

EFFICIENCY OF GROWING MAIZE FOR GRAIN DEPENDING ON THE METHODS OF PRIMARY TILLAGE

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Topicality. Climate change and food security necessitate the constant need for efficient use of agrochemical and material resources to increase the productivity of agrophytocenoses. To increase the yield of maize, which plays an important role in global food production, and given the economic crisis caused by the war, it is necessary to apply energy-saving tillage methods. **Purpose.** Our study was aimed to determine the impact of different tillage methods on maize productivity and economic efficiency. **Materials and Methods.** The research was conducted at the Dokuchaievsk Experimental Field Training and Research and Production Centre of the State Biotechnological University, namely at the experimental field of the Department of Agriculture and Herbology named after O. M. Mozheiko, which located in the Left Bank Forest-Steppe of Ukraine. Research methods: field trials used to study the methods of primary tillage and determine the grain yield of maize; calculation and comparison method used to assess the economic efficiency of tillage. **Results.** It was found that the grain yield of maize decreased by 0.28 t/ha due to moldboardless tillage with PRN-31000, local chisel tillage with PCh-2.5 – by 0.50 t/ha, and disking with BDM-2.5 – by 0.63 t/ha, compared to ploughing with PLN-4-35. The highest maize productivity was in the control variant, where the yield of feed units and feed protein units was 8.71 and 7.04 t/ha, respectively. When ploughing with PLN-4-35 tool at a depth of 25–27 cm, the highest economic efficiency was achieved at a net profit of 3,650 thousand UAH/ha and a profitability level of 13.8 %. **Conclusions.** Soil tillage plays a key role in creating the conditions for the maize growth and development, which directly affects the economic and energy efficiency of its cultivation. In the conditions of the Left-Bank Forest-Steppe of Ukraine, the conventional soil tillage with PLN-4-35 at a depth of 25–27 cm is required to obtain high yields and productivity of maize. As an alternative to ploughing, moldboardless tillage with the PRN-31000 at a depth of 33–35 cm can be used.

Key words: maize, economic efficiency, productivity, yield

Introduction. Maize is a multipurpose high-yielding crop. Its production volumes in Ukraine exceed domestic needs, so most of this crop is exported [1]. For example, Ukraine produces 31 million tonnes of maize, but according to USDA forecasts [2], this volume may decline to 27 million tonnes in 2024–2025. In general, the area under maize was 4,113,000 ha in 2023, and the yield achieved 7.8 t/ha [3; 4].

The dynamics of maize cultivation in Ukraine is closely related to many social and economic activities: global food security, income and social security, as well as insurance of harvest, etc. In order for maize cultivation to have a sufficiently high economic effect, with a profitability level of 110.9–165.2 %, the crop should be grown on well-aggregated soil with sufficient nutrients, moisture, etc. However, it should be borne in mind that in Ukraine, between 300–400 and 500–600 million tonnes of soil are annually destroyed by erosion, and up to 10–15 million tonnes of humus, 0.3–0.9 million

tonnes of nitrogen, 700,000–900,000 tonnes of phosphorus and 6–12 million tonnes of potassium are removed. Crop yields on such soils tend to be 20–60 % lower than on non-eroded soils. Losses from erosion exceed 9–12 million tonnes of grain units, and environmental and economic losses amount to USD 10 billion [5–8].

In the system of technological methods aimed at increasing the realisation of the productive potential of agricultural crops, including maize, soil cultivation technology plays a significant role [9, 10]. In particular, conventional tillage can reduce soil erosion, labour and fuel costs [11]. Natural and climatic conditions and the financial capacity of the farm are also considered [12]. Thus, in the Forest-Steppe region, moldboardless tillage is preferred since it improves soil resistance to erosion. However, the effectiveness of moldboardless tillage for maize is observed only in the first year, and ploughing is already preferred in the following years.

Today, classical plough tillage is not used

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anywhere, and more attention is paid to differentiated tillage in crop rotations, including ploughing, disking, subsurface tillage and chiselling [13]. The development of agriculture is impossible without modern machinery and the transition to more efficient resource-saving soil cultivation technologies [14, 15], given that this also affects the economic efficiency of production [16–18].

The purpose of the study was to determine the economic effectiveness of different methods of primary tillage and their impact on the yields of maize for grain.

Materials and Methods. The research was carried out at the Dokuchaevske Experimental Field Training and Research and Production Centre of the State Biotechnology University in 2021–2023. The soil cover of the experimental field was typical heavy loamy chernozem on loess loam [19]. The 0–30 cm soil layer contains 4.9–5.1 % humus, 81 mg/kg of soil – easily hydrolysed nitrogen (according to Kornfield), mobile forms of phosphorus and exchangeable potassium (according to Chirikov) – 100 and 200 mg/kg of soil. The content of exchangeable calcium cations is 37.8 %, magnesium – 6.6 %, sodium – 0.49 %, potassium – 0.5 %. Soil reaction: pH_{water} – 7.0, pH_{salt} – 5.2–5.6. Groundwater is located at a depth of about 18 m [20].

The mid-early hybrid DB Khotyn (FAO 280), developed by SE Institute of Grain Crops of NAAS, was used for the experiment. This hybrid was included in the State Register of Plant Varieties of Ukraine in 2013 and recommended for cultivation in all soil and

climatic zones.

The research was conducted on the third field of a five-field crop rotation with the following crop rotation: clean fallow – winter wheat – safflower, maize – winter rye – sunflower.

The experiment included the following variants of primary tillage: 1) ploughing with PLN-4-35 at a depth of 25–27 cm (control); 2) chisel local tillage with PCh-2.5 at a depth of 33–35 cm; 3) moldboardless ploughing with PRN-31000 at a depth of 33–35 cm; 4) disking with BDM-2.5 at a depth of 10–12 cm.

The experiment was repeated three times, and variants were arranged sequentially. The size of the experimental plot was 150 m², and the registration plot was 50 m². Research methods included field, calculation and comparison.

The maize yield was calculated at each plot of the experiment in terms of grain moisture content of 14 %. The economic effectiveness was calculated using technological maps and prices as of December 2023.

Results and Discussions. In 2021–2023, all methods of tillage were inferior to ploughing in terms of their effect on maize grain yield. The moldboardless tillage with PRN-31000 (at a depth of 33–35 cm) resulted in a 0.28 t/ha decrease in yield compared to ploughing, and the local chiseling with the PCh-2.5 at a depth of 33–35 cm decreased by 0.50 t/ha. A significant decrease in yield was observed in the variant of disking with BDM-2.5 (at a depth of 10–12 cm), where the difference with the control was 0.63 t/ha (Table 1).

Table 1. Productivity of maize for grain depending on the primary tillage method, 2021–2023

Methods of tillage	Grain yield, t/ha	Yield per 1 ha, t		
		feed units	digestible protein	feed protein units
Ploughing with PLN-4-35 at 25–27 cm (control)	6.70	8.71	0.54	7.04
Local chiselling with PCh-2.5 at 33–35 cm	6.20	8.06	0.50	6.51
Moldboardless tillage with PRN-31000 at 33–35 cm	6.42	8.34	0.51	6.74
Disking BDM-2.5 at 10–12 cm	6.07	7.89	0.49	6.37
LSD ₀₅	0.10–0.22			

According to S. V. Filonenko [13], a decrease in maize grain yield was also found after

minimal tillage at a depth of 14–16 cm. However, the highest yield of 10.5 t/ha in his experiment

was obtained after chiselling to a depth of 37–40 cm, which exceeded the value after ploughing by 0.90 t/ha.

Ploughing with PLN-4-35 to a depth of 25–27 cm had a significant advantage over other variants of tillage in terms of the impact on maize productivity. Thus, this variant produced the following product yield per 1 ha: 8.71 t of feed units, 0.54 t of digestible protein and 7.04 t of feed protein units. It is worth noting that the yield of digestible protein was almost equivalent for the variants of primary tillage. This indicator varied between 0.49 and 0.54 t, with a decrease when disking with BDM-2.5 to a depth of 10–12 cm. Chiselling and moldboardless tillage ensured the yield of feed units per 1 ha equalled almost 8.06 and 8.34 t. Disking with BDM-2.5 to a depth of 10–12 cm reduced the yield of feed by 0.82 t from the control.

Control variant had a comparative advantage in the yield of feed protein units (7.04 t). It was found that chiselling and disking significantly reduced the yield of feed protein units. The difference between these variants was insignificant, but chiselling with PCh-2.5 tool at a depth of 33–35 cm had an advantage as to the obtained values – 6.51 t of feed protein units. Studies by A. O. Butenko et al. [21] also indicate the advantage of ploughing in the formation of silage yield and maize productivity. Thus, moldboard tillage with PN-3-35 tool to a depth of 22–25 cm compared to shallow moldboardless tillage contributed to the highest feed units, digestible protein and feed protein units (22.2, 3.37, 27.6 t/ha, respectively).

The assessment of the methods of primary tillage shows a significant impact of these agricultural practices on basic economic indicators. M. S. Shevchenko et al. [8] argue that the main factor in assessing the efficiency is the cost of fuel and mineral fertilisers, which account for up to 60 % of energy costs. However, the level of grain yields and the energy potential of grain remains a decisive factor in energy effectiveness.

The economic efficiency of maize cultivation depends on a complex of natural, economic, technological, scientific and technical, and other factors [22]. For example, high production costs for deep ploughing reduce the self-cost and profitability of production. These data are confirmed by B. A. Ternovyi and V. M. Zubko [23], whose experiments showed that on the cultiva-

ted area of 196 ha, fuel costs for deep loosening were 4,704 litres. The cost of such cultivation, excluding the wear and tear of machinery and equipment, was 136,416 UAH. Scientists point out [24] that minimising tillage in maize cultivation significantly reduces the cost of fuel and energy resources, in particular, with chisel tillage by 8.3 l/ha and subsurface tillage by 13.8–14.8 l/ha, while profits increase by 127–132 and 161–279 UAH/t, respectively, and production profitability by 6–13 %. There is also evidence that these tillage methods save, in particular, fuel and energy resources: with chisel tillage – 7.0–8.3 l/ha, subsurface tillage – 17.4–22.1, disking – 15.7–17.6 l/ha, which had a positive effect on increasing the net operating profit and the profitability of grain production to 81.3–121.0 %.

In our studies, the economic efficiency of growing maize for grain, depending on the methods of primary tillage, was determined on the basis of technological maps, considering costs of labour, seeds, plant protection products and fertilisers, as well as the products obtained. The calculations were made according to the purchase prices set at December 2023. The calculations show that fuel costs differed between the research variants, given the depth of tillage and maize yield. The highest fuel costs were 25 l/ha for maize cultivation in the variant with ploughing to a depth of 25–27 cm (Table 2).

Despite the rather high costs of ploughing compared to other variants of tillage, this method was the most economically profitable, in particular, the highest value of net operating profit was 3,650 UAH/ha. The use of moldboardless tillage to a depth of 33–35 cm brought this indicator closer to the control with a difference of 1,000 UAH. S.V. Taranenko et al. [25] also proved the expediency of ploughing, as shown by 125 % profitability and net income per 1 ha, which is 3,480 and 6,920 UAH higher compared to the subsurface tillage and surface tillage. Such results were obtained by M. S. Shevchenko et al. [8], who found that the replacement of deep moldboard tillage with soil protection moldboardless tillage reduces production costs from 1,022 to 681 UAH/ha.

Disking to a depth of 10–12 cm was the least expensive agrotechnological operation.

Thus, the fuel and cost consumption was only 12 l/ha and 645.6 UAH/ha, respectively,

Table 2. Economic efficiency of growing maize for grain depending on the method of primary tillage, 2021–2023

Methods of tillage	Grain yield, t/ha	Fuel consumption for tillage, l/ha	Costs of tillage, UAH/ha	Profit, UAH/ha	Profitability, %
Ploughing with PLN-4-35 at 25–27 cm (control)	6.70	25	1340.0	3650.0	13.8
Local chiselling with PCh-2.5 at 33–35 cm	6.20	17	1055.0	1800.0	6.9
Moldboardless tillage with PRN-31000 at 33–35 cm	6.42	21	1248.0	2650.0	10.1
Disking BDM-2.5 at 10–12 cm	6.07	12	645.6	1615.0	6.3

but such low indicators did not give a high economic benefit. Disking and local chiselling created the worst conditions for maize growth and development. Low yields on these variants did not provide for high profits, so the profitability level was the lowest 6.3 i 6.9 %, respectively. Similar results were obtained by M. S. Shevchenko et al. [8], which showed that minimising tillage also led to a reduction in production costs, but there was no economic effect. The positive impact of ploughing on the yield of crops in the crop rotation resulted in the highest profitability of production (20.7–245.2 %). However, calculations by O. I. Tsiliuryk [26] show that minimised tillage during maize cultivation allows to significantly reduce the consumption of fuel and energy resources compared to chiselling by 8.3 l/ha, and to subsurface tillage by 14.8 l/ha, with increasing profitability by 9.0–12.6 %. Analogous results were obtained in the studies of A. O. Butenko et al. [21], who found that the moldboard tillage in maize cultivation provided a net profit of up to 1,950 UAH/ha and a maximum level of profitability of 44.1 %. However, a number of authors, such as N. Didenko et al. [12] note that ploughing in

maize cultivation, compared to modern technologies, is significantly inferior in terms of profitability and profit received.

Conclusions

It was found that ploughing in the cultivation of maize for grain provides the highest economic efficiency in the conditions of the Left-Bank Forest-Steppe of Ukraine. Ploughing with PLN-4-35 (25–27 cm) provided the best conditions for obtaining high maize productivity, with a grain yield of 6.70 t/ha and a feed protein yield of 7.04 t/ha. According to these indicators, the moldboardless tillage with PRN-3100 (33–35 cm) was the closest to the control. The lowest productivity of maize was in the variant with disc cultivation BDM-2.5 (10–12 cm). Under the conditions of unbalanced economic relations and risky agricultural production during the period of military operations, the variant with ploughing yielded a low, but the highest net operating profit among all tillage methods of 3,650,000 UAH/ha and a profitability level of 13.8 %. The profitability of maize cultivation in other variants was 6.3–10.1 %, with the highest value for moldboardless continuous cultivation with PRN-31000 (33–35 cm).

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Актуальність. Зміна клімату та забезпечення продовольчої безпеки зумовлюють постійну необхідність ефективного використання агрохімічних і матеріальних ресурсів для підвищення продуктивності агрофітоценозів. Для підвищення врожайності кукурудзи, яка відіграє важливу роль у світовому виробництві продуктів харчування, та враховуючи економічну кризу зумовлену війною, виникає необхідність застосовувати енергоощадні способи обробітку ґрунту. **Мета.** Визначити вплив різних способів основного обробітку ґрунту на продуктивність кукурудзи та економічну ефективність вирощування. **Матеріали та методи.** Дослідження проводили на базі навчально-науково-виробничого центру «Дослідне поле «Докучаєвське»» Державного біотехнологічного університету, на дослідному полі кафедри землеробства та гербології ім. О. М. Можейка, яке розташоване у Лівобережному Лісостепу України. Методи досліджень: польові – вивчення способів основного обробітку ґрунту та визначення врожайності кукурудзи на зерно; розрахунково-порівняльні – економічна оцінка ефективності обробітків ґрунту. **Результати.** Встановлено, що порівняно з оранкою ПЛН-4-35 врожайність кукурудзи за безполіцевого обробітку ПРН-31000 знизилася на 0,28 т/га, за чизельного локального ПЧ-2,5 – на 0,50 т/га і при дискуванні БДМ-2,5 – на 0,63 т/га. Кукурудза на контрольному варіанті мала найвищу продуктивність, вихід кормових і кормопротейнових одиниць склав 8,71 і 7,04 т/га відповідно. Найвищої економічної ефективності було досягнуто при проведенні оранки знаряддям ПЛН-4-35 на глибину 25–27 см з чистим прибутком 3650 грн/га та рівнем рентабельності 13,8 %. **Висновки.** Обробіток ґрунту відіграє ключову роль у формуванні умов для росту і розвитку кукурудзи, це безпосередньо впливає на економічну й енергетичну ефективність її вирощування. В умовах Лівобережного Лісостепу України для отримання високої врожайності та продуктивності кукурудзи необхідно проводити традиційний обробіток ґрунту ПЛН-4-35 на глибину 25–27 см. Як альтернативу оранці можна застосовувати безполіцевий обробіток ПРН-31000 на глибину 33–35 см.

Ключові слова: кукурудза, економічна ефективність, продуктивність, урожайність