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YIELD AND GRAIN QUALITY OF PROSO MILLET AS INFLUENCED BY MINERAL NUTRITION AND SOWING TIME

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Анотація: Строки сівби та система удобрення є ключовими чинниками формування врожайності та якості зерна проса. В умовах нестійкого зволоження Правобережного Лісостепу України ці питання залишаються недостатньо вивченими. Метою дослідження було встановити вплив строків сівби та доз азотних добрив на продуктивність і якість зерна проса. Дослідження проводили у короткотривалому польовому досліді з використанням аналітичних методів. Встановлено, що підвищене азотне живлення та більш ранні строки сівби є визначальними чинниками формування врожаю і якості зерна. Найвищу врожайність зерна (4,03 т/га) отримано за сівби проса у другій декаді квітня на фоні внесення $N_{80}P_{30}K_{30}$ із триразовим застосуванням азоту ($N_{30}P_{30}K_{30}$ під оранку, N_{30} у передпосівну культивацію та N_{20} позакоренево у фазі кінець кущення), що перевищувало контроль без добрив на 1,29 т/га. За сівби у третій декаді квітня за аналогічної системи удобрення врожайність була меншою на 0,42 т/га. Інтенсивне азотне удобрення сумарною дозою 80 кг/га у поєднанні з ранніми строками сівби забезпечило найвищу якість зерна – вміст білка становив 12,8 %, що на 1,4 % більше порівняно з контролем і на 0,4 % більше порівняно з пізнішими строками сівби.

Ключові слова: просо, азот, дози, врожайність, зерно, білок.

Introduction. Millet is an important cereal crop characterized by good palatability, and in terms of the nutritional properties of its grain, it ranks among the leading groat crops. The sown area of millet in Ukraine in 2025 amounted to 85.5 thousand hectares, which is 23 % higher than in 2024. An important feature of millet is its high drought tolerance, making it an indispensable crop in modern agricultural production, which is significantly affected by climate warming.

Achieving high millet yields depends on preceding crops, sowing dates, and fertilizer application. With climate warming, millet is increasingly sown at earlier dates, which allows plants to conserve and more efficiently utilize soil moisture. However, the application of mineral fertilizers has a more pronounced effect on millet grain yield and quality. Optimization of fertilizer composition in terms of nutrient elements, as well as the selection of effective forms and timing of nitrogen fertilizer application, are key factors in improving both yield and grain quality. Spring application of nitrogen fertilizers against the background of autumn phosphorus and

potassium fertilization or complete mineral fertilization significantly increases millet yield. The application of nitrogen fertilizers during pre-sowing cultivation and foliar feeding with urea at the end of the tillering stage are also effective practices for enhancing productivity. These methods substantially improve both yield and grain quality of millet.

Under conditions of unstable moisture supply in the Forest-Steppe zone, the issues of sowing dates and fertilization of millet remain insufficiently studied, which determined the relevance of this research.

The *aim of the study* was to investigate the effect of sowing dates and nitrogen fertilizer rates on the yield and grain quality of millet.

Materials and Methods. The research was conducted at Uman National University during 2023–2025 in a temporary field experiment. The total plot area was 50 m², and the accounting (harvested) area was 25 m². The experimental treatments were arranged in a systematic sequential design with four replications.

The soil was podzolized heavy loam chernozem. The 0–30 cm arable soil layer had pH (KCl) 5.9, humus content (according to Tyurin) of 3.5 %, and available phosphorus and potassium (according to Chirikov) of 102 and 136 mg/kg of soil, respectively.

The millet variety ‘Chabanivske’ (originator – NSC “Institute of Agriculture” of NAAS) was used in the experiment. The variety is undemanding to soil conditions, has a vegetation period of 80–90 days, and is resistant to drought, lodging, and diseases. The cultivation practices were conventional for the Forest-Steppe zone of Ukraine. Soybean was the preceding crop.

The experiment studied two sowing dates (the second and third decades of April) and different rates of nitrogen fertilizers within a complete mineral nutrition system. Complete mineral fertilizer (nitroammophoska, NPK 16 : 16 : 16) was applied in autumn under plowing. Nitrogen in the form of ammonium nitrate (34.5 % N) was applied in spring during pre-sowing cultivation, while urea (46 % N) was applied as foliar feeding at the end of the tillering stage.

Millet yield was determined using sample sheaves with recalculation per hectare. Grain protein content was measured by infrared spectroscopy according to DSTU 4117:2007.

The research results were processed using analysis of variance (ANOVA) and the Statistica 2010 software package.

The years of study differed in weather conditions. Thus, 2023 and 2025 were sufficiently supplied with moisture, with the Selyaninov hydrothermal coefficient (HTC) during the growing season of 1.89 and 1.34, respectively. In both years, July was extremely dry (HTC 0.27 and 0.19), while the remaining months were sufficiently or excessively moist. The year 2024 was moderately dry, with an HTC of 0.88 during the growing season. Severe drought was observed in July (HTC = 0.25), whereas other months had favorable weather conditions with HTC values ranging from 0.90 to 1.44.

Results. Based on three-year studies (2023–2025), it was established that millet cultivation under the conditions of the Right-Bank Forest-Steppe on podzolized chernozem was associated with obtaining moderate grain yields. When millet was sown in the second decade of April without fertilizer application, the average grain

yield over 2023–2025 amounted to 2.74 t/ha. In 2024, the lowest grain yield was recorded (2.33 t/ha), while in 2023 it was the highest (3.32 t/ha). Millet responded positively to adequate moisture supply during the growing season. In 2023, when moisture conditions were the most favorable, the yield exceeded the three-year average by 0.58 t/ha.

Later sowing dates were less productive. When millet was sown in the third decade of April, the grain yield in the unfertilized control was 2.45 t/ha, which was 0.29 t/ha lower compared to sowing in the second decade of April. This can likely be explained by the drying of the topsoil layer, which is often observed during this period and may have reduced moisture availability for plants, slowed their growth and development at the early stages of vegetation, and consequently led to lower yields.

The application of mineral fertilizers significantly increased millet yield. When nitroammophoska was applied under plowing at a rate of $N_{30}P_{30}K_{30}$, the yield increased compared to the unfertilized control by 0.55 t/ha for sowing in the second decade of April and by 0.59 t/ha for sowing in the third decade, with yields of 3.29 and 3.04 t/ha, respectively. Millet sown at the earlier date produced a higher grain yield by 0.25 t/ha.

The application of ammonium nitrate at a rate of 30 kg/ha during pre-sowing cultivation, combined with autumn application of nitroammophoska, resulted in a further increase in millet yield. This fertilization system provided grain yields of 3.73 t/ha for sowing in the second decade of April and 3.36 t/ha for sowing in the third decade, exceeding the unfertilized control by 0.99 and 0.91 t/ha, respectively. At the same time, sowing in the second decade of April resulted in a 0.37 t/ha higher yield.

The highest millet grain yield was obtained with triple nitrogen application: nitroammophoska at $N_{30}P_{30}K_{30}$ applied under plowing, 30 kg/ha of ammonium nitrate during pre-sowing cultivation, and 20 kg/ha of urea applied foliarly at the end of the tillering stage. Under these conditions, grain yield reached 4.03 t/ha for sowing in the second decade of April and 3.61 t/ha for sowing in the third decade, exceeding the unfertilized control by 1.29 and 1.16 t/ha, respectively. The earlier sowing date ensured an additional yield increase of 0.42 t/ha.

A strong correlation between nitrogen fertilizer rates and millet grain yield was established: for sowing in the second decade of April, the coefficient of determination was $R^2 = 0.997$, and for sowing in the third decade of April, $R^2 = 0.979$.

Thus, sowing millet in the second decade of April combined with intensive nitrogen fertilization ensured the highest grain yield.

Grain quality is an important indicator in millet cultivation, with protein content being its most reliable measure. On average, over 2023–2025, when millet was sown in the second decade of April without fertilizer application, the grain protein content was 11.4 %. The lowest protein content was recorded in 2023 (10.6 %), while the highest was observed in 2024 (12.5 %).

Later sowing dates were accompanied by a slight decrease in grain protein content. When sown in the third decade of April, the protein content in the unfertilized control was 11.2 %, which was 0.2 % lower compared to sowing in the second decade of April.

The application of fertilizers significantly improved millet grain quality. When nitroammophoska was applied under plowing at a rate of $N_{30}P_{30}K_{30}$, the protein content

increased compared to the unfertilized control by 0.7 % for sowing in the second decade of April and by 0.6 % for sowing in the third decade, reaching absolute values of 12.1 % and 11.8 %, respectively. Millet sown at the earlier date had a higher protein content by 0.3 %.

The application of ammonium nitrate at a rate of 30 kg/ha during pre-sowing cultivation, combined with autumn fertilization with nitroammophoska, further improved grain quality. This fertilization system resulted in protein contents of 12.5 % for sowing in the second decade of April and 12.3 % for sowing in the third decade, exceeding the unfertilized control by 1.1 % for both sowing dates. At the same time, sowing in the second decade of April increased protein content by 0.2 % compared to the third decade.

The highest protein content in millet grain was obtained under triple nitrogen application: nitroammophoska ($N_{30}P_{30}K_{30}$) applied under plowing, 30 kg/ha of ammonium nitrate during pre-sowing cultivation, and 20 kg/ha of urea applied foliarly at the end of the tillering stage. Under these conditions, protein content reached 12.8 % for sowing in the second decade of April and 12.4 % for sowing in the third decade, exceeding the unfertilized control by 1.4 % and 1.2 %, respectively. The earlier sowing date provided an additional increase of 0.4 %.

Thus, the application of fertilizers with triple nitrogen input at a total rate of 80 kg/ha combined with sowing in the second decade of April ensured the highest grain quality, with a protein content of 12.8 %.

Conclusions.

Under conditions of unstable moisture on podzolized chernozem, millet yield depended on sowing dates and fertilization. The highest grain yield (4.03 t/ha) was obtained when millet was sown in the second decade of April with the application of $N_{80}P_{30}K_{30}$ under triple nitrogen fertilization, exceeding the unfertilized control by 1.29 t/ha. Sowing in the third decade of April resulted in a yield decrease of 0.42 t/ha.

Intensive nitrogen fertilization at a total rate of 80 kg/ha combined with sowing in the second decade of April ensured the highest grain quality, with a protein content of 12.8 %, which was 1.4 % higher than in the unfertilized control and 0.4 % higher compared to sowing in the third decade of April.

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Abstract: Sowing dates and fertilization systems are key factors influencing millet yield and grain quality. Under conditions of unstable moisture in the Right-Bank Forest-Steppe of Ukraine, these issues remain insufficiently studied. The aim of the study was to determine the effect of sowing dates and nitrogen fertilizer rates on millet productivity and grain quality. The research was conducted in a short-term field experiment using analytical methods. The results showed that enhanced nitrogen nutrition and earlier sowing dates were the main factors determining yield formation and grain quality. The highest grain yield (4.03 t/ha) was obtained when millet was sown in the second decade of April with the application of $N_{80}P_{30}K_{30}$ and triple nitrogen fertilization ($N_{30}P_{30}K_{30}$ under plowing, N_{30} during pre-sowing cultivation, and N_{20} applied foliarly at the end of the tillering stage), exceeding the unfertilized control by 1.29 t/ha. Sowing in the third decade of April under the same fertilization system resulted in a lower yield by 0.42 t/ha. Intensive nitrogen fertilization at a total rate of 80 kg/ha combined with earlier sowing ensured the highest grain quality, with protein content reaching 12.8 %, which was 1.4 % higher than in the control and 0.4 % higher compared to later sowing.

Keywords: millet, nitrogen, rates, yield, grain, protein.