СІЛЬСЬКОГОСПОДАРСЬКІ НАУКИ

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THE YIELD AND PRODUCTIVITY OF SUNFLOWER DEPEND ON ITS SHARE IN CROP ROTATION

Abstract

The importance of sunflower as the main oilseed crop, high economic efficiency, saturation of the agricultural market with high-quality seeds of modern hybrids resistant to adverse environmental conditions, diseases, and pests with high yield potential contribute to increasing the share of the crop in crop rotations. Despite many researchers not recommending returning sunflower to the crop rotation earlier than five to eight years, growing sunflower after sunflower is possible. One of the main conditions for obtaining a high yield in continuous sunflower crops is the nutrient background.

Research was conducted on alternating sunflower and maize for grain in a two-field crop rotation and for sunflower cultivation in monoculture under different fertilization systems in the fields of the Institute of Steppe Agriculture of the National Academy of Sciences.

Annual alternation in the crop rotation of sunflower and maize contributed to an increase in sunflower yield to 1.75 t/ha compared to its continuous cultivation, where the yield did not exceed 1.39 t/ha; the yield increase due to the crop rotation factor was 0.36 t/ha or 21.5%.

The fertilization system significantly affected the yield of sunflower. The highest yield was achieved with the organo-mineral fertilization system in a crop rotation with 50% saturation with sunflower at 2.33 t/ha. Moreover, the application of mineral fertilizers together with sunflower residues in monoculture neutralized the effect of the crop rotation factor and provided a seed yield at the level of crop rotation with alternating crops, 0.71 t/ha.

The highest yield increase was obtained with the mineral fertilization system, 0.51 t/ha or 36.7%; for the organo-mineral system, the yield increase was slightly lower at 0.46 t/ha or 27.4%.

Higher productivity was formed by sunflower crops in a crop rotation with 50% saturation with crops. The crop rotations factor ensured an increase in grain units, feed units, and digestible protein to 3.51 t/ha, 1.93 t/ha, and 0.66 t/ha, respectively; the yield increase compared to sunflower monoculture was 0.72 t/ha, 0.39 t/ha, and 0.14 t/ha.

The increase in sunflower productivity due to the fertilization system factor was even more significant, and under the organo-mineral system in a crop rotation with 50% saturation with sunflower, they were the highest at 4.67 t/ha of grain units, 2.57 t/ha of feed units, and 0.89 t/ha of digestible protein.

Key words: *yield, productivity, crop rotation, saturation of crop rotation with sunflower, fertilization system.*

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Introduction. Crop rotation is an important component of the overall agricultural system. The rational alternation of crops in crop rotation reflects the organization of farming in the economy, the features of soil cultivation, the application of fertilizers, the selection of means to protect the soil from erosion, weed control, diseases, and pests [3, 9, 13].

The narrow specialization of most farms and the increased concentration of agricultural production necessitate changing the structure of sown areas, constantly improving and adjusting crop rotations, and enriching them with main and intermediate crops [4, 6].

The conditions of individual natural-climatic zones are quite different, so crop rotations should be developed for each of them, and even for each farm, taking into account its soil and climatic conditions. Crop rotation schemes also depend on the adopted structure of sown areas.

The high prices of sunflower seeds and relatively low costs compared to some other crops often encourage farmers to sow sunflower again on the same field. This means either increasing its share in crop rotation and sowing it for a second year in a row or growing it in monoculture, i.e., continuously [2, 11].

Despite many researchers not recommending returning sunflower to the crop rotation earlier than five to eight years, growing sunflower after sunflower is possible and can yield a high harvest. There are certain risks associated with implementing sunflower monoculture, such as an increase in disease development, an increase in the number of pests in the crop, intensified weed infestation, etc. However, a qualified field survey, the use of high-quality seed material of different hybrids resistant to existing crop diseases, a high-tech fertilization system, and quality soil treatment allow sunflower to be grown on the same field for several years [6, 7, 8, 10].

In recent years, humanity has faced a global problem of climate change. This problem is primarily accompanied by increased temperatures, which disrupt water circulation processes. As a result, drought is intensified in certain regions.

It is believed that sunflower is a crop that is best adapted to the conditions of various natural-climatic zones of Ukraine, including the conditions of the Steppe with insufficient precipitation. Sunflower has a deep root system that extends vertically to a depth of three meters and a large number of secondary roots, some of which are located parallel to the soil surface and others are buried parallel to the main root at a distance of 20–40 cm. This root structure allows the crop to withstand drought. These morphological features of sunflower also affect soil structure, aeration, nutrient movement, etc. [12, 15].

The yield of sunflower, like any agricultural crop, is influenced by a complex of natural and agrotechnical factors. Soil and climatic conditions play a leading role in this zone. The nutrient background is one of the determining factors in sunflower cultivation technology. Fertilizer application increases the content of plant-available mineral nutrients in the soil and thus changes the chemical composition, physical properties, and other characteristics of the soil. Improving mineral nutrition positively affects the process of photosynthesis, contributes to increased plant productivity, and improves seed quality [1, 5, 12, 14].

Thus, the importance of sunflower as the main oilseed crop, high economic efficiency, saturation of the agricultural market with high-quality seeds of modern hybrids resistant to adverse environmental conditions, diseases, and pests with high yield potential contribute to increasing the share of the crop in short crop rotations. However, agronomic techniques for growing in crop rotations with different levels of sunflower saturation in the conditions of the northern steppe of Ukraine are not sufficiently studied.

The aim of the research. To determine the level of yield and productivity of sunflower depending on crop rotation saturation and fertilization system. To establish the influence of crop rotation factor on sunflower productivity depending on fertilization.

The research objects were fertilization systems and crop rotation with 50% and 100% saturation of the crop.

Research methodology. The yield and productivity of sunflower were studied in a stationary experiment in different crop rotations in the fields of the agriculture laboratory of the Institute of Agriculture of the Steppe NAAS.

Factor A was short rotation grain-legume crop rotation with 50% saturation of sunflower and maize, and the variant of growing sunflower in monoculture. Factor B was fertilization systems, with options including control (without fertilizers), mineral fertilization system $N_{40}P_{40}K_{40}$, and organo-mineral system – $N_{40}P_{40}K_{40}$ + by-product of maize, or under continuous cultivation – sunflower. The plot area was 105.9 m^2, with three repetitions.

Sunflower was grown using generally accepted agrotechnology for the Northern Steppe zone, except for factors studied in the experiment. The hybrid sunflower LG 50510, recommended for the Forest-Steppe, Polissia, and the northern part of the Steppe zone of Ukraine, was used for sowing under classical technology. Field and laboratory research were conducted using field research methods and mathematical-statistical analysis.

The short meteorological characteristics of the research conditions varied significantly over the years, which had a significant impact on the level of yield and productivity indicators of sunflower. It was found that favorable conditions were in 2019 and 2021, providing sufficient moisture levels during the sunflower growing period. Unfavorable conditions were in 2022 and 2023, especially in the early stages of sunflower growth and development. 2021 was excessively wet, but despite the decrease in temperature caused by frequent rains during sunflower cultivation, a sufficiently high productivity level and yield of the studied crop were obtained.

However, despite weather conditions, the studied factors also had a significant impact. Therefore, the weather conditions in the years of research were not sufficiently favorable for obtaining high sunflower yield indicators, but to a large extent, the fertilization system factor and the timing of sunflower return to the previous location mitigated the environmental conditions.

The presentation of the main material of the research. The development of plants and the formation of sunflower yield in 2019–2020 occurred under high average daily temperatures and insufficient moisture. In the conditions of 2019, the highest sunflower yield was in the crop rotation with 50% saturation, ranging from 2.28–3.22 t/ha. Precipitation in this year was uneven, but the maximum amount during seed filling contributed to the utilization of the plants' biological potential. The difference in yield indicators compared to sunflower monoculture was within 0.01–0.16 t/ha. The fertilization system had a greater impact on yield increase (+2.29 t/ha and +2.74 t/ha for mineral, and +0.59 t/ha and +0.35 t/ha for organo-mineral system) (Figure 1).

Particular attention is drawn to the sunflower yield indicators in 2020. Severe summer drought against average daily temperatures exceeding the norm by 4.0–4.5 °C did not allow most plants to pollinate, form full baskets, and seeds. For sunflower cultivation in monoculture, regardless of the fertilization system, the yield was at the level of 0.04 t/ha, while for 50% crop rotation saturation, this indicator ranged from 0.52–0.90 t/ha, with higher yields without fertilization.

The weather conditions were more favorable in 2021 (GTC 1.37, which is 0.37 higher than the norm). In this year, the crop rotation factor had a more significant impact on yield, and with 50% saturation of sunflower in the rotation, it was at the level of 2.20 t/ha. It should be noted that a greater yield increase in this rotation was obtained with the mineral fertilization system, +0.81 t/ha, whereas in monoculture, it was with the organo-mineral system, +0.70 t/ha.

The weather conditions during the research period in 2022 were not conducive to achieving high sunflower yields: a very wet and cold May, drought in July, and heavy rains in September. Sunflower yield in this year ranged from 1.40–2.13 t/ha, and it was only lower in 2020. The crop rotation factor did not significantly affect the yield indicators, with a difference of 0.06 t/ha, ranging from 1.40–1.46 t/ha. The highest sunflower yield was in the crop rotation with 50% saturation and fertilization: under the organo-mineral system – 2.13 t/ha, under the mineral system – 2.04 t/ha, with an increase of +0.67 t/ha and +0.58 t/ha compared to the variant without fertilizers, respectively.

The challenging conditions during the growth, development, and formation of generative organs of late-sown sunflower plants in 2023 had a negative impact on the level of sunflower yield. The highest yield in our research did not exceed 2.44 t/ha. It is worth noting that the yield increase due to the factors under study was consistent at 0.30 t/ha. Only the use of the organo-mineral fertilization system in the crop rotation with 50% sunflower saturation resulted in a yield increase of 0.58 t/ha.

Based on the results of five years of research on crop rotations with different levels of sunflower saturation, we have found that increasing the share of sunflower in their structure from 50% to 100% had a negative impact on yield. For instance, the average yield for sunflower monoculture was 1.39 t/ha. Introducing corn into the crop rotation contributed to an increase in sunflower yield to 1.75 t/ha, with a yield increase due to the crop rotation factor of 0.36 t/ha or 21.5%. According to our research, this difference was significant at LSD_{05} = 0.18 t/ha (Table 1).

The application of mineral fertilizers under continuous sunflower crops resulted in an increase in its yield level to 1.67 t/ha, +0.27 t/ha or 19.5% compared to the variant without fertilizers. Incorporating crop residues in combination with the use of mineral fertilizers contributed to a higher yield indicator in the crop rotation – 1.88 t/ha. Furthermore, due to the action of the organo-mineral fertilization system, the increase in sunflower seed yield was more significant, +0.48 t/ha or 29.1%.

It should be noted that the application of mineral fertilizers in combination with crop residues in the crop rotation with 100% sunflower saturation neutralized the influence of the crop rotation factor. The slightly higher indicator,

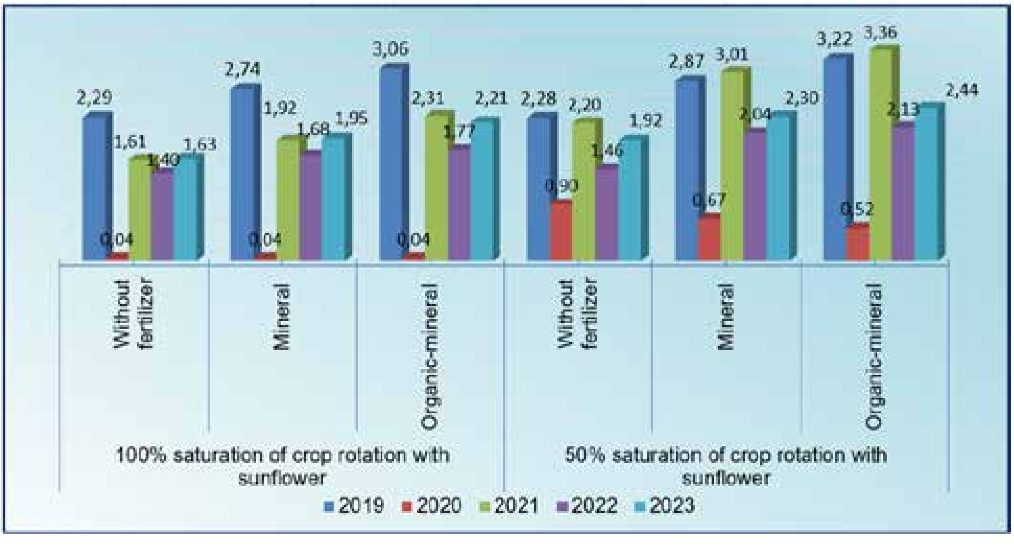

Fig. 1. Sunflower yield over the years of research, 2019–2023, t/ha

Table 1. Sunflower yield depending on its share in the crop rotation and fertilization system, t/ha

Share of sunflower in crop rotation structure, factor A	Fertilizer system, factor B	Average for 2019–2023	Difference factor A		Difference factor B	
			t/ha	%	t/ha	%
100%	Without fertilizer	1,39	–	–	–	–
	Mineral	1,67	–	–	0,27	19,5
	Organic-mineral	1,88	–	–	0,48	29,1
50%	Without fertilizer	1,75	0,36	21,5	–	–
	Mineral	2,18	0,51	36,7	0,43	24,3
	Organic-mineral	2,33	0,46	27,4	0,58	26,7
LSD_{05}: A=0,18; B=0,22; AB=0,31						

1.88 t/ha, compared to the crop rotation where sunflower made up 50% of the structure – 1.75 t/ha, was within a significant difference, meaning it was equal.

Fertilization systems had a more intensive effect on sunflower yield in crop rotations where the crop was grown a year after corn. The application of a mineral fertilization system ensured a sunflower yield of 2.18 t/ha, with a yield increase of 0.43 t/ha or 24.3%. Using an organo-mineral fertilization system resulted in the highest sunflower yield, 2.33 t/ha, but the intensity of the action of mineral fertilizers in combination with corn crop residues was slightly lower, +26.7% compared to the monoculture yield, +29.1%.

Taking into account the effect of two factors – the share of sunflower in the crop rotation and the fertilization system – the highest yield was obtained in the crop rotation with up to 50% saturation and the application of an organo-mineral fertilization system – 2.33 t/ha, but the largest yield increase was achieved by applying only mineral fertilizers, +0.51 t/ha or 36.7%. Although corn crop residues promoted the accumulation of more organic matter in sunflower seeds, they suppressed the action of mineral fertilizers.

The productivity of sunflower in terms of grain units, feed units, and digestible protein also depended on the share of sunflower in the crop rotation structure and the application of fertilizers, and there were some tendencies observed in their formation.

In our experiments, the yield grain units was lowest when grown as a monoculture, at 2.79 t/ha. Introducing corn into the crop rotation led to an increase in grain units content to 3.51 t/ha, with an increase due to the crop rotation factor amounting to 0.72 t/ha, according to LSD_{05} = 0.36 t/ha (Table 2).

The mineral fertilization system, which was used for growing sunflower as a monoculture, had the least impact on the yield grain units. Although this indicator increased to 3.33 t/ha, the yield increase in grain units was the smallest - +0.55 t/ha or 19.6%.

The organo-mineral fertilization system provided higher yields grain units both in crop rotations with 100% crop saturation and 50% saturation. In monoculture, the grain unit yield from the crop was at the level of 3.76 t/ha, and when sunflower was grown on the same field after a year, it increased to 4.67 t/ha. However, the yield increase was greater than that of the mineral fertilization system, +1.02 t/ha or 36.7%.

The productivity of sunflower in terms of feed units averaged 1.53–2.57 t/ha over five years of research. The higher yield of feed units was observed in the crop rotation with 50% sunflower saturation. Additionally, the productivity of the crop increased by 0.4 t/ha solely due to the introduction of corn into the crop rotation. It should be noted that the application of an organo-mineral fertilization system in sunflower monoculture led to a feed unit yield of 2.07 t/ha, which is 0.14 t/ha higher than growing sunflower after corn without fertilizers. However, this difference was insignificant (Table 3).

Greater yield of feed units was observed in the crop rotation with 50% sunflower saturation and the organo-mineral fertilization system – 2.57 t/ha. The yield increase in this variant was 0.50 t/ha or 27.3%, while under the mineral fertilization system, it was the highest – +0.56 t/ha or 36.5%.

Our research showed a tendency for the formation of digestible protein in sunflower seeds. The highest his yield was in the crop rotation where sunflower comprised 50% of the structure. The crop rotation factor allowed an increase

Table 2. Yield grain units from sunflower harvest, t/ha

Share of sunflower in crop rotation structure, factor A	Fertilizer system, factor B	Average for 2019–2023	Difference factor A		Difference factor B	
			t/ha	%	t/ha	%
100%	Without fertilizer	2,79	–	–	–	–
	Mineral	3,33	–	–	0,55	19,6
	Organic-mineral	3,76	–	–	0,97	29,2
50%	Without fertilizer	3,51	0,72	21,6	–	–
	Mineral	4,35	1,02	36,7	0,85	24,2
	Organic-mineral	4,67	0,91	27,3	1,16	26,6
LSD_{05}: A=0,36; B=0,44; AB=0,62						

Table 3. Yield of feed units from sunflower harvest, t/ha

Share of sunflower in crop rotation structure, factor A	Fertilizer system, factor B	Average for 2019–2023	Difference factor A		Difference factor B	
			t/ha	%	t/ha	%
100%	Without fertilizer	1,53	–	–	–	–
	Mineral	1,83	–	–	0,30	19,6
	Organic-mineral	2,07	–	–	0,53	29,1
50%	Without fertilizer	1,93	0,39	21,5	–	–
	Mineral	2,39	0,56	36,5	0,47	24,2
	Organic-mineral	2,57	0,50	27,3	0,64	26,7
LSD_{05}: A=0,20; B=0,24; AB=0,34						

in this indicator by 0.14 t/ha or 21.5%, resulting in a yield of 0.66 t/ha of protein compared to monoculture, where the yield of digestible protein was 0.53 t/ha. The application of mineral fertilizers and their combination with organic residues under continuous sunflower cultivation led to an increase in protein yield to 0.63 t/ha and 0.71 t/ha, respectively. Moreover, the yield of digestible protein from the sunflower harvest in monoculture using the organo-mineral fertilization system and in the crop rotation with 50% crop saturation was within a significant difference (Table 4).

Table 4. Yield digestible protein from sunflower harvest, t/ha

Share of sunflower in crop rotation structure, factor A	**Fertilizer system, factor B**	**Average for 2019–2023**	**Difference factor A**		**Difference factor B**	
			t/ha	**%**	**t/ha**	**%**
100%	Without fertilizer	0,53	–	–	–	–
	Mineral	0,63	–	–	0,11	20,1
	Organic-mineral	0,71	–	–	0,18	29,0
50%	Without fertilizer	0,66	0,14	21,5	–	–
	Mineral	0,83	0,19	36,7	0,16	24,7
	Organic-mineral	0,89	0,18	27,8	0,22	27,1
LSD_{05}: A=0,07; B=0,08; AB=0,12						

The highest yield of digestible protein was with 50% sunflower saturation in the crop rotation and the organo-mineral fertilization system – 0.89 t/ha. However, as with previous productivity indicators, a more significant increase in protein was observed under the mineral fertilization system, +0.19 t/ha or 36.7%. The fertilization systems had a more active influence on increasing sunflower productivity regarding the yield of digestible protein in the crop rotation with 50% crop saturation.

Conclusions and prospects for further research. Thus, five years of research on crop rotations of different structures allow us to draw conclusions about the influence of crop rotation factors and fertilization systems on the yield and productivity of sunflower in the conditions of the northern Steppe of Ukraine.

The annual alternation in the crop rotation of sunflower and corn contributed to an increase in sunflower yield to 1.75 t/ha compared to its continuous cultivation, where the yield did not exceed 1.39 t/ha; the yield increase due to the crop rotation factor was 0.36 t/ha or 21.5%.

The factor that had a more significant impact on sunflower yield was the fertilization system. The highest yield was under the organo-mineral fertilization system with 50% sunflower saturation in the crop rotation – 2.33 t/ha. Moreover, the application of mineral fertilizers together with sunflower residues in monoculture neutralized the effect of the crop rotation factor and ensured a yield at the level of crop rotation with alternating crops, 0.71 t/ha.

The most significant yield increase was obtained under the mineral fertilization system, +0.51 t/ha or 36.7%, while under the organo-mineral system, the yield increase was slightly lower – by 0.46 t/ha or 27.4%.

Higher productivity was formed by sunflower plantings in the crop rotation with 50% crop saturation. The crop rotation factor resulted in increased yield grain units, feed units, and digestible protein to 3.51 t/ha, 1.93 t/ha, and 0.66 t/ha respectively; the yield increase compared to sunflower monoculture was 0.72 t/ha, 0.39 t/ha, and 0.14 t/ha.

The increase in sunflower productivity indicators due to the fertilization system factor was even more significant, and under the organo-mineral system with 50% sunflower saturation in the crop rotation, they were the highest: 4.67 t/ha of grain units, 2.57 t/ha of feed units, and 0.89 t/ha of digestible protein.

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УРОЖАЙНІСТЬ ТА ПРОДУКТИВНІСТЬ СОНЯШНИКУ ЗАЛЕЖНО ВІД ЙОГО ЧАСТКИ В СТРУКТУРІ СІВОЗМІНИ

Анотація

Важливість соняшника як основної олійної культури, висока економічна ефективність, насиченість аграрного ринку якісним насінням сучасних гібридів, стійких до несприятливих умов середовища, хвороб та шкідників з високим потенціалом врожайності сприяє підвищенню частки культури в сівозмінах. Не зважаючи на те, що багато дослідників не рекомендують повертати соняшник в сівозміну раніше ніж через п'ять-вісім років, вирощування соняшнику після соняшнику можливе. Однією із основних умов отримання високого врожаю в беззмінних посівах соняшника є ***фон живлення.***

Дослідження проводили з чергування соняшнику та кукурудзи на зерно через рік в двопільній сівозміні та за вирощування соняшнику в монокультурі за різних систем удобрення на полях ІСГС НААН.

Щорічна черговість в сівозміні соняшника та кукурудзи сприяла підвищенню врожайності соняшника до 1,75 т/га порівняно до беззмінного його вирощування, де показник врожайності не перевищував 1,39 т/га, прибавка врожаю за рахунок сівозмінного фактору складала 0,36 т/га або 21,5%.

Більш істотно на врожайність соняшнику впливав фактор система удобрення. Вищий показник врожайності був за органо-мінеральної системи удобрення у сівозміні з насиченням соняшником 50% – 2,33 т/га. До того ж, внесення мінеральних добрив разом з пожнивними рештками соняшника в монокультурі нівелювало дію сівозмінного фактору і забезпечувало врожайність насіння на рівні сівозміни з чергуванням культур, 0,71 т/га.

Найбільшу прибавку врожаю отримали за мінеральної системи удобрення, 0,51 т/га або 36,7%, за органо-мінеральної системи збільшення врожаю було дещо меншим – на 0,46 т/га або 27,4%.

Вищу продуктивність формували посіви соняшника в сівозміні з насичення культурою 50%. Сівозмінний фактор забезпечив збільшення виходу зернових, кормових одиниць та перетравного протеїну до 3,51 т/га, 1,93 т/га та 0,66 т/га відповідно, прибавка врожаю до монокультури соняшнику складала 0,72 т/га, 0,39 т/га та 0,14 т/га.

Збільшення показників продуктивності соняшника за рахунок дії фактору система удобрення було ще більш істотним і за органо-мінеральної системи у сівозміні з насичення соняшником 50% вони були найбільшими, 4,67 т/га зернових одиниць, 2,57 т/га кормових одиниць, 0,89 т/га перетравного протеїну.

Ключові слова: *урожайність, продуктивність, сівозміна, насиченість сівозміни соняшником, система удобрення.*

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