

Choosing the optimal elements of corn cultivation technology in the conditions of Ukraine

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Abstract

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The research conducted in the north Steppe of Ukraine throughout 2020–2022 studied such elements of corn growing technique as the basic tillage method and mineral fertilization for corn hybrids of different ripeness groups. It was found that the highest yield among all hybrids under experiment was achieved as a result of using turning plowing method. The LG 31377 hybrid showed itself as the most productive with the result of 8.91 t/ha. Change from turning plowing to subsoiling led to insignificant yield reduction, which constituted 1.7% and 1.9% for middle-early LG 31272 and Adevey hybrids and to minor but essential 3.5% for middle-ripe LG 31330 and LG 31377 hybrids. Growing corn after shallow tillage caused yield losses of 15.5–24.0%. While studying the impact of fertilizers on corn hybrid productivity, it was concluded, that the lowest yield was harvested on plots with no mineral fertilization. Within the range of hybrids under research, in case of no fertilizers used, the lowest productivity 7.33 t/ha was registered for the LG 31377 hybrid, while the highest yield of 7.48 t/ha was formed by the LG 31272. The application of mineral fertilizers in the amount of $N_{30}P_{30}K_{30}$ contributed to the yield growth by 10.1–17.2% among the hybrids under research, which constituted 0.76 t/ha for the LG 31272, 1.04 t/ha for the Adevey, 1.08 t/ha for the LG 31330 and 1.26 t/ha for the LG 31377 hybrid. The increase of mineral fertilizers amount to $N_{60}P_{60}K_{60}$ resulted in further yield growth of 0.6–2.2% only. In case of application of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ the LG 31377 had the highest yield among other hybrids – 8.59 and 8.78 t/ha.

Keywords: corn; leaf surface area; tillage; mineral fertilization; productivity

Introduction

For Ukraine, corn is one of the strategic crops which provides its food, feed and energy safety (Bahtiar et al., 2020). It is grown in almost all country's regions, considering climate conditions and farm size. Corn seed yield exceeds that of most feed and food crops. Corn comes after sunflower and wheat according to its cultivation area (Vasytkovska et al., 2021a). It is generally known that corn is grown on all continents with the exception of Antarctica only. The USA and China are leading in world corn seed production and provide 35% and 21%, respectively. The

main exporters of corn are the USA, Argentina, Brazil and Ukraine (Vasytkovska et al., 2021b).

The variety of use of this crop proves the importance of creating and providing quality growing techniques, adapted to the specific soil and climate zones. In terms of Ukrainian Steppe, it is necessary to refer to such a requirement as maximum moisture accumulation and retention in the soil layer up to 1.5 m deep during autumn, winter and early spring period as well as prevention of water and wind erosion. Proper choice and conduct of tillage provides positive solution to the problem, and, furthermore, improves soil structure and nutrient accumulation in it.

A large number of corn hybrids featured by high productivity were presented lately. They largely differ in certain characteristics, such as genetic origin, length of vegetation period, adaptability and reaction to soil and climate change. The usage of such hybrids in arid zones of Ukraine enables stabilization of corn productivity and minimization of harvesting fluctuations in case of adverse weather conditions (Pashchenko et al., 2006).

However, the majority of instructions given to basic tillage and mineral fertilization for these corn hybrids are, to some extent, generalized and are based on the data about the moisture index of the cultivation area and group of hybrid ripeness. Only a few researchers focused on the specific reaction of hybrids to the change of agrotechnical methods (Pashchenko et al., 2006; Len et al., 2021).

It is impossible to unleash the high potential of hybrids considering manufacturers' neglect to such key factors of yield formation as basic tillage and mineral fertilization conditions. Subject to these factors being used at optimal parameters, it is more likely to reach optimum programmable yield and balanced production costs (Pashchenko et al., 2006; Zolotov, 2010). All these require detailed research on hybrid reaction to the change of basic agrotechnical methods, namely basic tillage and mineral fertilization rate.

The method and depth of basic tillage define soil agro-physical parameters, moisture contents, fertility rate, etc. Tillage conduct influences phytosanitary condition and weediness of crops. Then, the aim of tillage is also the protection from water and wind erosion, provision of optimal conditions for crops growth and development and high yield formation (Len et al., 2021).

For the Ukrainian Steppe zone, humidity is the main limiting factor for high yields of corn. In order to reduce yield losses caused by drought, it is advisable to use early-maturing hybrids of corn subject to improved root system development (Farid et al., 2022).

Deep turning plowing (25–27 cm) is traditionally considered to be most advantageous. This kind of tillage provides maximum moisture accumulation in autumn and winter periods, its rational use in spring and summer periods and is the basis for effective weed control (Pashchenko et al., 2006; Mostipan et al., 2017; Krnjaja et al., 2022).

As to the use of chisel plowing instead of turning plowing there is no agreement among the researchers. One group of researchers claims that chisel plowing can serve as a full substitute to turning plowing (Vasylykivska et al., 2016), while the second group considers chisel plowing as an advantage for improving a range of parameters including corn crop productivity (Giannoulis et al., 2020). The third group of scientists supports the idea of adverse influ-

ence of such substitute on the crop growing conditions (Jin et al., 2012).

When it comes to shallow tillage, the scientists generally disapprove of this method as it is unable to become an equivalent substitute to deep turning and chisel plowing (Giannoulis et al., 2020; Sadeghi et al., 2018). However, such a technological procedure, despite yield reduction, has certain economic advantages due to reduction of expenses for tillage (Krnjaja et al., 2022). The use of shallow tillage is only possible at the field with high soil fertility and low weediness (Fejér et al., 2022).

As stated above, the liming factor for high yields of corn crops in Steppe is insufficient moisture content, which is an important factor for the effective use of mineral fertilizers. In arid regions most of agrotechnical methods must be aimed at conservation and accumulation of moisture in order to improve the efficiency of mineral fertilizers. Optimal nutrition contributes to better moisture use by the crops and the increase of yield. In case of sufficient mineral fertilization of corn plant the consumption of moisture for producing a unit of dry substance reduces to 20% (Giannoulis et al., 2020; Yakunin & Zavertaliuk, 2003).

Barlog claims that the correct combination of fertilizers and irrigation is one of the most important factors in the intensification of corn production (Barlog & Frckowiak-Pawlak, 2008). Thus, the potential of corn can be unleashed under sufficient soil nutrition and hydration conditions.

In their field experiments, conducted in different soil and climate conditions, Zolotov (Zolotov, 2010), Pashchenko (Pashchenko et al., 2006) and Borysov (Pashchenko et al., 2009) showed the effectiveness of mineral fertilization and its high dependence on sufficient moisture content.

In case of insufficient hydration, the efficiency of fertilizers reduces dramatically and the use of norms that exceed 50–60 kg of effective substance in basic elements is non-productive (Jin et al., 2012; Tsykov, 2003). According to alternative data, in north Steppe zone, corn crops react better to application of $N_{60-90}P_{45-60}K_{40}$ (Pashchenko et al., 2009), although the amount of $N_{45}P_{45}K_{45}$ may show itself prevailing for certain hybrids that belong to different ripeness groups (Cherenkov et al., 2005).

Thus, it can be claimed the difference in corn hybrids reactions to the amount of mineral fertilizers (Giannoulis et al., 2020).

In the course of research at Zhrebkivska Research Station it was found that hybrids that belong to different ripeness groups respond unequally to the level of mineral fertilization. The increase of the amount of mineral fertilizers from $N_{60}P_{60}K_{60}$ to $N_{90}P_{90}K_{90}$ proved itself ineffective (Pashchenko et al., 2009). In contrast, Jin et al. (2012) reported that with

an increase of fertilizer application there was no increase in corn yields beyond certain limit of fertilization.

While applying average amounts of fertilizers $N_{45}P_{45}K_{45}$ to ordinary chernozem in north steppe of Ukraine there was an increase in corn seed yield for all the hybrids under research (Yakunin & Zavertaliuk, 2003).

Therefore, it can be stated that there is a distinction between the reactions of corn hybrids to the amount of mineral fertilizers (Jin et al., 2012; Pashchenko et al., 2009).

Despite comprehensive research of basic tillage and application of mineral fertilizers to corn conducted by scientists, there is no uniform conclusion in agricultural scientific literature as to the best basic tillage method and the amount of mineral fertilizers for growing corn in the Ukrainian Steppe, especially when it comes to new hybrids.

Material and Methods

Field experiment was conducted in 2020–2021 at the testing ground of “Agro Volodymyr” (farm in Velyka Vyska, Novoukrainka district, Kirovohrad region, Ukraine – 48.545011, 31.876756). The testing ground is located in the zone of north Steppe of Ukraine. The climate is moderate continental where the insufficient moisture is accompanied by unequal distribution of precipitation throughout the year. The soil cover of the testing ground is ordinary chernozem with mid humus content, heavy clay loam and moderately eroded soil that lumps at the depth of 45–55 cm. Soil absorption complex is saturated with bases of calcium and magnesium in the ratio of 5:1. Reaction of soil solution is neutral pH 6.5–7.0, total depth of humus about 70 cm thick. In the plow layer, humus content is 4.0–4.2%, the content of the main nutrients (according to Chirikov) is: hydrolyzing nitrogen – $11.2 \cdot 10^{-7}$ kg/1 kg, moving phosphorus – $13.6 \cdot 10^{-7}$ kg/1 kg, exchangeable potassium – $17.4 \cdot 10^{-7}$ kg/1 kg of soil (DSTU 4115–2002). That is, soil on the site has average fertility rates.

Wetting conditions are characterized by heterogeneity. According to average long-term data, the amount of precipitation per year is about 450 mm. About 3/4 of them fall during the growing season. The majority of this precipitation falls in the form of spring and summer showers from mid-April to early August. The years of research were significantly different by their hydrothermal conditions. The amount of precipitation during corn vegetation period in 2020 was 212 mm, in 2021 – 381.5 mm, in 2022–322.7 mm. Accordingly, the hydrothermal coefficients, calculated by H. Selyaninov’s methodology, were 0.5, 1.1 and 1.0, which indicates dry conditions in 2020 and their negative impact on the productivity level.

The field experiment with corn was conducted according to the guidelines from the studies (Dospekhov, 1985; Filev et al., 1980).

The research program included the study of peculiarities of growth, development and formation of new corn hybrids yield that belong to middle early-maturing and middle-ripe groups of ripeness according to the method of basic tillage and mineral nutrition level in north Steppe of Ukraine. The subject of the research is new hybrids, enlisted to the Register of Plant Varieties of Ukraine and recommended for cultivation in Steppe zone.

The number of variants in each of studies is 12, with triple recurrence; total number of plots in each study is 36. Crop area of the plot is 560 m², accounted area is 420 m². The basic research methods were field and field to laboratory experiments. General scientific methods, such as hypothesis, dialectic method, analysis, induction, deduction and math statistics were also used. The research was conducted using the following corn hybrids: middle-early LG 31272 and Adevey; middle-ripe LG 31330 and LG 31377. LG 31272 is a mid-early (FAO 270) corn hybrid with a high grain yield potential. The growing season in the conditions of the northern Steppe is 100–115 days. Advantages of the hybrid: high resistance to pests, no tendency to lodging, resistant to low temperatures, adapts well to seasonal stress conditions, has excellent drought resistance. Adevey is a mid-early (FAO 290) corn hybrid. The growing season in the conditions of the northern Steppe is 110–115 days. Advantages of the hybrid: resistance to the main diseases of corn, suitable for early sowing, the ability to form a high yield under different weather conditions. LG 31330 is a mid-ripening (FAO 320) corn hybrid. The growing season in the conditions of the northern Steppe is 115–120 days. Advantages of the hybrid: resistance to the main diseases of corn, resistance to lodging, high resistance to long dry periods. LH 31377 is a mid-ripening (FAO 350) corn hybrid. The growing season in the conditions of the northern Steppe is 115–120 days. Advantages of the hybrid: high resistance to the main diseases of corn and to lodging, has high drought resistance and is able to form a high yield under different weather conditions. They all belong to the selection of Limagrain (Groupe Limagrain Holding S.A.).

The technique used for growing corn during the research was generally accepted for this soil and climate zone. The previous crop on the plot of research was winter wheat.

The basic tillage was conducted in three variants. The first variant was disking at 6–8 cm with further plowing at 25–27 cm using Lemken Vari Diamant 6+1 plow (LEMKEN, Germany). The second variant was disking at 6–8 cm with further subsoiling at 30–32 cm using Quivogne subsoiler

(QUIVOGNE, France). The third variant was disking at 6-8 cm with further shallow cultivation at 10–12 cm using KPE–3.8 cultivator (VOSKHOD, Ukraine). In the course of the experiment such complex fertilizers as Nitroammophoska were applied at the rate of 30 kg in active substance of NPK.

In the course of research on the influence of mineral fertilizers, they were applied before plowing according to the experimental pattern – plots without fertilizers, $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$. Further technique of growing corn was identical for both experiments. Thus, sowing was executed within the most favorable period for north Steppe zone (soil warming temperatures at the enfolding depth is up to 10–12°C), which was May 2–3 in the year of the research, using the Tempo F8 Väderstad seed drill (VÄDERSTAD, Denmark). Standard seeds of high sowing quality were used for sowing with their laboratory germination of 92-94%, purity – 99%, and mass per 1000 seeds of 280-300 g. They were treated by Forse Zea 280 FS. The seed rate of 60 thousands of sprouted seeds per 1 ha was used. The row spacing was 70 cm. Pest control was conducted, as recommended, in case of exceeding the economic threshold of harm with the help of Coragen 20SC normally at 0.15 l/ha.

The accounting of leaf surface area (according to the generally accepted method) was conducted in the phases of panicle flowering and wax ripeness of seeds, while individual plant productivity and seed moisture level were measured immediately before harvesting. The seed moisture level was defined in the laboratory. Plots were harvested in turns by means of threshing. The harvest was recalculated to 14% moister level of seeds.

In order to analyze the data received, statistic models and a package of Excel Microsoft Office applications were used (Vasylykovskiy et al., 2016).

Results and Discussion

Corn has a distinct reaction to the change of tillage method and its depth. One of the main parameters of assessing the conditions of growing plant of this crop is leaf surface area of a single plant as well as the whole area of sowing. In order to reach appropriate photosynthesis level a plant needs to have certain leaf surface area. Biotic and abiotic factors influence its formation. Among the biotic factors are sowing time, tillage, fertilization system, etc. They contribute to the use of such abiotic factors as sunlight, precipitation and to the reduction of the negative impact of extreme moisture parameters of air and soil.

The leaf area of a single plant of corn hybrids was assessed twice during the vegetation. First assessment was conducted in the phase of panicle flowering when a corn plant forms maximum leaf area, while the second was conducted in the phase of seed wax ripeness, when a great deal of plastic substances flow out of leaves to seeds and the leaf surface area reduces immensely.

Leaf surface area of a single plant as well as the total area of all leaves of the sowing area was greater among those hybrids that were cultivated using turning plowing. The use of subsoiling as the basic tillage method did not cause any significant reduction of these parameters, while shallow cultivation, on the contrary, led to their immense reduction (Table 1). So, depending on the hybrid, leaf surface area of a single leaf constituted 46.8–48.9 $m^2 \cdot 10^{-2}$ in case of plowing and it was slightly less in case of subsoiling (46.5–48.7 $m^2 \cdot 10^{-2}$) and the least of 43.2–44.9 $m^2 \cdot 10^{-2}$ in case of shallow cultivation. The lowest parameters of leaf surface area among all hybrids were registered with the LG 31272 hybrid, which

Table 1. Leaf surface area of corn hybrids according to the basic tillage method in 2020–2022

Variant	Hybrid (factor A)	Basic tillage method (factor B)	Single plant leaf surface area, $m^2 \cdot 10^{-2}$		Total leaf surface area of plants sown, thousand, m^2/ha	
			panicle flowering	wax ripeness of a seed	panicle flowering	wax ripeness of a seed
1	LG 31272	plowing (25-27 cm)	46.8	28.1	15.0	25.1
2		subsoiling (30-32 cm)	46.5	27.9	14.8	24.6
3		shallow (12-14 cm)	43.2	25.9	12.6	20.9
4	Adevey	plowing (25-27 cm)	47.4	28.4	15.6	26.1
5		subsoiling (30-32 cm)	47.2	28.3	15.6	25.9
6		shallow (12-14 cm)	43.4	26.0	12.6	21.1
7	LG 31330	plowing (25-27 cm)	47.7	28.6	15.6	26.0
8		subsoiling (30-32 cm)	47.5	28.5	15.3	25.4
9		shallow (12-14 cm)	44.3	26.6	12.7	21.1
10	LG 31377	plowing (25-27 cm)	48.9	29.3	16.1	26.9
11		subsoiling (30-32 cm)	48.7	29.2	15.9	26.5
12		shallow (12-14 cm)	44.9	26.9	12.8	21.3

constituted 43.2–46.8 $\text{m}^2 \cdot 10^{-2}$. Adevey and LG 31330 hybrids showed slightly better parameters of 43.4–47.4 and 44.3–47.7 $\text{m}^2 \cdot 10^{-2}$ respectively. The largest area of leaf surface of 44.9–48.9 $\text{m}^2 \cdot 10^{-2}$ was registered with the LG 31377 hybrid. Thus, the leaf surface area of hybrids increased with the increase of their FAO.

The above mentioned tendencies were also relevant to the next assessment of a single leaf surface area of corn hybrids. In particular, greater leaf surface area during wax ripeness was registered among the hybrid plants under research that were cultivated using turning plowing and the parameter increased with the increase in their FAO data. Yet it is worth mentioning that leaf area of those plants cultivated using plowing varied within 25.1–26.9 $\text{m}^2 \cdot 10^{-2}$, while that using subsoiling amounted to 24.6–26.5 $\text{m}^2 \cdot 10^{-2}$. So, the difference did not exceed 5%, which makes it not critical. However, growing hybrids after shallow tillage led to reduced leaf surface of a single plant to 20.9–21.3 $\text{m}^2 \cdot 10^{-2}$, which was by 16.7–20.8% smaller than those plowed.

While studying the impact of mineral fertilization on corn hybrids, it was defined that individual parameters of leaf surface area as well as general leaf area of crops for all hybrids under research were higher for higher norms of fertilizer application and reduced as a result of reduction of this norm with the lowest results for control variant without any fertilizers (Table 2).

Thus, growing corn on unfertilized soil let the plants form leaf area of 43.3–44.8 $\text{m}^2 \cdot 10^{-2}$ in the period of panicle flowering depending on the hybrid. The lowest parameters were shown by the LG 31272 and Adevey hybrids, the LG 31330 and LG 31377 hybrids showed somewhat better results of 44.5 and 44.8 $\text{m}^2 \cdot 10^{-2}$ respectively. The applica-

tion of mineral fertilizers in the amount of $\text{N}_{30}\text{P}_{30}\text{K}_{30}$ provided for the formation of much greater leaf surface area of a single plant for all hybrids under research and amounted to 46.5–48.9 $\text{m}^2 \cdot 10^{-2}$. So, fertilizer application contributed to the increase of individual leaf area by 7.4–9.7%. Double amount of fertilizers applied (amount applied is $\text{N}_{60}\text{P}_{60}\text{K}_{60}$), led to natural but disproportionate increase in individual leaf surface area. It increased by 1.5–2.6% only, which is irrelevant. This tendency was true for all hybrids in the phase of seed wax ripeness too.

Similar results were seen while assessing leaf surface area in the abovementioned periods of growth. In both cases, all hybrids under research showed the lowest parameters of 25.3–26.2 thousand m^2/ha (panicle flowering) and 12.2–13.2 thousand m^2/ha (wax ripeness of a seed) with no mineral fertilization. The application of mineral fertilizers in the amount of $\text{N}_{30}\text{P}_{30}\text{K}_{30}$ caused the increase in general leaf area growth of plants sown, but further enlargement of the amount did not give any essential result. Among the hybrids there was an increase of parameter in a row of LG 31272, Adevey, LG 31330 and LG 31377 with all variants of fertilization. It should be mentioned that in wax ripeness period the LG 31330 hybrid had larger general leaf area of all plants sown (15.7 thousand m^2/ha) when the amount of $\text{N}_{30}\text{P}_{30}\text{K}_{30}$ was applied rather than $\text{N}_{60}\text{P}_{60}\text{K}_{60}$ application (15.6 thousand m^2/ha).

An important feature of hybrid productivity, except for yield, is an individual number of cobs and seed moisture. This parameter was estimated during all three years of the research. The analysis of the number of cobs formed per 100 of plants showed the tendency for its reduction in case of using shallow tillage, while in case of subsoiling it was closer to the variant when turning plowing was used (Table 3, Figure 1).

Table 2. Leaf surface area of corn hybrids under various mineral fertilization, 2020–2022

Variant	Hybrid (factor A)	Mineral fertilization (factor B)	Single plant leaf surface area, $\text{m}^2 \cdot 10^{-2}$		Total leaf surface area of plants sown, thousand, m^2/ha	
			panicle flowering	wax ripeness of a seed	panicle flowering	wax ripeness of a seed
1	LG 31272	no fertilization	43.3	21.2	25.3	12.2
2		$\text{N}_{30}\text{P}_{30}\text{K}_{30}$	46.5	25.4	27.7	14.8
3		$\text{N}_{60}\text{P}_{60}\text{K}_{60}$	47.2	25.8	28.1	15.1
4	Adevey	no fertilization	43.3	22.3	25.5	12.5
5		$\text{N}_{30}\text{P}_{30}\text{K}_{30}$	47.5	26.4	28.4	15.5
6		$\text{N}_{60}\text{P}_{60}\text{K}_{60}$	48.2	26.8	28.6	15.8
7	LG 31330	no fertilization	44.5	21.2	25.5	12.6
8		$\text{N}_{30}\text{P}_{30}\text{K}_{30}$	47.8	25.9	28.2	15.7
9		$\text{N}_{60}\text{P}_{60}\text{K}_{60}$	48.5	26.2	28.7	15.6
10	LG 31377	no fertilization	44.8	21.5	26.2	13.2
11		$\text{N}_{30}\text{P}_{30}\text{K}_{30}$	48.9	27.2	29.2	15.7
12		$\text{N}_{60}\text{P}_{60}\text{K}_{60}$	50.2	27.4	29.5	15.9

Table 3. Corn hybrid productivity in case of different tillage methods, 2020-2022

Variant	Hybrid (factor A)	Basic tillage method (factor B)	Individual cob productivity per 100 plants	Moisture before harvesting, %	Yield at 14%, t/ha
1	LG 31272	no fertilization	91.0	18.2	7.48
2		N ₃₀ P ₃₀ K ₃₀	99.0	18.5	8.24
3		N ₆₀ P ₆₀ K ₆₀	100.7	18.2	8.36
4	Adevey	no fertilization	91.3	18.6	7.41
5		N ₃₀ P ₃₀ K ₃₀	100.7	19.0	8.44
6		N ₆₀ P ₆₀ K ₆₀	101.3	18.9	8.50
7	LG 31330	no fertilization	91.3	16.9	7.45
8		N ₃₀ P ₃₀ K ₃₀	100.7	17.7	8.52
9		N ₆₀ P ₆₀ K ₆₀	101.3	17.6	8.60
10	LG 31377	no fertilization	91.3	18.2	7.33
11		N ₃₀ P ₃₀ K ₃₀	98.0	18.3	8.59
12		N ₆₀ P ₆₀ K ₆₀	99.7	18.3	8.78
			2020	2021	2022
LSD _{0.05} by factor B by factor AB		by factor A	0.13	0.21	0.20
			0.12	0.19	
			0.20	0.30	

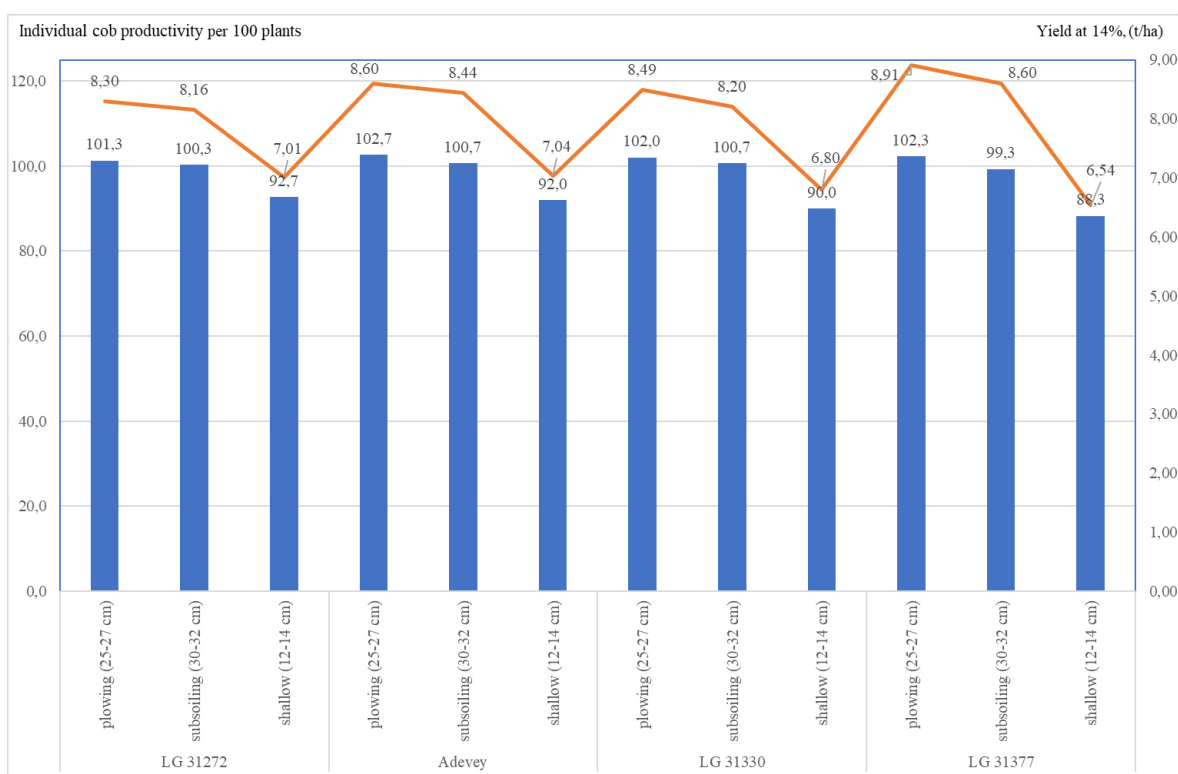


Fig. 1. Corn hybrid productivity in case of different tillage methods

Too arid conditions of 2020 caused suppression of corn plants (especially middle-ripe hybrids) and influenced greatly on their productivity. In 2020, the number of cobs per 100 plants with the middle-early LG 31272 and Adevey hybrids varied within 78–86 cobs, while middle-ripe hybrids had 72–82 pcs per 100 plants. It had a substantial impact on seed productivity in 2020 and on the average data of three years of research.

Thus, in 2020–2022, all hybrids cultivated with the use of turning plowing showed the best productivity results of cob formation of 101.3–102.7 pcs. Therefore, there were plants in these crops that formed more than one cob which is a proof of favorable conditions for their formation. In the context of hybrids, the biggest number of cobs was formed by the Adevey hybrid with 102.7 pcs, with a little fewer number by the LG 31377 and LG 31330 hybrids with 102.3 and 102.0 pcs, respectively. The lowest result was shown by the LG 31272 hybrid with 101.3 pcs. The use of deep subsoiling changed the situation and the number of cobs per 100 plants reduced by 1–2 cobs to 99.3–100.7 pcs. With the use of this cultivation method the best results belong to the Adevey and LG 31330 hybrids with 100.7 pcs, the LG 31272 hybrid has the similar result of 100.3 pcs. The only hybrid that formed less than 100 cobs per 100 plants was the LG 31377. In cases of shallow tillage, the results were the lowest. Not every plant was able to form a cob which proves that the growing and development conditions deteriorated. As mentioned before, the worst result was shown by the LG 31377 hybrid with 88.3 cobs only. The LG 31272 hybrid was the best with 92.7 pcs, while Adevey and LG 31330 hybrids showed average results of 92.0 and 90.0 pcs, respectively.

Another parameter which is not the least important is seed moisture, which allows us to define if the harvested crop would require additional expenses for its conditioning as to its moisture content, i.e. if it requires additional drying which is expensive. The process of defining seed moisture before harvesting does not demonstrate any clear tendency of its dependence on tillage method. In case of plowing, seed moisture was, therefore, defined at the level of 17.6–18.8%, in case of subsoiling – 17.4–18.7%, which are extremely similar results. They were similar for different hybrids (LG 31377), either with the use of plowing (LG 31272) or subsoiling (Adevey and LG 31330). A slightly lower parameter of seed moisture of 17.6–16.3% was registered among the plants grown after shallow tillage. As to the hybrids, the parameters of seed moisture were significantly higher for the Adevey hybrid of 17.6–18.8%, which is caused by its genetic peculiarities. The lowest seed moisture before harvesting of 16.3–17.6% was

defined with the LG 31330 hybrid. Average parameters, extremely close in figures, were shown by the LG 31272 and LG 31377 hybrids of 17.3–18.2%.

Yield is one of the major indicators of tillage impact on corn plant productivity. Based on three years of yield observations of various hybrids under different basic tillage methods, it became noticeable that all hybrids show higher yields after plowing. The highest result of 8.91 t/ha was achieved as a result of growing the LG 31377 hybrid. The change of plowing for turning plowing lead to a significant reduction of productivity among the middle-early hybrids LG 31272 and Adevey and amounted to 1.7 and 1.9%, while among the middle-ripe hybrids LG 31330 and LG 31377 it led to slight but significant reduction by 3.5%. Instead, the disadvantage of growing corn after shallow tillage was yield at the level of 6.54–7.04 t/ha, i.e. if compared to plowing, there was a 15.5–24.0% loss of harvest for hybrids under research.

As a result of the analysis of individual corn plant productivity, namely the number of cobs formed per 100 plants, relative to the amounts of mineral fertilization, it is worth mentioning highly arid year 2020, when this parameter for the LG 31272 hybrid was within the range of 75–86 pcs/100 plants, and within 74–80 and 72–82 pcs/100 plants for the Adevey and LG 31330 hybrids, for the LG 31377 hybrid it constituted 72–74 pcs per 100 plants. In 2020 all hybrids had a tendency to increase in cob number with the mineral fertilization in the amount of $N_{30}P_{30}K_{30}$, although with the increase of fertilizers to $N_{60}P_{60}K_{60}$ this indicator showed a decrease. 2021 and 2022 were favorable for corn growth and development which provided good parameters of both individual and general crop productivity.

As a result of the analysis of individual productivity of corn hybrids under research throughout 2020–2022, it was noticed that the number of cobs increased significantly with the increase of mineral fertilization for these plants (Table 4). For instance, the Adevey and LG 31330 hybrids showed equal cob number of 91.3–101.3 pcs per 100 plants under mineral fertilization used in the experiment. Smaller number of 91.0–100.7 pcs per 100 plants was registered for the LG 31272 hybrid, with the lowest result of 91.3–99.7 pcs/100 plants for the LG 31377 hybrid.

In case of mineral fertilization of $N_{60}P_{60}K_{60}$ all hybrids under research showed top results in cob formation of 99.7–101.3 pieces. A part of plants of all these hybrids formed more than one cob. In case of mineral fertilization of $N_{30}P_{30}K_{30}$ though, there was a difference of individual productivity of 0.6–1.7 cobs only, which was close to the highest amount of fertilizers. In case of no fertilization growth, there were the lowest results of cobs formed of 91.0–91.3 productive cobs per 100 plants (Table 4, Figure 2).

Table 4. Corn hybrid productivity in case of different mineral fertilization, 2020–2022

Variant	Hybrid (factor A)	Basic tillage method (factor B)	Individual cob productivity per 100 plants	Moisture before harvesting, %	Yield at 14%, t/ha
1	LG 31272	plowing (25-27 cm)	101.3	18.2	8.30
2		subsoiling (30-32 cm)	100.3	18.3	8.16
3		shallow (12-14 cm)	92.7	17.3	7.01
4	Adevey	plowing (25-27 cm)	102.7	18.8	8.60
5		subsoiling (30-32 cm)	100.7	18.7	8.44
6		shallow (12-14 cm)	92.0	17.6	7.04
7	LG 31330	plowing (25-27 cm)	102.0	17.6	8.49
8		subsoiling (30-32 cm)	100.7	17.4	8.20
9		shallow (12-14 cm)	90.0	16.3	6.80
10	LG 31377	plowing (25-27 cm)	102.3	18.2	8.91
11		subsoiling (30-32 cm)	99.3	18.2	8.60
12		shallow (12-14 cm)	88.3	17.4	6.54
			2020	2021	2022
LSD _{0.05} by factor B by factor AB		by factor A	0.11	0.16	0.18
			0.10	0.16	
			0.19	0.27	

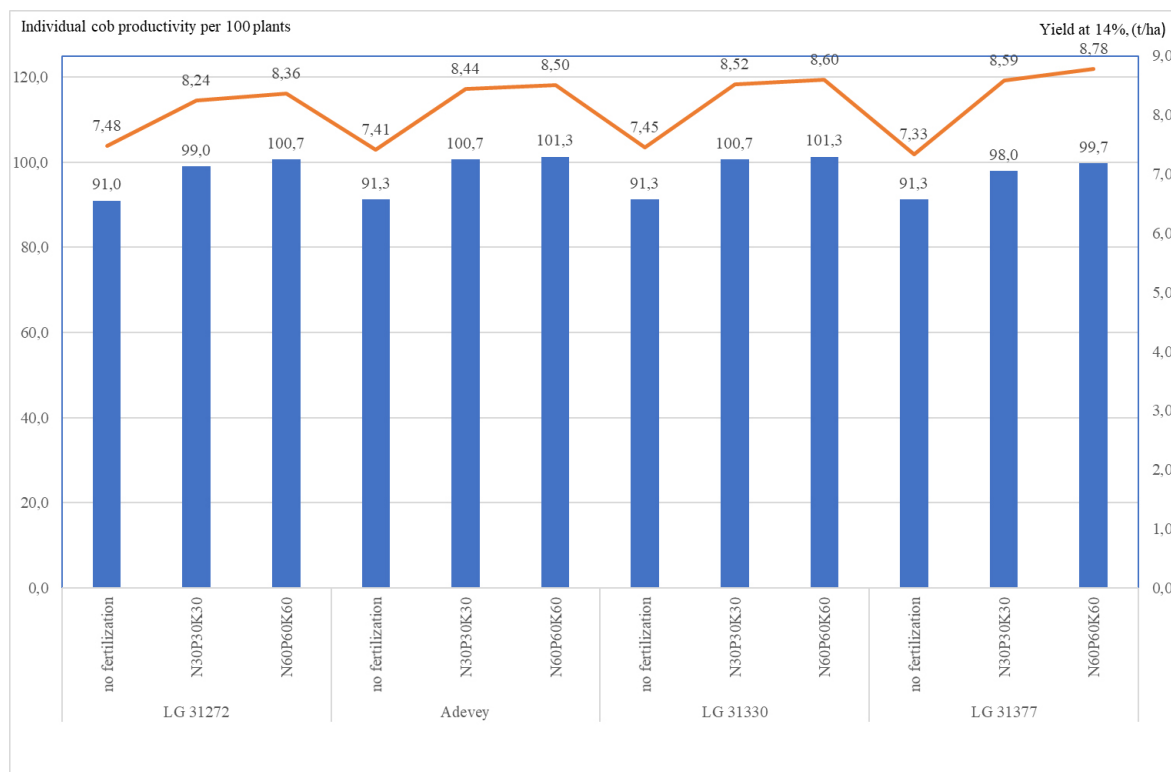


Fig. 2. Corn hybrid productivity in case of different mineral fertilization

Various conditions of mineral fertilization had its influence on seed moisture content before harvesting for different hybrids. The middle-early LG 31272 and Adevey hybrids showed enhanced seed moisture content before harvesting by 0.3 and 0.4% in case of increased mineral fertilization of $N_{30}P_{30}K_{30}$, and in case of $N_{60}P_{60}K_{60}$ fertilization it was true for Adevey hybrid only by 0.3%. The middle-ripe LG 31330 hybrid had an increase of seed moisture content before harvesting by 0.7 and 0.8% in general in case of greater level of mineral fertilization, while the middle-ripe LG 31377 hybrid had stable seed moisture parameters despite greater level of fertilization. The LG 31330 hybrid demonstrated the lowest seed moisture content, which equaled the basic 14.2% of no feed variant in 2020. Overall, this parameter varied within 16.9–19.0%, therefore, seed grown required insignificant drying only.

Yield is one of the major indicators of mineral fertilization impact on corn plant productivity. In 2020, all the hybrids demonstrated maximum harvesting with mineral fertilization of $N_{30}P_{30}K_{30}$, while in 2021 and 2022 – of $N_{60}P_{60}K_{60}$.

On average throughout the research years, hybrids showed change of productivity in case of variations in mineral fertilization. The lowest productivity was achieved at the plots with no mineral fertilization. Mineral fertilization applied in the amount of $N_{30}P_{30}K_{30}$ contributed to yield growth by 10.1–17.2% for hybrids under research, which constituted 0.76 t/ha for the LG 31272 hybrid, and 1.04 t/ha for Adevey hybrids, 1.08 t/ha for the LG 31330 and 1.26 t/ha for the LG 31377. Further increase in the amount applied to $N_{60}P_{60}K_{60}$ led to productivity improvement for LG 31272, Adevey, LG 31330 and LG 31377 hybrids by 0.05–0.18 t/ha, which is 0.6–2.2% only.

In all the range of hybrids under research grown without any mineral fertilization, the lowest yield was recorded for the LG 31377 hybrid with 7.33 t/ha, while the highest yield parameters were demonstrated by the LG 31272 with 7.48 t/ha. In case of mineral fertilization of $N_{30}P_{30}K_{30}$ LG 31377 hybrid showed the highest yield of 8.59 t/ha, contrary to the lowest yield of 8.24 t/ha by the LG 31272. The LG 31377 hybrid had the best yield of 8.78 t/ha when the fertilization in the amount of $N_{60}P_{60}K_{60}$ was applied.

Thus, we can conclude that the highest yield was formed by all hybrids in case of mineral fertilization in the amount of $N_{60}P_{60}K_{60}$. For all hybrids under research there was no significant reduction in yield in case of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ fertilization.

Conclusion

Field research of basic tillage and mineral fertilization conditions for growing corn in the Ukrainian Steppe zone al-

low claiming that proper choice of tillage method and of the amount of mineral fertilizers are the key to future harvest.

The influence of different tillage methods, their depth and amount of mineral fertilization was irrelevant to the variations in seed moisture content and lay within 1.0%. The LG 31330 hybrid demonstrated the lowest moisture level which equaled the basic indications of 14.2% in 2020. The overall variation of this parameter was within the range of 16.3–19.0%, which meant that seeds did not require significant drying.

Higher yield level was achieved as a result of turning plowing. The LG 31377 hybrid showed the highest yield of 8.91 t/ha. The use of subsoiling plowing instead of plowing did not cause any dramatic decrease in productivity, but was within 1.7 and 1.9% for the middle-early LG 31272 and Adevey hybrids, and was of 3.5% for the middle-ripe LG 31330 and LG 31377 hybrids, which is not great but still essential. Growing corn after shallow tillage led to yield loss of about 15.5–24.0% depending on the hybrid.

The lowest yield was achieved as a result of growing corn without using any fertilizers. Feed application in the amount of $N_{30}P_{30}K_{30}$ caused yield growth by 10.1–17.2%, which constituted 0.76 t/ha for the LG 31272 hybrid, 1.04 t/ha for the Adevey hybrid, 1.08 t/ha for the LG 31330 hybrid, and 1.26 t/ha for the LG 31377 hybrid. Further increase in the amount of fertilization up to $N_{60}P_{60}K_{60}$ led to yield growth of 0.6–2.2% only.

In all the range of hybrids under research grown without any mineral fertilization, the lowest yield of 7.33 t/ha was recorded for the LG 31377 hybrid, while the highest yield of 7.48 t/ha was recorded for the LG 31272 hybrid. In case of mineral feed application of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ the LG 31377 hybrid produced higher yield of 8.59 and 8.78 t/ha.

Thus, the highest yield in the first experiment was formed by all the hybrids under study in case of turning plowing and in the second experiment – mineral fertilization which amounted to $N_{60}P_{60}K_{60}$, while the difference between $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ was insignificant.

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