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Fertiliser Efficiency in the Formation of Sunflower Productivity

Abstract. Plant nutrition throughout the vegetation period is one of the main factors aimed at realising the genetic potential of sunflower hybrids when cultivated in all soil and climatic conditions. Currently, it is important to study the genetic potential of domestic hybrids under different growing conditions to identify their competitiveness, thus improving crop quality and yields. The use of a wide range of complex microfertilisers in production along with the main fertiliser helps to increase the efficiency of plant nutrient utilisation of mineral fertilisers and soil and is one of the ways to improve crop yields and agricultural product quality. While sunflower is considered to be a key oilseed crop, its cultivation technology is not fully researched, and previous studies often contain contradictory data. An important part of the agrotechnical measures aimed at increasing crop productivity is to ensure

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optimal plant nutrition during the vegetation period. The purpose of the study was to determine the influence of crop nutrition conditions and to select high-yielding hybrids (*NK Diamantis*, *SI Kupava*, *NK Neoma*) for specific soil and climatic conditions through the formation of their productivity. The study was conducted in 2018-2019 on typical low-humus chernozems. The research program included a three-factor field experiment in which hybrids (*factor A*), fertiliser options (*factor B*), and foliar feeding of crops (*factor C*) were studied in the phase of 4 and 8 leaves of sunflower with *Ecoline Boron*, *Nertus Boron*, and *Bast Boron*. The sunflower hybrids studied were *NK Diamantis*, *SI Kupava*, and *NK Neoma*. The research results revealed significant changes in the diameter of the sunflower inflorescence under the influence of different nutritional conditions created by fertiliser variants. The influence of hybrid features also determined this indicator. Plants of the hybrid *NK Diamantis* formed heads with diameters ranging from 17.6 to 21.2 cm, *SI Kupava* - from 18.8 to 22.1 cm, *NK Neoma* – from 17.2 to 21.6 cm. The maximum index was achieved in the variant with the introduction of $N_{36}R_{56}K_{108}S_{28}$ + N_{23} + *Ecoline Boron* (phase 4 and 8 leaves) in plants of hybrid *SI Kupava*, and it amounted to 22.1 cm. The weight of 1,000 achenes, which is one of the genetically determined traits of the crop, in plants of the hybrid *NK Diamantis*, depending on the fertiliser variant, varied from 59.3 to 62.3 g, *SI Kupava* from 69.8 to 74.0 g, *NK Neoma* from 68.8 to 72.6 g. The maximum result was provided by the variant with the use of $N_{36}R_{56}K_{108}S_{28}$ +N_{23} + *Ecoline Boron* (phase 4 and 8 leaves). Studies have shown that the most productive hybrid was *Si Kupava* with the maximum yield in the variant with the use of $N_{36}R_{56}K_{108}S_{28}$ +N_{23} + *Ecoline Boron* (in the phase of 4 and 8 leaves of 1 l/ha) – 3.46 t / ha

Keywords: sunflower, fertilisers, microelements, boron, hybrids, *Ecoline Boron*, *Nertus Boron*, *Bast Boron*, head diameter, the weight of 1,000 achenes, yield

RELEVANCE

The appeal of sunflower lies in the strategic and significant economic efficiency of its cultivation. Compared to other oilseeds, sunflower has the highest oil yield per unit area (750 kg/ha on average in Ukraine). The share of sunflower oil reaches 90% of the total oil production in Ukraine. Sunflower seed oil is characterised by the high nutritional value. It is second only to olive oil. Sunflower oil contains polyunsaturated fatty linolenic acid, phosphates, stearins, and vitamins.

Along with the increase in the area under the crop, there is a decrease in its yield. The reasons for the decline in yields are a variety of factors, the most important of which are violations of crop rotation and cultivation technologies. At the same time, the excessive use of foreign hybrids characterised by low adaptability to the conditions of Ukraine has been recognised.

Among the factors that ensure high sunflower yields are plant nutrition conditions throughout the growing season and technological measures aimed at realising the genetic potential of the crop in certain regions of Ukraine. Today, it is necessary to study in-depth the potential of hybrids and varieties for growing them in different conditions to determine their competitiveness and popularisation, which will increase the quality and yield of the crop. (Eremenko *et al.*, 2019; Eremenko *et al.*, 2018, Ieremenko & Kalitka, 2016). That is why today much attention is paid to the study of the influence of nutritional conditions on the formation of productivity of hybrids of both foreign and domestic breeding, in specific soil and climatic conditions of Ukraine (Kalenska *et al.*, 2020; Domaratskiy *et al.*, 2018).

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The registered new sunflower hybrids have a high productivity potential, however, it is only partially realised in production, as evidenced by a number of literature sources (Ieremenko *et al.* 2017; Pysarenko *et al.*, 2006; Bondarenko *et al.*, 2002;)

Elements of any crop cultivation technology are determined by the characteristics of the variety or hybrid cultivated, its agrobiological profile, which includes requirements for growing conditions, as well as data on the crop's impact on soil properties depending on the specifics of biology and agricultural technology.

In recent years, the number of sunflower hybrids listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine has increased significantly. The advantage of foreign-bred seed is its ability to produce high seed productivity, but these hybrids are inferior to domestic hybrids that are resistant to a number of pathogens inherent in the climatic conditions of the sunflower growing regions of Ukraine. The productivity of sunflower hybrids and varieties is a determining factor in yield formation and depends on both their biological characteristics and meteorological conditions and the cultivation technologies used (Alves *et al.*, 2017).

The formation of reproductive organs of sunflower hybrids and varieties, in particular, the diameter of the head, the weight of 1,000 seeds, and husk level are the determining factors in the formation of seed yield and quality (Markova, 2011).

Today, auxiliary elements of cultivation technology, such as inoculation of seeds with microorganism-based preparations, foliar feeding with biological products and microfertilisers, are widely used to increase sunflower productivity. For this purpose, complex fertilisers are often used, containing a full set of nutrients necessary to create optimal plant nutrition conditions during the so-called critical periods of their growth and development (Miao *et al.*, 2015; Carvalho *et al.*, 2016; Calvo *et al.*, 2014; Domaratskyi *et al.*, 2017; Domaratsky & Dobrovolsky, 2018).

Optimisation of sunflower plant nutrition during the vegetation period contributes to the creation of optimal nutritional conditions for the crop and ensures the formation of optimal leaf surface area and maximum realisation of the genetic potential of sunflower hybrids and varieties (Kalenska *et al.*, 2020; Helmy & Ramadan, 2009; Nizamov, 2018).

The fertilisation system for growing sunflower hybrids is determined based on the specific soil and climatic conditions, the level of intended yield, agronomic and organisational factors. At the same time, sunflower plants produce significantly higher amounts of nitrogen and phosphorus than other crops.

Sunflower has a prolonged period of nutrient absorption, so it requires significantly more nutrients (especially potassium) compared to cereals.

During the vegetation period, sunflower absorbs nutrients rather unevenly. The majority of nitrogen and phosphorus is consumed before the flowering phase, and during the formation of the leaf apparatus, stems and root system. After the heads form, phosphorus uptake decreases dramatically. Potassium is absorbed by sunflower almost throughout the entire vegetation period, but most intensively before flowering.

From the stage of 3-4 pairs of leaves to the flowering stage, plants use 70-80% of nitrogen. The lack of nitrogen during head formation has a negative effect. Excess nitrogen leads to excessive vegetative growth but reduces the fat content of the seeds.

Different nutrients affect growth, development, crop formation, and product quality differently. Thus, nitrogen enhances growth processes and promotes the formation of larger plants and heads. However, excessive nitrogen nutrition prolongs the vegetation, negatively affects the processes of oil accumulation in seeds, as the protein content in the seeds increases, and the oil content decreases sharply. Excessive nitrogen levels increase the risk of plant lodging and pathogen damage (phomopsis, white rot, etc.) (Vozhehova *et al.*, 2013; Tkalich, 2016, Shakaliy, 2017).

Phosphorus is absorbed by the plant from germination to flowering. It accumulates before flowering in the stem and leaves, then moves to the heads and eventually to the achenes. Plants absorb 60-70% of the total phosphorus required during the period of head formation – the end of flowering. Lack of phosphorus negatively affects the formation and filling of achenes and limits sunflower productivity. A sufficient amount of phosphorus increases the drought resistance of plants and the oil content of seeds. Phosphorus contributes to the formation of a powerful root system, the laying of reproductive organs with a large number of rudimentary flowers in the head. It is important to provide plants with phosphorus in the initial stages of organogenesis from seed germination to 3-4 pairs of true leaves. With sufficient phosphorus nutrition, the development of plants is accelerated, and there is a more rational consumption of moisture, as a result of which they can withstand dry winds and soil moisture deficit. With increased phosphorus nutrition, the coefficient of water consumption by sunflower plants sharply decreases (Buldykova *et al.*, 2015; Yeremenko *et al.*, 2017).

The purpose of the study was to identify the influence of the factors studied on the formation of productivity elements of sunflower hybrids.

MATERIALS AND METHODS

The study was conducted in 2018-2019 in the Chernihiv Oblast on typical low-humus chernozems. According to the set objective, a study plan and a field experiment programme were developed (Table 1). The design of the experiment involved the study of hybrids (*factor A*), fertiliser options (*factor B*) and the use of foliar fertilisation of crops (*factor C*) in the phase of 4 and 8 leaves of sunflower.

Table 1. Formation of sunflower productivity elements under the influence of nutritional parameters (experimental scheme)

Hybrids (*factor A*)/variant designation	Fertilisation variants (*factor B*)/variant designation	Foliar fertilisation (*factor C*)/variant designation
1. *NK Diamantis*; 2. *SI Kupava*; 3. *NK Neoma*	1. $N_{27}R_{42}K_{81}S_{21}+N_{23}$; 2. $N_{36}R_{56}K_{108}S_{28}+N_{23}$	1. *Ecoline Boron;* 2. *Nertus Boron;* 3. *Bast Boron*

Ecoline Boron Organic micronutrient fertiliser (nitrogen ($N\text{-}NH_2$) – 6.5%; boron (*B*) – 15.5%) is a concentrated liquid boron fertiliser intended for foliar feeding of crops requiring boron supply, containing boron in the form of an organic compound. The application of the fertiliser during critical periods of plant development contributes to stress resistance, cold resistance of plants, provides regulation of the flowering process and improves the quality of the crop. The rate of foliar fertilisation is 1-2 l/ha.

Hertus Boron microfertiliser (150 g/l (boron-ethanolamine) helps to increase yields and resistance to stresses, bacterial damage, reduces the risk of fruit and root rot, is compatible with most pesticides without reducing their effectiveness in mixtures. The rate of foliar fertilisation is 1-5 l/ha.

BAST Boron (B (200 g/l); N (70 g/l)) quickly eliminates boron deficiency, stimulates the formation and development of growth points, leaves, flowers, fertilisation, and fruit formation, provides drought resistance of crops, prevents diseases resulting from boron deficiency, increases yields and improves product quality. The rate of foliar fertilisation is 1-2 l/ha.

The accounting area is 50 m^2 with four repetitions. The location of the plots is systematic (Ermantraut *et al.*, 2014; Rozhkov *et al.*, 2016).

The seeding rate is 50,000 germinating seeds/ha. Fertilisers $N_{27}R_{42}K_{81}S_{21}$ and $N_{36}R_{56}K_{108}S_{28}$ were introduced into pre-sowing cultivation, N_{23} in the form of urea was applied during sowing. Fertilisation was performed twice foliarly with *Ecoline Boron*, *Nertus Boron*, *Bast Boron* in the phase of 4 and 8 leaves at 1 litre/ha. The weight of 1,000 seeds was determined in accordance with DSTU 4138-2002, the yield was determined by the accounting method, and the statistical processing of the data was performed using SAS 9.4.

RESULTS AND DISCUSSION

The research program included investigating the influence of the factors under study on the formation of productivity elements of sunflower hybrids. The results obtained show that structural analysis of sunflower generative organs allows for a better understanding of the structure of yield formation and the identification of indicators that are crucial for achieving a particular level of yield. To complete these analyses, the following parameters were determined: head diameter, number of heads per unit area, weight of 1,000 seeds.

The diameter of the sunflower head is an important indicator for sunflower, which varies widely depending on the growing conditions. According to previous studies, on 5 linear meters of a row on with 18-20 plants, the diameter of the plant head can vary from 10-12 to 20-24 cm.

When determining the number of achenes in the head, the scientists consider the total number of seeds and the number of performed seeds among them.

There were significant changes in the diameter of sunflower inflorescence under the influence of different nutritional conditions created by fertiliser variants. Notably, there was a significant difference between the hybrids. Thus, plants of the hybrid *NK Diamantis* formed heads whose diameter, depending on the fertiliser varied from 17.6 to 21.2 cm, *SI Kupava* – from 18.8 to 22.1 cm, *NK Neoma* – from 17.2 to 21.6 cm (Table 2).

Table 2. Sunflower hybrid head diameter, cm (average for 2018-2019)

Fertiliser variant	Hybrid		
	NK Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1)	17.6	18.8	17.2
$N_{36}R_{56}K_{108}S_{28}+N_{23}$(background 2)	19.9	21.3	20.7
Background 1 + Ecoline Boron (5-6 leaves)	19.9	20.7	20.1
Background 1 + Nertus Boron (5-6 leaves)	18.4	19.3	18.5
Background 1+ Bast Boron (5-6 leaves)	20.3	20.5	21.0
Background 2 + Ecoline Boron (5-6 leaves)	21.2	22.1	21.6
Background 2 + Nertus Boron (5-6 leaves)	19.6	21.6	20.9
Background 2 + Bast Boron (5-6 leaves)	20.7	21.7	21.3

The maximum index was achieved in the variant with the introduction of $N_{36}P_{56}K_{108}S_{28}$ $+N_{23}$ +N23 + *Ecoline Boron* (phase 4 and 8 leaves) in plants of hybrid *SI Kupava*, and it amounted to 22.1 cm. The weight of 1,000 seeds is a genetically determined trait, but the response rate of this indicator is significant. Analysis of the results showed that in plants of the hybrid *NK Diamantis*, the weight of 1,000 seeds, depending on the fertilisation, varied from 59.3 to 62.3 g, *SI Kupava* – from 69.8 to 74.0 g, *NK Neoma* – from 68.8 to 72.6 g (Table 3).

Table 3. Weight of 1,000 seeds of sunflower hybrids, g (average for 2018-2019)

Fertiliser variant	Hybrid		
	NC Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1)	59.3	69.8	68.8
$N_{36}P_{56}K_{108}S_{28}+N_{23}$(background 2)	61.0	72.8	71.4
Background 1 + Ecoline Boron (5-6 leaves)	61.8	72.2	71.9
Background 1 + Nertus Boron (5-6 leaves)	59.6	70.2	69.1
Background 1+ Bast Boron (5-6 leaves)	61.2	71.0	71.3
Background 2 + Ecoline Boron (5-6 leaves)	62.3	74.0	72.6
Background 2 + Nertus Boron (5-6 leaves)	61.4	73.1	71.6
Background 2 + Bast Boron (5-6 leaves)	61.7	73.4	72.1

The maximum index was achieved in the variant with the introduction of $N_{36}P_{56}K_{108}S_{28}$ $+N_{23}$ +N23 +N23 + *Ecoline Boron* (phase 4 and 8 leaves) in plants of hybrid *SI Kupava*, and it amounted to 22.1 cm.

The yield of seeds from sunflower heads differed only slightly under the influence of the factors studied. According to the study results, the average seed yield for the variants of the hybrid *NK Diamantis* was 72.0%, the hybrid *SI Kupava* – 74.3%, *NK Neoma* – 73.2%. At the same time, the indicators varied within the limits: *NK Diamantis* – from 69.7 to 73.4%, *SI Kupava* – 72.6-75.7%, *NK Neoma* – 71.0-75.0% (Table 4).

Table 4. Seed yield per head, % (average for 2018-2019)

Fertiliser variant	Hybrid		
	NC Diamantis	SI Kupava	NK Neoma
$N_{27}R_{42}K_{81}S_{21}+N_{23}$ (background 1)	69.7	72.6	71.0
$N_{36}P_{56}K_{108}S_{28}+N_{23}$(background 2)	72.3	74.4	74.0
Background 1 + Ecoline Boron (5-6 leaves)	72.8	74.8	73.2
Background 1 + Nertus Boron (5-6 leaves)	70.1	72.8	71.4
Background 1+ Bast Boron (5-6 leaves)	72.1	74.0	72.3
Background 2 + Ecoline Boron (5-6 leaves)	73.7	75.7	75.0
Background 2 + Nertus Boron (5-6 leaves)	72.4	74.7	74.3
Background 2 + Bast Boron (5-6 leaves)	73.1	75.1	74.6

Analysis of the huskiness of sunflower achenes showed that the lowest values were in hybrid *SI Kupava*, which varied from 20.2 to 21.9% under different nutritional conditions. There was no clear correlation between the fertiliser variants.

The main task of cultivation technology is to provide the most favourable regulated factors during the growth and development of plants while ensuring the rational use of materials and funds.

It is worth noting that providing sunflower plants with the necessary nutrients (macro- and micro-nutrients) throughout the growing season allows for an increase in crop productivity, but at the same time, production costs increase significantly.

The level of the yield of hybrids in the experiment was affected by the weather conditions of the year of research, morphobiological characteristics of the hybrids that were subject to the study and nutritional conditions formed by fertiliser variants (Fig. 1).

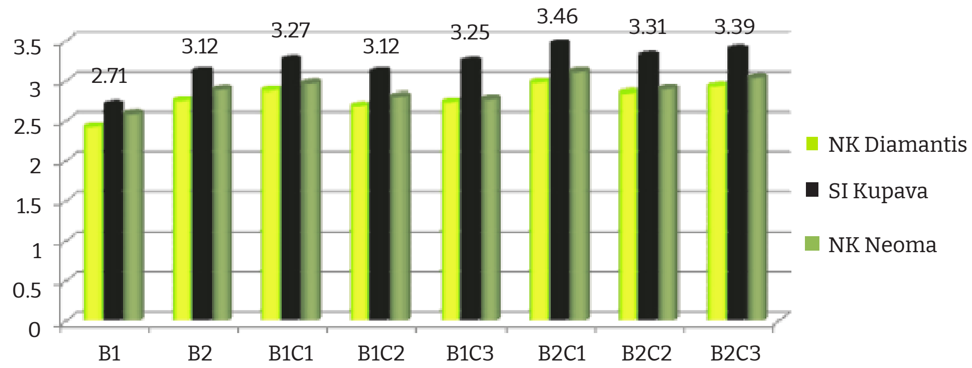

Figure 1. Yield of sunflower hybrids, t/ha

Note: LSD^{05} A = 0.27; B = 0.14; C = 0.11; ABC = NN0.39

The study results showed that in the variants without fertilisation, the yield of the hybrid *NK Diamantis* varied 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.

Foliar fertilisation in combination with the basic microelement fertilisation contributed to yield increase compared to the basic fertiliser variants in the range from 0.46 to 0.56 t/ha in 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* (Fig. 1).

The most productive hybrid was *SI Kupava* with the maximum yield in the variant with the application of $N_{36}P_{56}K_{108}S_{28}$ +N_{23} + N23 + *Ecoline Boron* – 3.46 t/ha.

The correlation analysis allowed to establish a close correlation between the weight of 1,000 achenes of sunflower hybrids and the yield of sunflower hybrids. The correlation coefficient varied depending on the fertiliser variant from 0.845 to 0.943.

The weather conditions during the vegetation period in 2018 proved to be more favourable for the cultivation of the sunflower hybrids studied.

CONCLUSIONS

The findings of the research showed that the use of *Ecoline Boron*, *Nertus Boron*, and *Bast Boron* twice in fertilisation at the initial stages of plant growth and development (phase 4 and 8 leaves) of sunflower hybrids in combination with the basic fertiliser provided favourable conditions for the formation of hybrid productivity elements and contributed to an increase in yield. The maximum effect from the application of fertilisers was obtained by applying $N_{36}P_{56}K_{108}S_{28}$ +N_{23} + N23 and foliar fertilisation with *Ecoline Boron* in plants of the *SI Kupava* hybrid, resulting in the formation of heads with a diameter of 22.1 cm and a weight of 1,000 achenes of 74 g.

The influence of unregulated environmental factors and factors studied contributed to the formation of the yield of the hybrid *SI Kupava* in the variant with the use of $N_{36}P_{56}K_{108}S_{28} + N_{23}$ + N23 and foliar feeding with *Ecoline Boron* (phase 4 and 8 leaves (0.1 l / ha)) with an output of 3.46 t/ha.

The study revealed a close correlation between the weight of 1,000 cotyledons and crop yield, which varied from 0.845 to 0.943 depending on the factors of the experiment.

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Ефективність добрив у формуванні продуктивності соняшнику

Анотація. Живлення рослин протягом усього періоду вегетації є одним з основних факторів, спрямованих на реалізацію генетичного потенціалу гібридів соняшнику при вирощуванні в будь-яких ґрунтово-кліматичних умовах. Наразі актуальним є вивчення генетичного потенціалу вітчизняних гібридів за різних умов вирощування з метою виявлення їх конкурентоспроможності, що дасть змогу підвищити якість продукції та врожайність. Використання широкого спектру комплексних мікродобрив у виробництві разом з основним добривом сприяє підвищенню ефективності використання рослинами поживних речовин мінеральних добрив та ґрунту і є одним із шляхів підвищення врожайності та якості сільськогосподарської продукції. Хоча соняшник вважається однією з ключових олійних культур, технологія його вирощування не є повністю вивченою, а попередні дослідження часто містять суперечливі дані. Важливою частиною агротехнічних заходів, спрямованих на підвищення продуктивності культури, є забезпечення оптимального живлення рослин протягом вегетації. Метою дослідження було визначення впливу умов живлення рослин та добір високоврожайних гібридів (НК Діамантіс, СІ Купава, НК Неома) для конкретних ґрунтово-кліматичних умов через формування їх продуктивності. Дослідження проводили у 2018-2019 роках на чорноземах типових малогумусних. Програма досліджень включала трифакторний польовий дослід, в якому вивчали гібриди (фактор А), варіанти удобрення (фактор В) та позакореневе підживлення посівів (фактор С) у фазі 4 та 8 листків соняшнику препаратами Еколайн Бор, Нертус Бор та Баст Бор. Досліджували гібриди соняшнику НК Діамантіс, СІ Купава та НК Неома. Результати досліджень виявили суттєві зміни діаметра суцвіття соняшнику під впливом різних умов живлення, створених варіантами удобрення. Вплив гібридних особливостей також визначав цей показник. Рослини гібриду НК Діамант формували головки діаметром від 17,6 до 21,2 см, СІ Купава – від 18,8 до 22,1 см, НК Неома – від 17,2 до 21,6 см. Максимального показника було досягнуто у варіанті з внесенням N36R56K108S28 + N23 + Еколайн Бор (фаза 4 і 8 листків) у рослин гібрида СІ Купава, і він становив 22,1 см. Маса 1000 сім'янок, яка є однією з генетично детермінованих ознак врожаю, у рослин гібрида НК Діамантіс залежно від варіанту удобрення варіювала від 59,3 до 62,3 г, СІ Купава - від 69,8 до 74,0 г, НК Неома - від 68,8 до 72,6 г. Максимальний результат забезпечив варіант із застосуванням N36R56K108S28 + N23 + Еколайн Бор (фаза 4 і 8 листків). Дослідження показали, що найбільш продуктивним виявився гібрид Сі Купава з максимальною врожайністю у варіанті із застосуванням N36R56K108S28 + N23 + Еколайн Бор (у фазу 4 та 8 листків по 1 л/га) – 3,46 т/га

Ключові слова: соняшник, добрива, мікроелементи, бор, гібриди, Еколайн Бор, Нертус Бор, Баст Бор, діаметр кошика, маса 1000 сім'янок, урожайність