage, the yield of white mustard of the White Princess variety increased by 2.11 t/ha, and with an increase in the rate of phosphorus-potassium fertilisers N₃₀P₆₀K₇₀ and fertilization with N₄₀ in the rosette stage + N₂₀ in the bud stage, the yield of the variety increased by 2.70 t/ha, compared to the control without fertilizer application (Voloshchuk, 2024).

These results are consistent with the results of our research. It has been determined that the use of mineral fertilizers in the main and foliar feeding provided a significant increase in seed yield compared to the control. Significantly higher yields from 1.64 t/ha (Tsarivna Pivnochki) to 1.78 t/ha (Oslava) were obtained with the combined application of phosphorus-potassium fertilizers, at the rate of P₄₅K₄₅ in the main fertilizer together, with two foliar fertilization with nitrogen fertilizers, on the seedlings at the rate of N₁₅, and in the rosette-stem stage at the rate of N₃₀ compared to the control and other varieties (Table 2).

The introduction of phosphorus-potassium fertilizers in the main fertilizer provided a significant increase in the yield of mustard seeds of all varieties, which ranged from 0.14 t/ha (Tsarivna Pivnochki) to 0.27 t/ha (Oslava) compared to the control. With the main fertilization and foliar feeding with nitrogen fertilizers, the seed yield increased significantly both in comparison with the control, and with the introduction of phosphorus-potassium fertilizers into the main fertilization of all varieties. It is worth noting that the smallest increase in seed yield was observed with the main fertilizer, and the largest increase was observed with the combined application of phosphorus-potassium fertilizer and two foliar feeding. With the main fertilizer alone, the highest yield increase was observed for Etalon (0.26 t/ha), Oslava (0.27 t/ha) and

Table 1. Seed productivity of mustard depending on fertilizer application (average of five varieties in 2020–2023)

Variant	Seed yield, t/ha	Germination energy, %	Germination rate, %	Weight of 1000 seeds, g
No fertilizer – control	1.17	96	96	4.15
P ₄₅ K ₄₅ in the main without fertilization	1.49	95	96	4.18
P ₄₅ K ₄₅ in the main + fertilization with N ₁₅ on the seedlings	1.69	97	97	4.40
P ₄₅ K ₄₅ in the main + two fertilizers N ₁₅ along the seedlings + N ₃₀ in the rosette-stem phase	1.73	96	96	4.48
LSD ₀₅	0.02	1.6	1.6	0.13

Source: Authors' own elaboration

Table 2. Mustard seed yield depending on varietal characteristics and fertilizer application (average for 2020–2023)

Variant		Yield	
variety	Fertilizer application	t/ha	± to controls
Etalon	Fertiliser – free control	1.21	–
	P ₄₅ K ₄₅ mainly without fertilisation	1.47	0.26
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	1.69	0.48
	P ₄₅ K ₄₅ in the main + two fertilisers N ₁₅ in the germination + N ₃₀ in the rosette-stem phase	1.73	0.52
Tsarivna Pivnochi	Fertiliser – free control	1.18	–
	P ₄₅ K ₄₅ mainly without fertilisation	1.32	0.14
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	1.59	0.41
	P ₄₅ K ₄₅ in the main + two fertilisers N ₁₅ in the germination + N ₃₀ in the rosette-stem phase	1.64	0.46
Pidpecheretska	Fertiliser – free control	1.36	–
	P ₄₅ K ₄₅ mainly without fertilisation	1.54	0.18
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	1.71	0.35
	P ₄₅ K ₄₅ in the main + two fertilisers N ₁₅ in the germination + N ₃₀ in the rosette-stem phase	1.73	0.37
Ariadna	Fertiliser – free control	1.30	–
	P ₄₅ K ₄₅ mainly without fertilisation	1.50	0,20
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	1.73	0,43
	P ₄₅ K ₄₅ in the main + two fertilisers N ₁₅ in the germination + N ₃₀ in the rosette-stem phase	1.77	0.47
Oslava	Fertiliser – free control	1.35	–
	P ₄₅ K ₄₅ mainly without fertilisation	1.62	0.27
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	1.74	0.39
	P ₄₅ K ₄₅ in the main + two fertilizers N ₁₅ in the germination + N ₃₀ in the rosette-stem phase	1.78	0.43
LSD ₀₅ general		0.04	
LSD ₀₅ grade		0.02	
LSD ₀₅ fertilisers		0.02	

Source: Authors' own elaboration

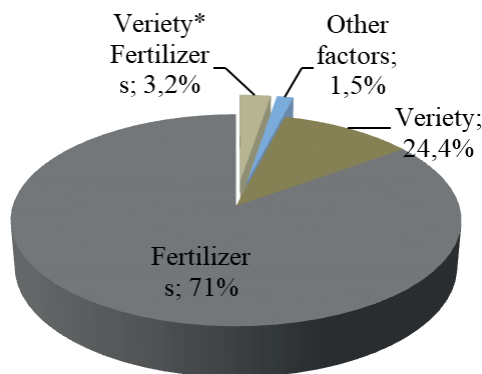


Fig. 1. Influence of factors on seed yield depending on varietal characteristics and fertilization (average for 2020–2023)

Source: Authors' own elaboration

Ariadna (0.20 t/ha), which indicates a high response of these varieties to mineral fertilization.

The analysis of factors showed that the greatest influence on seed yield was the “fertilizer” factor, which accounted for 85.1%, while the influence of the “variety” factor was much lower (Figure 1).

A significant increase or decrease in seed quality indicators of germination energy and germination rate depending on fertilizer application was not found in all varieties. These indicators were at the control level (Table 3).

The weight of 1000 seeds varied depending on both varietal characteristics and the use of mineral fertilizers. The highest weight of 1000 seeds (more than 4 g) was in the varieties Tsarivna Pivnochi, Pidpecheretskaya, and Oslava.

The analysis of factors showed that the greatest influence on germination energy and seed germination was the factor

Table 3. Quality of mustard seeds depending on varietal characteristics and fertilizer application (average for 2020–2023)

Variant		Germination energy, %	Similarity, %	Weight of 1000 seeds, g
variety	fertiliser application			
Etalon	Fertiliser-free control	94	95	3.17
	P ₄₅ K ₄₅ mainly without fertilisation	92	93	3.33
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	97	97	3.79
	P ₄₅ K ₄₅ in the main + two top dressings N ₁₅ along the seedlings + N ₃₀ in the rosette-stem phase	95	95	3.83
Tsarivna Pivnochi	Fertiliser-free control	97	97	4.53
	P ₄₅ K ₄₅ mainly without fertilisation	97	98	4.65
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	98	98	4.76
	P ₄₅ K ₄₅ in the main + two top dressings N ₁₅ along the seedlings + N ₃₀ in the rosette-stem phase	97	98	4.72
Pidpecheretska	Fertiliser-free control	97	98	4.81
	P ₄₅ K ₄₅ mainly without fertilisation	95	96	4.58
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	94	95	4.81
	P ₄₅ K ₄₅ in the main + two top dressings N ₁₅ along the seedlings + N ₃₀ in the rosette-stem phase	96	96	4.89
Ariadna	Fertiliser-free control	96	95	3.52
	P ₄₅ K ₄₅ mainly without fertilisation	96	96	3.67
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	97	97	3.81
	P ₄₅ K ₄₅ in the main + two top dressings N ₁₅ along the seedlings + N ₃₀ in the rosette-stem phase	97	97	3.99
Oslava	Fertiliser-free control	96	96	4.74
	P ₄₅ K ₄₅ mainly without fertilisation	97	97	4.67
	P ₄₅ K ₄₅ in the main + top dressing N ₁₅ on the shoots	96	97	4.84
	P ₄₅ K ₄₅ in the main + two top dressings N ₁₅ along the seedlings + N ₃₀ in the rosette-stem phase	95	96	4.96
LSD ₀₅ general		1.4	1.3	0.28
LSD ₀₅ grade		1.7	1.7	0.14
LSD ₀₅ fertilisers		1.6	1.6	0.13

Source: Authors' own elaboration

“variety”, which was 38.8% and 36.1%, respectively, and the interaction of factors “variety*fertilizer”, the influence of the factor “fertilizer” was much lower (Figure 2).

The greatest influence on the weight of 1000 seeds was the influence of the «variety» factor, the influence of other factors was not significant.

Conclusions

Thus, it has been determined that using of mineral fertilizers in the main and foliar feeding, significantly increased

seed yield compared to the control. With the combined application of phosphorus-potassium fertilizers, at the rate of P₄₅K₄₅ in the main fertilization with two foliar fertilization, with nitrogen fertilizers, on the seedlings at the rate of N₁₅, and in the rosette-stem stage at the rate of N₃₀, the yield of Tsarina Severa and Oslava varieties was 0.46 and 0.43 t/ha higher than in the control.

Therefore, in order to increase the yield of mustard seeds when grown in the Right-Bank Forest-Steppe, it is advisable to apply P₄₅K₄₅ as the main fertilizer, and to carry out two fertilization with nitrogen fertilizers at a rate of N₁₅, and in

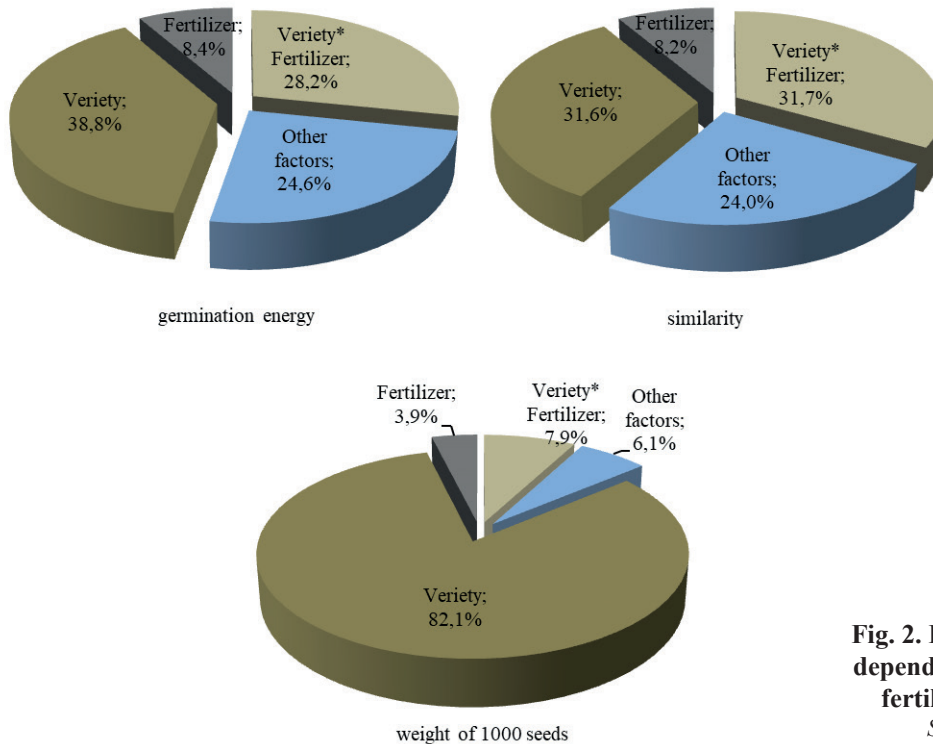


Fig. 2. Influence of factors on seed quality depending on varietal characteristics and fertilization (average for 2020–2023)

Source: Authors' own elaboration

the rosette-stemming stage at a rate of N_{30} , which ensures high seed productivity of mustard.

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Received: November, 21, 2024; Approved: January, 31, 2025; Published: April, 2026