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The realisation of the genetic potential of sunflower hybrids under the influence of feeding conditions

Abstract. The use of microfertilisers against the background of the main fertiliser helps to increase the efficiency of using nutrients of mineral fertilisers and soil by plants, which ensures an increase in yield and an improvement in the quality indicators of the grown crop. The purpose of the study was to establish the influence of crop nutrition conditions and select highly productive hybrids (NK Diamantis, SI Kupava, NK Neoma) for specific soil and climatic conditions through the formation of their productivity. Field studies were conducted during 2018-2019 on typical low-humus chernozems of the Chernihiv region. The study programme provided for the laying of a three-factor field experiment, in which hybrids (factor A) fertiliser options (Factor B), and foliar top dressing (factor C) were examined in the phases of 4 and 8 sunflower leaves with Ecoline Boron, Nertus Boron, Bast Boron products. Sunflower hybrids under study are NK Diamantis, SI Kupava, and NK Neoma. Studies showed that the most productive was the SI Kupava hybrid with the maximum yield indicator in the option with the application of $N_{36}R_{56}K_{108}S_{28} + N_{23}$ + Ecoline Boron (in the phases of 4 and 8 leaves of 1 l/ha) – 3.46 t/ha. The fat content in sunflower seeds was determined by the morphobiological features of the hybrid and fertiliser options. The use of foliar top dressing with microelements had a positive effect on the fat content in the seeds of sunflower hybrids, which allowed obtaining the maximum indicator in the option with the application of $N_{36}R_{56}K_{108}S_{28} + N_{23}$ + Ecoline Boron (5-6 leaves) in plants of the SI Kupava hybrid – 51.1%. The maximum content of oleic acid was identified in the SI Kupava hybrid in the option with added $N_{27}R_{42}K_{81}S_{21} + N_{23}$ + Ecoline Boron (5-6 leaves) – 77.2%. Due to the use of fertilisers containing boron, the content of this polyunsaturated acid can be increased, improving the quality indicators of sunflower seed oil. The highest oil yield, according to the

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calculations performed, was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}$+$N_{23}$ + Ecoline Boron (5-6 leaves) in plants of the SI Kupava hybrid, which amounted to 1.64 tonnes per 1 hectare

Keywords: sunflower; hybrids; nutrients; Boron; Ecoline Boron; Nertus Boron; Bast Boron; yield; fat content; protein content; oleic acid content

INTRODUCTION

Today, sunflower has become a conventional crop for modern agricultural business in Ukraine. This is mainly due to the stable demand of foreign markets for sunflower oil, which led to the formation of attractive purchase prices for producers of the internal market for seeds of the crop, which contributed to the expansion of acreage and the introduction of modern technologies for its cultivation. It is for this reason that the culture remains attractive to producers.

Factors that can ensure the formation of high crop yields include plant nutrition conditions throughout the growing season and technological measures aimed at realising the genetic potential of the crop in certain regions of Ukraine. It is necessary today to thoroughly examine the potential possibilities of hybrids and varieties for cultivating them in different growing conditions to identify their competitiveness and popularise them, which will increase the quality and yield indicators of the crop in general (Eremenko, O., Kalenska, S., & Pokoptseva, L. *et al.*, 2019; Ieremenko, O. & Kalitka, V., 2016).

That is why today much attention is paid to examining the influence of feeding conditions on the formation of productivity of hybrids, both foreign and Ukrainian selection, in specific soil and climatic conditions of Ukraine (Kalenska, Ryzhenko & Novytska *et al.*, 2020; Domaratskiy, Bazaliy *et al.*, 2018).

The efficiency of oilseed production in Ukraine in recent years has led to problems associated with the oversaturation of sunflower crop rotations. An increase in the production of sunflower seeds can be conducted due to the improvement of elements of its cultivation technology, and the rational use of fertilisers is important for it. The effectiveness of applying mineral fertilisers on sunflower crops in different agroclimatic zones varies (Havryliuk, 2007; Totskyi, 2014).

ANALYSIS OF RECENT STUDIES AND PAPERS

Recently, a substantial number of sunflower varieties and hybrids with high productivity potential have been added to the State register of plant varieties suitable for distribution in Ukraine. However, the realisation of this potential occurs only partially (Ieremenko, Kalitka & Kalenska, 2017; Bondarenko, Korytnyk & Pysmennyi, 2002).

Technological processes for growing a crop are determined by the characteristics of its variety or hybrid, agrobiological features, which include requirements for growing conditions and information about the influence of the crop on soil properties, depending on the characteristics of biology and agricultural technology.

Along with this, preference for growing sunflower seeds is given to hybrids of foreign selection. The advantages of the seed material of these hybrids are the ability to form high crop productivity. However, it should be considered that these hybrids are inferior to the resistance of Ukrainian ones to a number of pathogens characteristic of the climatic conditions of sunflower-growing regions in Ukraine. Features of the formation of productivity of hybrids and varieties of crops, their plasticity and adaptability to soil and climatic conditions are the determining factor in the case of their choice (Alves *et al.*, 2017).

The selection of varieties and hybrids, the features of the formation of reproductive organs of the crop and the quality indicators of the formed seeds are considered (Markova, 2011; Havryliuk *et al.*, 2007).

Auxiliary elements in crop cultivation technologies have now become relevant to increase sunflower productivity, in particular, seed inoculation with microbial-based preparations, and foliar top dressing with biologics and microfertilisers. The preference is often given to complex fertilisers with a full set of nutrients necessary to create optimal conditions for plant nutrition at certain stages of their growth and development (Bailly *et al.*, 2016; Calvo, Nelson, Kloepper, 2014; Domaratsky & Dobrovolsky 2018; Yeremenko & Kalytka, 2016; Luhmenev, 2015).

The effectiveness of mineral fertilisers depends both on the ratio of nutrients and on their forms. With the same amount of active substance, different forms of fertilisers provide different results, which is due to the physiological characteristics of fertilisers and plants.

Creating optimal conditions for crop nutrition ensures the formation of an optimal leaf surface area and maximum realisation of the genetic potential of sunflower hybrids and varieties (Kalenska, Gorbatyuk, Garbar, 2020; Helmy & Ramadan, 2009).

The crop fertilisation system is determined considering a number of factors. It should be considered that sunflower plants take substantially higher amounts of nitrogen and phosphorus from the soil compared to other agricultural crops.

Due to the long period of consumption of nutrients, the crop requires a much larger amount of them compared to the group of grain crops.

Notably, sunflowers need a different amount of nutrients at different stages of their growth and development: the overwhelming amount of nitrogen and phosphorus is consumed before the flowering phase and the formation of the leaf apparatus, stems, and root system; after the appearance of baskets, phosphorus absorption decreases sharply; potassium is absorbed by sunflower throughout the growing season.

Food elements have different effects on growth, development, crop formation, and product quality: nitrogen enhances growth processes and promotes the formation of larger baskets. However, excessive nitrogen nutrition leads to an extension of the growing season, and has a negative impact on the processes of oil accumulation in seeds, while increasing the protein content in it. If there is an excess of nitrogen and a sufficient amount of moisture, there is a possibility of lodging of plants and their damage by pathogens (Phomopsis, white rot, etc.) (Melnyk, Stepanenko, 2000; Shakaliy, 2017).

Sunflowers need phosphorus from germination to flowering. The element accumulates before the flowering phase in the stem and leaves, and later it moves to generative organs. Plants absorb up to 70% of their phosphorus needs during the basket formation period – the end of flowering. The lack of phosphorus has a negative impact on the formation and filling of achenes and limits the productivity of sunflower seeds. Phosphorus increases the drought resistance of plants and the oil content of seeds, ensures the formation of a powerful root system, and promotes the laying of reproductive organs.

Enhanced phosphorous nutrition reduces the water consumption coefficient of sunflower plants (Yeremenko *et al.*, 2017; Buldykova, Sheudzhen & Bondareva, 2015).

The purpose of the study is to establish the influence of factors that were examined on the formation of yield and quality indicators of sunflower hybrid seeds.

MATERIALS AND METHODS

Studies were conducted during 2018-2019 on typical low-humus chernozems in the conditions of the Chernihiv region.

In accordance with this goal, a study programme and a field experiment scheme were developed (Table 1). The scheme of the experiment included the examination of hybrids (factor A), fertiliser options (Factor B), and the use of foliar top dressing of crops (factor C) in the phases of 4 and 8 sunflower leaves.

Table 1. Formation of sunflower productivity elements (experiment scheme)

Hybrids (factor A) / option designation	Fertiliser options (Factor B) / option designation	Foliar use of protective products (factor C) / option designation
1. NK Diamantis, 2. SI Kupava, 3. NK Neoma	1. $N_{27}R_{42}K_{81}S21+N_{23}$; 2. $N_{36}R_{56}K_{108}S_{28}+N_{23}$	1. Ecoline Boron; 2. Nertus Boron; 3. Bast Boron

Microfertiliser Ecoline Boron organic (nitrogen ($N\text{-}NH_2$) boron (B) – 15.5%) is a liquid boron fertiliser for foliar top dressing containing boron in the form of an organic compound. Provides stress and cold resistance for plants. The rate of foliar application is 1-2 l/ha.

Microfertiliser Nertus Boron (150 g/l (boron-ethanolamine) provides an increase in the yield and resistance of the plant to stress, bacterial damage. The rate of foliar application is 1-1.5 l/ha. Bast Boron (B (200 g/L); N (70 g/L) – provides drought resistance of crops, prevents diseases that occur as a result of boron deficiency, increases yield and improves product quality indicators. The rate of foliar application is 1-2 l/ha.

The registered area is 50 m^2 with a fourfold repetition. The placement of land plots is systematic (Rozhkov, A.O., Puzik, V.K., & Kalenska, S.M., 2016). The seeding rate is 50 thousand germinating seeds/ha. Fertilisers $N_{27}R_{42}K_{81}S_{21}$ and $N_{36}R_{56}K_{108}S_{28}$ were applied during pre-sowing cultivation, N_{23} – during sowing. Top dressing was conducted twice by foliar application of Ecoline Boron, Nertus Boron, and Bast Boron in phases 4 and 8 leaves at the rate of 1 l/ha. Yield determination was conducted using the accounting method, statistical data processing was conducted using the SAS 9,4 programme.

RESULTS AND DISCUSSION

The study programme included investigating the influence of the factors under study on the formation of elements of productivity of sunflower hybrids. After analysing the results obtained, it is noted that providing sunflower plants with the necessary macro – and micro-nutrients during the entire growing season allows for increasing the yield of the crop.

The level of the yield of sunflower hybrids in the experiment depended on the weather conditions of the years of the study, the morphobiological features of the hybrids under study, and the nutritional conditions created by fertiliser options. The results show that in the options without top dressing, the yield varied in the hybrid NK Diamantis from 2.42 to 2.76 t/ha, SI Kupava from 2.71 to 3.12 t/ha, NK Neoma from 2.59 to 2.89 t/ha (Fig. 1).

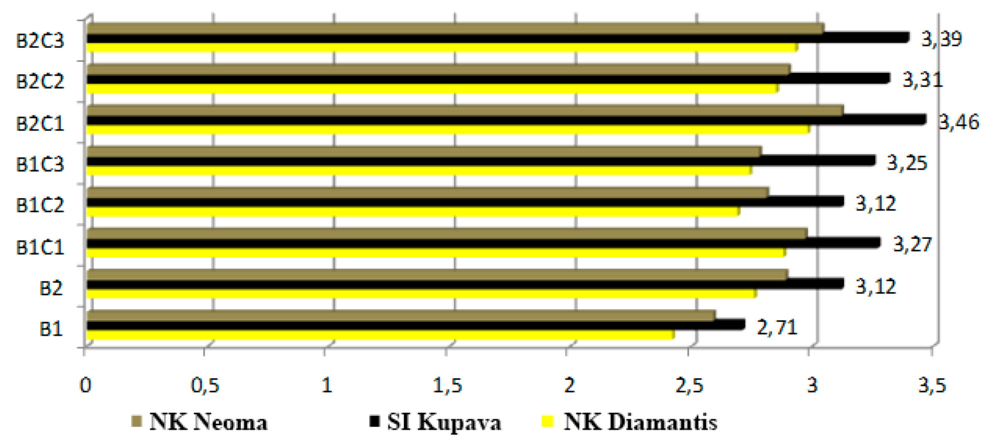

Figure 1. Yield of sunflower hybrids, t/ha

Note: (HIP_{05} A=0.27; B=0.14; C=0.11; ABC=0.39)

The use of foliar top dressing against the background of the main fertiliser with protective preparations with microelements contributed to an increase in the yield growth to the corresponding options of the main fertiliser from 0.46 to 0.56 t/ha in the hybrid NK Diamantis, from 0.56 to 0.71 t/ha in SI Kupava and from 0.38 to 0.52 t/ha in NK Neoma.

The most productive hybrid was SI Kupava with the maximum yield indicator in the option with the application of $N_{36}R_{56}K_{108}S_{28}$ + N_{23} + Ecoline Boron – 3.46 t / ha.

The conducted studies allow stating a positive strong correlation r = 0.93 in the relationship between the yield of the SI Kupava sunflower hybrid and the fertiliser option (Fig. 2).

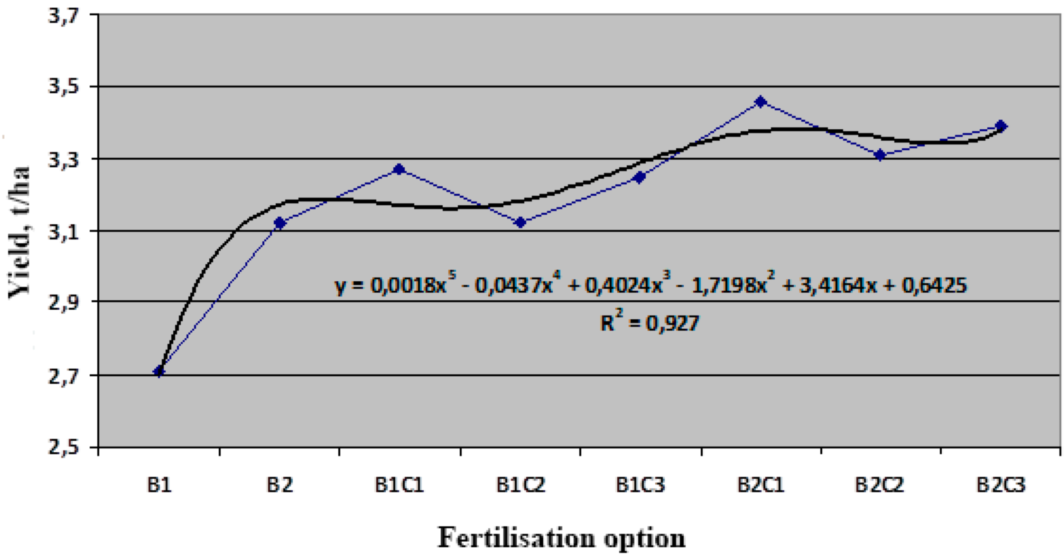

Figure 2. Yield formation model and correlation between yield and fertiliser option of SI Kupava sunflower hybrid

Based on regression analysis, it was identified that yield changes have a polynomial curve type and the yield of a medium-ripened Sunflower hybrid SI Kupava (Y) depending on the fertiliser option (X) can be described by the following equation: $y = 0.0018x^5 – 0.0437x^4 + 0.4024x^3 – 1{,}7198x^2 + 3.4164x + 0.6425$.

An important element of the characteristics of sunflower products is the quality indicators of oilseeds. The concept of quality covers many indicators of physical and chemical origin. Physical indicators include: pericarp ratio, huskiness, size, and volume mass. Chemical indicators include the fat content in achenes and kernels, the protein content in seeds and meal, the content of oleic acid, the ratio of amino acids, and the acid and iodine numbers of oil. This study included the assessment of fat and protein content in sunflower seeds. Determination of these indicators allows for characterising the quality of grown oilseeds.

Sunflower oil, unlike others, has a fatty acid composition with a great advantage of oleic acid over others. Conventional varieties and brids of sunflower produce oil with a content of 65-70% of oleic acid, and recently created high-oleic forms have a content of this component in the range of 80-90%. Therefore, the most valuable oil is the one that contains the maximum proportion of oleic acid. Notably, due to fertilisers and protective preparations containing microelements, the oil content in the sunflower seed core can be increased in this way to improve the quality of raw materials. When introducing new varieties and hybrids into production, it is important to consider not only their yield but also the content and output of oil and protein, and the dynamics of their changes under the influence of growing conditions (Horbatiuk, E.M., 2017). The fat content in the seeds of sunflower hybrids under study depended both on the morphobiological features of the hybrid and on the conditions created by fertiliser options. Analysis of the results obtained showed that the use of foliar top dressing with microelements had a positive effect on the fat content in sunflower hybrid seeds (Table 2).

Table 2. Fat content in sunflower seeds, % (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S21+N_{23}$ (background 1);	49.7	50.1	50.0
$N_{36}R_{56}K_{108}S_{28}+N_{23}$(background 2);	49.3	49.2	49.1
Background 1 + Ecoline Boron (5–6 leaves)	50.4	50.7	50.6
Background 1 + Nertus Boron (5–6 leaves)	49.8	49.9	49.8
Background 1 + Bast Boron (5–6 leaves)	50.0	50.4	50.3
Background 2 + Ecoline Boron (5–6 leaves)	50.8	51.1	51.0
Background 2 + Nertus Boron (5–6 leaves)	50.2	50.4	50.3
Background 2 + Bast Boron (5–6 leaves)	50.1	50.8	50.7

The maximum indicator was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5–6 leaves) in plants of the SI Kupava hybrid, which corresponded to 51.1%. The protein content in sunflower seeds depended more on genetic characteristics than the examined factors (Table 3).

Table 3. Crude protein content in sunflower seeds, % (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S21+N_{23}$ (background 1);	17.6	18.0	17.8
$N_{36}R_{56}K_{108}S_{28}+N_{23}$(background 2);	18.0	18.6	18.4
Background 1 + Ecoline Boron (5–6 leaves)	18.4	18.9	18.7
Background 1 + Nertus Boron (5–6 leaves)	17.8	18.1	17.9
Background 1 + Bast Boron (5–6 leaves)	18.2	18.4	18.2
Background 2 + Ecoline Boron (5–6 leaves)	18.7	19.0	18.8
Background 2 + Nertus Boron (5–6 leaves)	18.2	18.4	18.2
Background 2 + Bast Boron (5–6 leaves)	18.6	18.7	18.5

In Ukraine, there are no standards regarding the optimal size of seeds and their huskiness in various processing methods. Notably, hybrids, unlike varieties, have small seeds with greater huskiness and lower oil content. Therefore, due to the different quality of oilseeds, it is recommended to process them without preliminary hull separation – by direct extraction.

Sowing with high-quality seeds is one of the main agrotechnical measures aimed at growing high yields of agricultural crops. High-quality seed material allows for ensuring proper plant growth without additional energy costs (fertilisers, pesticides), reducing the negative impact of weeds, diseases, pests, and increasing the yield and quality of the resulting products on this basis, improving the ecological state of the field.

Sunflower oil is characterised by a fatty acid composition with a substantial advantage of oleic acid over others. The most valuable oil is considered to contain the maximum proportion of oleic acid. The results of studies showed that the highest content of oleic acid was identified in the SI Kupava hybrid in the option with the application of $N_{27}R_{42}K_{81}S21+N_{23}$ + Ecoline Boron (5–6 leaves). Due to fertilisers and protective product, the content of this polyunsaturated acid can be increased and thus improve the quality of oil (Table 4).

Table 4. Percentage of oleic acid in sunflower hybrid oil, % (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S21+N_{23}$ (background 1);	72.7	76.1	74.2
$N_{36}R_{56}K_{108}S_{28}+N_{23}$(background 2);	72.4	75.2	73.5
Background 1 + Ecoline Boron (5–6 leaves)	74.6	77.2	75.9
Background 1 + Nertus Boron (5–6 leaves)	74.1	75.7	75.5
Background 1 + Bast Boron (5–6 leaves)	73.9	75.4	75.3
Background 2 + Ecoline Boron (5–6 leaves)	73.7	76.9	74.7
Background 2 + Nertus Boron (5–6 leaves)	73.3	75.4	74.4
Background 2 + Bast Boron (5–6 leaves)	73.9	75.2	74.0

The total oil yield is an indicator that, on the one hand, is determined by the fat content, and on the other – by the yield. Consequently, even reducing the fat content of sunflower seeds on fertilised backgrounds generally makes it difficult to achieve an increase in the amount of oil per 1 ha.

The highest oil yield, according to calculations, was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5–6 leaves) in plants of the SI Kupava hybrid, which amounted to 1.64 tonnes per 1 hectare (Table 5). Similar calculations were performed to determine protein output (Table 6).

Table 5. Oil yield from 1 hectare of sunflower, t (average for 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S21+N_{23}$ (background 1);	1.20	1.36	1.30
$N_{36}R_{56}K_{108}S_{28}+N_{23}$(background 2);	1.36	1.54	1.42
Background 1 + Ecoline Boron (5–6 leaves)	1.45	1.66	1.50

Table 5. Continued

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
Background 1 + Nertus Boron (5–6 leaves)	1.34	1.56	1.40
Background 1 + Bast Boron (5–6 leaves)	1.37	1.64	1.40
Background 2 + Ecoline Boron (5–6 leaves)	1.51	1.77	1.59
Background 2 + Nertus Boron (5–6 leaves)	1.43	1.67	1.46
Background 2 + Bast Boron (5–6 leaves)	1.47	1.72	1.54

Table 6. Protein output from 1 ha of sunflower hybrids, t (average 2018–2019)

Fertiliser option	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S21+N_{23}$ (background 1);	0.43	0.49	0.46
$N_{36}R_{56}K_{108}S_{28}+N_{23}$(background 2);	0.50	0.58	0.53
Background 1 + Ecoline Boron (5–6 leaves)	0.53	0.62	0.56
Background 1 + Nertus Boron (5–6 leaves)	0.48	0.56	0.50
Background 1 + Bast Boron (5–6 leaves)	0.50	0.60	0.51
Background 2 + Ecoline Boron (5–6 leaves)	0.56	0.66	0.59
Background 2 + Nertus Boron (5–6 leaves)	0.52	0.61	0.53
Background 2 + Bast Boron (5–6 leaves)	0.54	0.63	0.56

The maximum indicator was obtained in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ + Ecoline Boron (5–6 leaves) in the SI Kupava hybrid, which was 0.66 tonnes per 1 hectare.

The weather conditions during the growing seasons under study in 2018 were the most favourable for growing sunflower hybrids.

CONCLUSIONS

The results of the study showed that the use of Ecoline Boron, Nertus Boron, Bast Boron preparations twice in the top dressing in phases 4 and 8 of sunflower hybrid leaves against the background of the main fertiliser provided the creation of favourable conditions for the formation of hybrid productivity elements and contributed to an increase in yield and seed quality indicators.

The highest effect of applying fertilisers was obtained by applying $N_{36}R_{56}K_{108}S_{28}+N_{23}$ and foliar top dressing of Ecoline Boron to plants of the SI Kupava hybrid.

The complex influence of the factors under study ensured the formation of the yield of the SI Kupava hybrid in the option with the application of $N_{36}R_{56}K_{108}S_{28}+N_{23}$ and foliar top dressing of Ecoline Boron (phases 4 and 8 leaves (0.1 l/ha each) with an indicator of 3.46 t/ha and a fat content of 51.1%.

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Реалізація генетичного потенціалу гібридів соняшнику за впливу умов живлення

Анотація. Застосування мікродобрив на фоні основного удобрення сприяє підвищенню ефективності використання рослинами поживних елементів мінеральних добрив та ґрунту, що забезпечує зростання урожайності та поліпшення показників якості вирощеного урожаю. Метою проведення досліджень було встановлення впливу умов живлення культури та підбір високопродуктивних гібридів (НК Діамантіс, СИ Купава, НК Неома) для конкретних ґрунтово-кліматичних умов через формування їхньої продуктивності. Польові дослідження проводили впродовж 2018-2019 рр. на чорноземах типових малогумусних Чернігівської області. Програмою досліджень передбачалося закладення трифакторного польового досліду, у якому вивчали гібриди (чинник А) варіанти удобрення (чинник В) та позакореневе підживлення (чинник С) у фазі 4 та 8 листків соняшнику препаратами Еколайн Бор, Нертус Бор, Баст Бор. Гібриди соняшника, що вивчалися, – НК Діамантіс, СИ Купава, НК Неома. Дослідження показали, що найбільш урожайним виявився гібрид СИ Купава з максимальним показником урожайності на варіанті із застосуванням N36P56K108S28 + N23 + Еколайн Бор (у фазі 4 та 8 листків по 1 л/га) – 3,46 т/га. Уміст жиру в насінні гібридів соняшнику визначався морфобіологічними особливостями гібриду та варіантами удобрення. Застосування позакореневих підживлень мікроелементами мало позитивний вплив на вміст жиру в насінні гібридів соняшнику, що дало змогу отримати максимальний показник на варіанті за внесення N36P56K108S28 + N23 + Еколайн Бор (5-6 листків) у рослин гібриду СИКупава – 51,1 %. Максимальний вміст олеїнової кислоти було виявлено в гібриду СИ Купава на варіанті з внесенням N36P56K108S28 +N23 + Еколайн Бор (5-6 листків) – 77,2 %. Завдяки застосуванню добрив, що містять бор, уміст цієї поліненасиченої кислоти можна підвищити, поліпшуючи показники якості олії насіння соняшнику. Найвищий вихід олії, відповідно до проведених розрахунків, було отримано на варіанті з внесенням N36P56K108S28 + N23 + Еколайн Бор (5-6 листків) у рослин гібриду СИ Купава, що становив 1,64 т з 1 гектара

Ключові слова: соняшник; гібриди; елементи живлення; бор; ЕколайнБор; Нертус Бор; Баст Бор; урожайність; уміст жиру; вміст білку; вміст олеїнової кислоти