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Productivity of high-oleic sunflower when grown in the conditions of the Southern Steppe of Ukraine

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Abstract. In modern agricultural systems, the basis of cultivation technology and an important factor determining the yield and quality of high-oleic sunflower seeds is regulation of mineral fertilizer rates. Therefore, the determination of their influence on the productivity of the culture determines the relevance of the conducted research. The purpose of the study is to determine the optimal rates of mineral fertilizer application to increase the yield of high-oleic sunflower hybrids in non-irrigated conditions of the Southern Steppe of Ukraine. To achieve the goal, a field study was conducted in the fields of the Mykolaiv State Agricultural Research Station of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine. The subjects of the study are high-oleic sunflower hybrids Kadet, Hektor and Oplot, the originator of which is the V.Ya. Institute of Plant Breeding. Yuryev of the National Academy of Agrarian Sciences of Ukraine. As a result of the study, it was found that when applying $N_{90}P_{90}K_{60}$, the Kadet hybrid formed the largest diameter of the basket – 19.5 cm, under the same feeding conditions, the diameter of the basket in the Hektor and Oplot hybrids was 14.3 cm and 16.4 cm, respectively. The largest mass of 1000 seeds for the level of $N_{90}P_{90}K_{60}$ fertilization was established in the hybrid Cadet – 59.8 g, and at the level of fertilization $N_{30}P_{40}K_{30}$ the lowest mass of 1000 seeds – 41.7 g was formed in the hybrid Hector. In addition, in the high-oleic sunflower hybrid Kadet, the content of crude fat in seeds and oleic acid in oil was the highest compared to other hybrids in all variants of fertilization. The application of mineral fertilizers also

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affected the yield of high-oleic sunflower, so the yield of the Kadet hybrid was 24.1% higher with the application of $N_{90}P_{90}K_{60}$, compared to the variant of application of $N_{30}P_{40}K_{30}$, and the yield of the Hektor and Oplot hybrids was 33.3% and 28%, respectively, which makes it possible to state that the level provision of mineral fertilizers helps to increase crop productivity. The obtained results provide an opportunity to improve the technology of growing high-oleic sunflower under conditions of insufficient moisture, and the perspective of further research may be to study the effect of increased norms of each individual macroelement or their joint effect on the productivity and quality of the high-oleic sunflower crop

Keywords: oil; hybrid; fertilizer; productivity; plant nutrition

INTRODUCTION

High-oleic sunflower is a hybrid variety of sunflower that has a high content of oleic acid in the seeds. Oleic acid is a monounsaturated fatty acid that is more beneficial to human health than other fatty acids such as palmitic and stearic acids. When frying in high-oleic oil, much less so-called trans fats, which can initiate oncological processes, are released. High-oleic oil withstands a greater number of frying cycles, which is valuable when using it in deep-frying, when making margarine from high-oleic oil, 10-15% less energy is required. In addition, high oleic oil is an excellent alternative to olive oil (Ryzhenko *et al.*, 2020).

High-oleic sunflower is grown in many countries, including Ukraine, Kazakhstan, Canada, the USA, and others. High-oleic sunflower is an important crop not only for oil production, but also for use in the feed sector, as well as as an energy crop for biofuel production, which increases the importance and relevance of conducting research on its productivity. The productivity of high-oleic sunflower can vary depending on growing conditions, such as soil, climate, humidity level, presence of pests and diseases.

Thus, in their work, S. Kalenska *et al.* (2020) claim that in Ukraine, high-oleic sunflower can yield from 2.5 to 4 tons per hectare. Productivity depends on many factors, including the quality of the seed, the use of mineral fertilizers and the application of the irrigation system.

I. Kolosok (2022) believes that to increase the productivity of sunflower, it is important to use high-quality seeds and apply the necessary amounts of mineral fertilizers, especially nitrogen, phosphorus and potassium. It is also important to maintain a sufficient level of soil moisture and protect plants from pests and diseases.

A similar opinion is expressed by J. Akuaku *et al.* (2020), who claim that fertilization can have a positive effect on the yield of high-oleic sunflower. Thus, according to the research carried out by the authors, it was established that the introduction of fertilizers with an increased content of phosphorus and potassium in areas with high-oleic sunflower led to an increase in productivity by 6-8%. In addition, research by R. Vozhegova *et al.* (2013) proved that the correct cultivation technology can also lead to an increase in the yield of high-oleic sunflower by 15-20%.

It is worth noting that a number of scientists, in particular O. Kovalenko *et al.* (2021), agree that an important factor that can affect the performance of high-oleic sunflower is the use of proper agricultural practices, such as proper soil preparation, pre-sowing seed treatment, regular watering and supplemental plant nutrition. These aspects add importance and relevance to the study of the formation of productivity of high-oleic sunflower depending on the elements of cultivation.

The sunflower fertilization system takes into account specific growing conditions and plant needs, since there is no universal approach to providing fertilizers to the crop. Taking into account such factors as climatic conditions, soil properties, physiological features of the sunflower hybrid, it is recommended to use an individual approach to providing nutrients.

Since the issue of mineral nutrition of high-oleic sunflower hybrids in conditions of insufficient moisture remains incompletely studied, the purpose of the study is to determine the effect of fertilizers on yield, the content of crude fat in seeds and the content of oleic acid in the oil of high-oleic sunflower.

MATERIALS AND METHODS

To determine the productivity of high-oleic sunflower, a field experiment was conducted using laboratory and field observations of the growth and development of hybrids of the culture grown under different conditions of mineral fertilization. The research was carried out in the fields of the Mykolaiv State Agricultural Research Station of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine in 2020-2022.

The study was carried out on the southern chernozem in the carbonate forest, this type of soil is characterized by the presence of a high content of potassium, medium – phosphorus and insufficient – nitrogen. It is a medium-loamy soil with a mechanical composition characterized by a humus horizon thickness of up to 50-70 cm and a humus content of 3.6%. The content of

easily hydrolyzed nitrogen is about 0.1-0.5 mg per 100 g of soil, mobile forms of phosphorus – 8.7-9.5 mg per 100 g of soil, the amount of exchangeable potassium – 30.2 mg per 100 g of soil. The pH value of the soil is 7.5.

The objects of the study were three hybrids of high-oleic sunflower: Cadet, Hector and Oplot, the originator of which is the Institute of Plant Breeding named after V.Ya. Yuryev of the National Academy of Agrarian Sciences of Ukraine.

Since climatic factors are of great importance for the formation of the high-oleic sunflower crop, it should be noted that the territory on which the study was carried out belongs to the zone of insufficient moisture, and during the research, all years were characterized by a lack of moisture.

The experiment was repeated three times, the total size of the plot was 300 m^2, the area of the accounting plot was 90 m^2. The predecessor of sunflower is winter wheat. Sunflower hybrids were sown between April 25 and 30, the sowing rate is 50,000 similar seeds per hectare.

In all variants of the experiment, organic fertilizer (manure) was applied to the soil under field plowing before sowing sunflower at the rate of 25 t/ha, and 2/3 of the norm of phosphorus and potassium fertilizers was applied under field tillage, and 1/3 of the norm in the spring for cultivation nitrogen 1/3 of the norm of phosphorus and potash and the remaining 2/3 of nitrogen fertilizers were applied 2 weeks after sowing as top dressing according to the experimental scheme: I option – $N_{30}P_{40}K_{30}$, II – $N_{40}P_{60}K_{60}$, III – $N_{90}P_{90}K_{60}$. Urea was used as a nitrogen fertilizer, granulated superphosphate as a phosphorous fertilizer, and potassium chloride as a potassium fertilizer.

Data on sunflower growth parameters, such as the diameter of the basket and the weight of 1000 seeds, were obtained directly during harvesting by measurement and weighing. The content of crude fat in seeds is determined by the defatted residue (according to Rushkovsky), the content of oleic acid in oils – by the refractometric method. Calculation of sunflower productivity was carried out manually, from each plot. In addition, during the data analysis, a statistical analysis was conducted to determine the average and relative values of the influence of the mineral fertilizer level on the yield of sunflower hybrids and a comparative analysis to compare the data obtained for 2020-2022.

All experiments were repeated three times for each variant of the experiment. Processing of the obtained research results for reliability was carried out using the multivariate MANOVA method of variance analysis using Microsoft Excel software and the Statistica 10 program package. Differences in the obtained results are possible at the level of significance $P \leq 0.05$ according to the Student's test.

RESULTS

One of the key aspects of the high-oleic sunflower fertilization system is the provision of sufficient amounts of macro- and micronutrients to meet plant needs. Organic and mineral fertilizers can be used for this.

Usually, the high-oleic sunflower fertilization system involves the introduction of complex mineral fertilizers that contain nitrogen, phosphorus and potassium, as well as trace elements necessary to ensure normal growth and development of plants. It is important to consider that the distribution of fertilizers must be balanced and meet the needs of plants, soil and climatic conditions, as well as take into account the loss of fertilizers due to evaporation, washing and other factors. When applying fertilizers to various agricultural crops, in particular, to high-oleic sunflower, it should be noted that the maximum result is achieved only with the correct selection of optimal doses and types of fertilizers, which are applied in the most optimal phase of crop vegetation (Trotsenko *et al.*, 2020).

Fertilizer helps to increase the resistance of agricultural crops to adverse environmental factors, which directly affects the increase in their productivity. Without proper and timely application of nutrients, high-oleic sunflower will grow slowly, and its seeds will be small. In addition, an insufficient amount of nutrients in the soil can lead to a decrease in the growth and development of sunflower plants, and the plant itself can be affected by pests and diseases (Tsyliuryk *et al.*, 2021).

It is important to note that sunflower fertilization can significantly affect the quality of the crop. The optimal rate and type of fertilizers, their timing and method of application can determine the quantity and quality of seeds, as well as the content of fatty acids in them, which plays an important role in shaping the quality of sunflower oil (Melnyk *et al.*, 2019).

One of the tasks of the research was to study the features of mineral nutrition of high-oleic sunflower and its fertilizer needs, therefore it is important to note that one ton of grown high-oleic sunflower yields approximately 8 kg of nitrogen, 3 kg of phosphorus and 15 kg of potassium, and mineral fertilizer provides a culture of macro- and trace elements in the most vulnerable phases of development: seedlings, budding, as well as the seed filling phase.

Nitrogen is a key element for stimulating the growth and development of high-oleic sunflower plants, increasing its photosynthetic activity, as well as for the formation of large and high-quality seeds. Phosphorus is an important element for energy processes in plants, promotes the development of the root system, the formation of seeds, as well as increasing the yield of crops. Potassium is necessary to maintain the water balance, affects the resistance of plants to stressful

conditions, the development of flower buds, as well as the formation of seeds and the improvement of their quality (Kovalenko *et al.*, 2021).

In the conducted research, the introduction of different rates of mineral fertilizers on the studied hybrids of high-oleic sunflower had a significant impact on the indicators of the crop yield structure for three years, namely the diameter of the basket and the weight of 1000 seeds.

The sunflower basket is the main reproductive organ of the plant, where seeds are formed, so its size and structure are important for the formation of crop yield. In addition, the diameter of the basket can be an important indicator when determining the quality and quantity of seeds, as well as for determining the efficiency of sunflower cultivation technology in general.

Thus, in the course of the study, it was established that the largest sunflower basket diameter at the $N_{90}P_{90}K_{60}$ fertilizer level was formed by the Kadet hybrid – 19.5 cm, the Hektor and Oplot hybrids under the same feeding conditions formed smaller baskets by 5.2 cm and 3.1 cm, and were 14.3 cm and 16.4 cm, respectively (Table 1).

It is worth noting that the application of mineral nutrition also affected the mass of 1000 sunflower seeds, despite the fact that this is a genetically determined feature. Thus, at the $N_{30}P_{40}K_{30}$ level of fertilization, the smallest mass of 1,000 seeds was established in the Hector hybrid, which was 41.7 g. The highest mass of 1,000 seeds at the $N_{90}P_{90}K_{60}$ fertilization level was formed by the Kadet hybrid, which was 59.8 g.

So, with the application of $N_{90}P_{90}K_{60}$, the diameter of the sunflower basket in the Kadet hybrid was 23.4% greater than with the application of $N_{30}P_{40}K_{30}$, and the weight of 1000 seeds was 29.2%, respectively. Thus, the increase in the structural parameters of the high-oleic sunflower crop in the study occurred due to the supply of sufficient nutrients from mineral fertilizers, which affected the growth and development of plants.

Table 1. *Basket diameter and weight of 1,000 seeds of sunflower hybrids (average for 2020-2022)*

High-oleic sunflower hybrid	Fertilizer application scheme	Basket diameter, cm	Weight of 1000 seeds, g
Cadet	$N_{30}P_{40}K_{30}$	15.8	46.3
	$N_{40}P_{60}K_{60}$	16.6	56.3
	$N_{90}P_{90}K_{60}$	19.5	59.8
Hector	$N_{30}P_{40}K_{30}$	10.3	41.7
	$N_{40}P_{60}K_{60}$	12.7	46.5
	$N_{90}P_{90}K_{60}$	14.3	49.6
Oplot	$N_{30}P_{40}K_{30}$	10.3	48.7
	$N_{40}P_{60}K_{60}$	12.7	51.3
	$N_{90}P_{90}K_{60}$	16.4	54.9

Source: *developed by the authors*

The results also established that the application of mineral fertilizers had a significant effect on sunflower yield indicators. On average, over three years, the highest yield was formed in the Kadet and Oplot hybrids, and amounted to 3.6 t/ha and 3.2 t/ha, respectively, when applying $N_{90}P_{90}K_{60}$, the yield of the Hector hybrid at the same level of fertilizer was 2.8 t/ha, which was 0.8 t/ha and 0.4 t/ha lower than that of the Kadet and Oplot hybrids, respectively (Table 2). Thus, the yield of the Kadet hybrid with the application of $N_{90}P_{90}K_{60}$ was 24.1% higher than with the application of $N_{30}P_{40}K_{30}$, and the yield of the Hektor and Oplot hybrids was 33.3% and 28%, respectively, which indicates that the level of mineral fertilizer supply increases the productivity of high-oleic sunflower.

Table 2*. Yield of sunflower hybrids, t/ha*

High-oleic sunflower hybrid	Fertilizer application scheme	Year			Average during 2020-2022
		2020	2021	2022	
Cadet	$N_{30}P_{40}K_{30}$	2.6	3.1	2.9	2.9
	$N_{40}P_{60}K_{60}$	2.9	3.2	3.4	3.2
	$N_{90}P_{90}K_{60}$	3.4	3.8	3.6	3.6
$HIP_{0.05}$		1.24	1.47	1.33	1.47
Hector	$N_{30}P_{40}K_{30}$	1.9	2.2	2.3	2.1
	$N_{40}P_{60}K_{60}$	2.1	2.5	2.3	2.3
	$N_{90}P_{90}K_{60}$	2.8	3.1	2.6	2.8

Table 2, Continued

High-oleic sunflower hybrid	Fertilizer application scheme	Year 2020	2021	2022	Average during 2020-2022
$HIP_{0.05}$		1.62	1.43	1.31	1.62
Oplot	$N_{30}P_{40}K_{30}$	2.4	2.5	2.6	2.5
	$N_{40}P_{60}K_{60}$	2.6	3.1	2.7	2.8
	$N_{90}P_{90}K_{60}$	3.1	3.3	3.2	3.2
$HIP_{0.05}$		1.62	1.47	1.53	1.23

Source: *developed by the authors*

Based on the obtained yield data, it is important to note that high-oleic sunflower is sensitive to an increase in nitrogen and phosphorus fertilizers, since the increase in yield between the $N_{40}P_{60}K_{60}$ and $N_{90}P_{90}K_{60}$ norms of the Kadet hybrid was 12.5%, and the Hektor and Oplot hybrids were 21.7% and 14.3%, respectively.

Indicators of the quality of oil raw materials are a very important element of the characteristics of sunflower products. This is due to the fact that oil feedstock is the main component used to produce sunflower seed oil. Also, these indicators make it possible to evaluate oil raw materials and determine whether they are suitable for the production of high-quality sunflower oil.

The crude fat content of sunflower seeds is the amount of fat-like substances contained in one gram of seeds. Oleic acid is a monounsaturated fatty acid that is one of the main fatty acids found in sunflower oil.

Therefore, the content of crude fat in seeds and the amount of oleic acid in sunflower oil are important indicators for the productivity and quality of high-oleic sunflower. To improve these indicators, it is necessary to use sunflower varieties and hybrids that have a high content of oleic acid and to carry out proper plant care, including regular watering and application of necessary mineral fertilizers.

In the conducted research, it was established that mineral fertilizers, in addition to the yield of sunflower seeds, also affect the content of crude fat in them. Thus, the influence of mineral nutrition on the content of crude fat in seeds and oleic acid in high-oleic sunflower oil was studied using a laboratory method. The obtained data indicate that different fertilization rates can increase these quality indicators. Thus, the content of crude fat in seeds and oleic acid in sunflower oil gradually increased with the introduction of higher rates of nitrogen, phosphorus and potassium. The Kadet sunflower hybrid has the highest content of both crude fat in seeds and oleic acid in oil compared to Hektor and Oplot hybrids in all fertilization options. The lowest content of crude fat in seeds – 36.9% and oleic acid in oil – 76.7% was noted in the hybrid Hector in the variant of application of mineral fertilizers $N_{30}P_{40}K_{30}$ (Table 3).

Table 3*. Content of crude fat in seeds and oleic acid in sunflower oil, % (average for 2020-2022)*

High-oleic sunflower hybrid	Fertilizer application scheme	Crude fat content	Oleic acid content
Cadet	$N_{30}P_{40}K_{30}$	44.8	84.8
	$N_{40}P_{60}K_{60}$	46.6	85.4
	$N_{90}P_{90}K_{60}$	47.4	87.3
Hector	$N_{30}P_{40}K_{30}$	36.9	76.7
	$N_{40}P_{60}K_{60}$	38.2	78.4
	$N_{90}P_{90}K_{60}$	39.3	80.6
Oplot	$N_{30}P_{40}K_{30}$	42.3	80.7
	$N_{40}P_{60}K_{60}$	44.1	81.5
	$N_{90}P_{90}K_{60}$	45.2	83.2

Source: *developed by the authors*

Thus, according to the obtained results, the indicators of crop texture, quality characteristics of high-oleic sunflower seeds and oil, as well as its yield are significantly influenced by the rates of mineral fertilizers.

However, to determine the reliability of the obtained results, a correlation-regression analysis was performed. This statistical method is a powerful tool used to determine relationships between two or more variables. In the case of the performed study, correlation-regression analysis was used to determine the relationship between the application of mineral fertilizers and the yield of high-oleic sunflower hybrids.

Also, this analysis will make it possible to build a model that predicts the yield of hybrids depending on the use of mineral fertilizers.

According to the conducted correlation-regression analysis, a tendency to increase the yield of high-oleic sunflower hybrids in case of an increase in the level of mineral fertilizers was revealed. The reliability value for the Cadet hybrid is R=0.9932, for the Hector hybrid R=0.9423, and for the Oplot hybrid R=0.9932, which means that the model accurately describes the available data (Fig. 1).

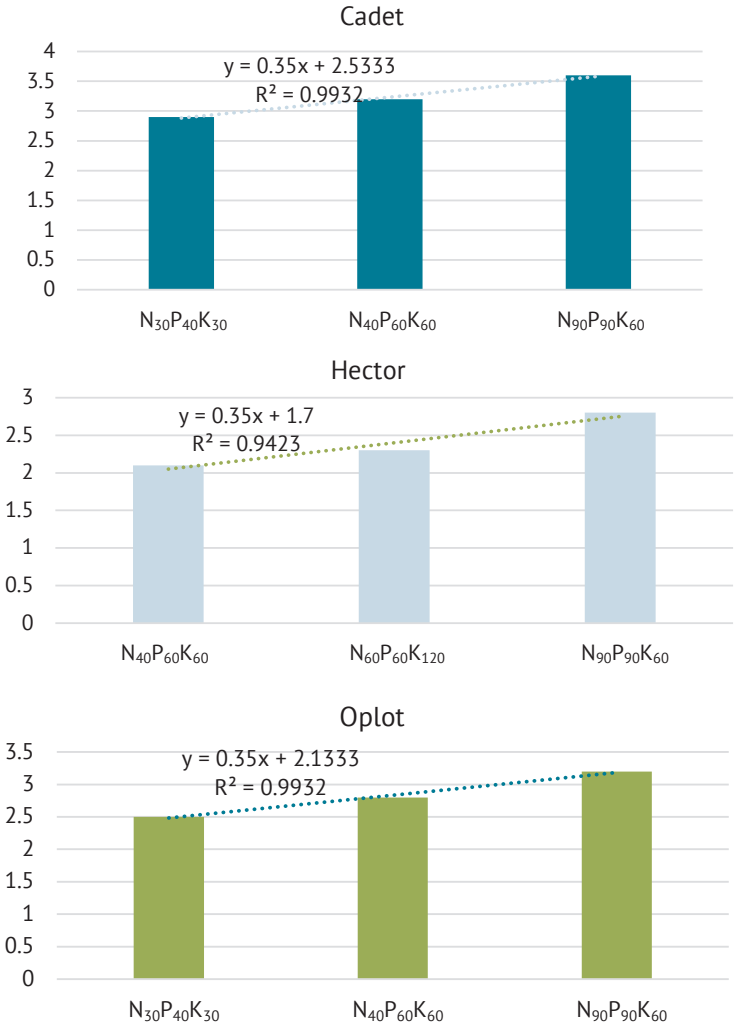

Figure 1. *Correlation-regression analysis of the effect of mineral fertilizers on the yield of high-oleic sunflower hybrids (average for 2020-2022)*

Source: *developed by the authors*

So, the obtained research results confirm that the relationship between the application of mineral fertilizers and the productivity of high-oleic sunflower is linear and directly proportional. Therefore, it is possible to recommend an increase in the amount of mineral fertilizers to achieve higher productivity of high-oleic sunflower. However, at the same time, recommendations for the application of mineral fertilizers should be followed to avoid their excessive use, which can affect both the quality of high-oleic sunflower products and the environment.

Thus, in the course of the study, it was established that increasing the rates of mineral fertilizers can affect the increase in the diameter of the basket, the weight of 1000 seeds, the content of crude fat in the seeds and oleic acid in the oil of high-oleic sunflower, as well as obtaining an increase in yield even under arid climatic conditions.

This allows us to state that in the conditions of insufficient moisture on the southern chernozem in the carbonate forest, preference should be given to the Kadet hybrid in the cultivation of high-oleic sunflower, and the optimal level of mineral fertilizer is $N_{90}P_{90}K_{60}$.

DISCUSSION

The technology of growing high-oleic sunflower is an important factor affecting its productivity. The crop

fertilization system includes the application of various types of fertilizers. This is due to the fact that high-oleic sunflower plants require large amounts of nutrients for their growth and development, most of which they cannot obtain from the soil in sufficient quantities.

Insufficient soil nutrients can lead to reduced yields, reduced seed quality, and increased risk of disease and pests. Therefore, it is important to provide high-oleic sunflower hybrids with a sufficient level of nutrients by applying fertilizers in the right amount and at the optimal time.

M. Duca *et al*. (2022) believe that the high-oleic sunflower fertilization system includes the application of various types of fertilizers with different concentrations and amounts depending on agrotechnical measures, soil type, climatic conditions, and other factors. The main elements of sunflower fertilizer are nitrogen, phosphorus, potassium and trace elements.

According to B. Casali *et al*. (2022), combining the use of organic fertilizers with mineral fertilizers, it is possible to obtain the most effective way of increasing the productivity of high-oleic sunflower, which is also reflected in the performed research. But in order to achieve a high crop yield, the nutrient regime of the soil must be improved in accordance with the needs of the crop, as well as to maintain the fertility of the soil itself.

V. Giannini *et al*. (2022) believe that organic fertilizers can contain nitrogen, phosphorus, potassium and other nutrients that decompose gradually and provide long-term effects on sunflower growth. Inorganic fertilizers usually contain large amounts of macronutrients and can quickly improve the condition of the crop. According to T. Howell *et al*. (2015), the system of fertilization of high-oleic sunflower can also use such organic fertilizers as compost, humus, humates, etc., which help to increase soil fertility and improve its structure.

A. Jan *et al*. (2022) in their works note that when growing high-oleic sunflower, it is recommended to apply starter fertilizers that contain phosphorus and potassium. Yes, you can apply 80-120 kg/ha of superphosphate and 60-80 kg/ha of potassium chloride. And during the development of the plant, it is necessary to make additional fertilizers, as top dressing, especially nitrogen, which will contribute to the formation of more seeds. To do this, you can apply up to 150 kg/ha of ammonium nitrate or 200 kg/ha of urea, which is also reflected in the performed research.

C. Nobile *et al*. (2020) notes that in order to reduce the negative impact of fertilizers on the environment and reduce the costs of fertilizers, it is possible to apply systems of precision agriculture and balanced fertilizer supply using modern technologies and equipment.

A. Ryzhenko *et al*. (2020) believe that the formation of the basket diameter of high-oleic sunflower can be significantly influenced by the fertilization system. Thus, the introduction of nitrogen fertilizers can help increase the diameter of the basket, since nitrogen is a key element for the growth of plants and the formation of their organs, including the basket. With an insufficient level of nitrogen in the soil, the plant can be limited in its growth and development, which can lead to a decrease in the size of the basket, which also confirms the performed research.

However, V. Trotsenko *et al*. (2020) point out that it is worth considering that excessive application of nitrogen fertilizers can also have a negative effect on plant development and crop quality. Excessive amounts of nitrogen can increase the height of the plant, but this will not always be accompanied by a corresponding increase in the size of the basket, as well as an increase in the moisture content of the plant and an increase in the risk of disease and pests.

The research results are echoed in the scientific works of O. Tsyliuryk *et al*. (2021) who state that the fertilization system can affect the mass of 1000 high-oleic sunflower seeds. The authors established that the application of phosphorus fertilizers can improve the formation and development of the plant's root system and provide energy for its growth, which in turn affects the mass of seeds. Potassium is an important element for the development of plants and maintaining their resistance to stressful conditions such as drought and low temperatures. An insufficient level of potassium in the soil can lead to a decrease in the mass of seeds and the overall yield of sunflower, which is also demonstrated by the results of the performed study.

The results of the conducted research are also confirmed in the scientific works of O. Kovalenko *et al*. (2021), who claim that in the conditions of the Southern Steppe of Ukraine, high-oleic sunflower can demonstrate a sufficiently high yield under justified norms of mineral nutrition.

However, R. Vozhegova *et al*. (2013) point out that excessive application of fertilizers in sunflower cultivation technology can have a negative impact on plant development, seed quality and yield, therefore, in order to ensure optimal values of crop structure indicators and overall productivity, it is important to follow the balance of application of different types of fertilizers and recommendations regarding their rates.

Research by Z. Flagella *et al*. (2002) showed that different rates and composition of mineral fertilizers can have different effects on the content of crude fat in seeds and oleic acid in sunflower oil. For example, the use of fertilizers containing nitrogen and phosphorus can contribute to an increase in the crude fat content of the seeds, while the use of fertilizers containing potassium can contribute to an increase in the oleic acid content of sunflower oil.

Similar results were also obtained in the studies of E. Domaratsky *et al.* (2018), in which the authors claim that the application of nitrogen fertilizers in a complex with phosphate and potassium fertilizers increases the content of crude fat in seeds and the amount of oleic acid in sunflower oil. However, according to the results of P. Deepika & D. Ali (2020), the use of nitrogen fertilizers can contribute to an increase in crude fat content, while the use of phosphoric fertilizers can have the opposite effect, in which the content of crude fat in seeds decreases.

Therefore, B. Li *et al.* (2022) note that the effect of fertilizers on crude fat and oleic acid content may depend on many factors, such as soil type, climatic conditions, and high-oleic sunflower hybrids used. Therefore, in order to obtain the best results, it is necessary to take into account all these factors when applying fertilizers and carrying out agrotechnical measures. Thus, the effect of fertilization on the content of crude fat in seeds and oleic acid in high-oleic sunflower oil can be complex and depend on a complex of factors that requires additional study.

Taking into account the mentioned research of the authors, as well as the results of the conducted research, it can be stated that the increase in the productivity of high-oleic sunflower depends on the use of mineral fertilizers, therefore, it is necessary to observe their rational introduction when growing the crop.

CONCLUSIONS

In order to achieve the maximum productivity of high-oleic sunflower, it is necessary to use agricultural methods that include the introduction of nutrients for additional enrichment of the soil with the necessary macro- and microelements. As a result of the research, it was established that at the $N_{90}P_{90}K_{60}$ fertilizer level, the largest diameter of the basket – 19.5 cm was formed in the Kadet hybrid, this indicator was 14.3 cm and 16.4 cm in the Hektor and Oplot hybrids under the same feeding conditions, respectively.

The highest mass of 1000 seeds at the $N_{90}P_{90}K_{60}$ fertilization level was established in the high-oleic sunflower hybrid Kadet – 59.8 g, and at the $N_{30}P_{40}K_{30}$ fertilization level, the smallest mass of 1000 seeds, which was 41.7 g, was formed in the Hector hybrid. The content of crude fat in the seeds and oleic acid in the oil in all variants of fertilization was the highest in the high-oleic sunflower hybrid Kadet compared to the hybrids Hektor and Oplot.

The application of mineral fertilizers affected the yield of sunflower, so with the application of $N_{90}P_{90}K_{60}$, the yield of the Kadet hybrid was 24.1% higher than with the application of $N_{30}P_{40}K_{30}$, and the yield of the Hektor and Oplot hybrids was 33.3% and 28%, respectively, which indicates that the level of provision of mineral fertilizers contributes to increasing the productivity of high-oleic sunflower.

The conducted correlation-regression analysis of high-oleic sunflower productivity data determined a tendency to increase this indicator in the event of an increase in the level of mineral fertilizers. Therefore, the prospect of further research may be to study even higher levels of each individual macroelement, as well as their joint impact on the yield structure and quality of the high-oleic sunflower crop.

Thus, it was established that increasing the rates of mineral fertilizers can influence the increase in the indicators of the structure of the crop of high-oleic sunflower and obtaining an increase in its yield even under adverse arid climatic conditions. However, it is important to follow the fertilizer recommendations to avoid deterioration in the quality of crop products.

Therefore, in order to increase the production and genetic potential of high-oleic sunflower hybrids in conditions of insufficient moisture, it is advisable to use mineral fertilizers under the condition of their rational application. The practical significance of the obtained results makes it possible to improve the technology of growing high-oleic sunflower in farms of various forms.

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CONFLICT OF INTEREST

None.

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Продуктивність високоолеїнового соняшнику при вирощуванні в умовах Південного Степу України

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Анотація. У сучасних системах землеробства основою технології вирощування та важливим фактором, що визначає врожайність та якість насіння високоолеїнового соняшнику, є регулювання норм мінеральних добрив. Тому визначення їх впливу на продуктивність культури зумовлюють актуальність проведеного дослідження. Мета дослідження – визначити оптимальні норми внесення мінеральних добрив для підвищення врожайності гібридів високоолеїнового соняшнику в незрошуваних умовах Південного Степу України. Для досягнення мети проведено польове дослідження на полях Миколаївської державної сільськогосподарської дослідної станції Інституту зрошуваного землеробства Національної академії аграрних наук України. Об'єкти дослідження – гібриди високоолеїнового соняшнику Кадет, Гектор та Оплот, оригінатором яких є Інститут рослинництва імені В.Я. Юр'єва Національної академії аграрних наук України. В результаті дослідження встановлено, що при внесенні $N_{90}P_{90}K_{60}$ гібрид Кадет сформував набільший діаметр кошику – 19.5 см, за тих же умов живлення у гібридів Гектор та Оплот діаметр кошику становив відповідно 14.3 см та 16.4 см. Набільша маса 1000 насінин за рівня удобрення $N_{90}P_{90}K_{60}$ встановлена у гібриду Кадет – 59.8 г, а за рівня удобрення $N_{30}P_{40}K_{30}$ найменша маса 1000 насінин – 41.7 г сформувалась у гібриду Гектор. Крім того, у гібриду високоолеїнового соняшнику Кадет вміст сирого жиру в насінні та олеїнової кислоти в олії у всіх варіантах внесення добрив був найвищим порівняно до інших гібридів. Внесення мінеральних добрив вплинуло й на врожайність високоолеїнового соняшнику, так урожайність гібриду Кадет була на 24.1 % вищою за внесення $N_{90}P_{90}K_{60}$, у порівнянні до варінту внесення $N_{30}P_{40}K_{30}$, а врожайність гібридів Гектор та Оплот на 33.3 % та 28 % відповідно, це уможливлює стверджувати, що рівень забезпечення мінеральними добривами сприяє підвищенню продуктивності культури. Отримані результати дають можливість удосконалити технологію вирощування високоолеїнового соняшнику за умов недостатього зволоження, а перспективою подальших досліджень може бути вивчення дії підвищених норм кожного окремого макроелемента чи їх спільного впливу на продуктивність та якість урожаю високоолеїнового соняшнику

Ключові слова: олія; гібрид; добриво; врожайність; живлення рослин