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EFFECTIVENESS OF USING BACTERIAL PREPARATIONS AND THEIR IMPACT ON SUNFLOWER SEED PRODUCTIVITY

O.M. KOLISNYK Candidate of Agricultural Sciences, Associate Professor
M.A. SURZHYKOV post-graduate student of VNAU

Sunflower cultivation is one of the most profitable areas of agricultural production. It is one of the main crops in Ukraine, capable of producing about 750 kg of oil per hectare. In 2021, a record 6.5 million ha were allocated for sunflower cultivation. This article presents the results of studying the effect of plant density on the productivity of the studied sunflower hybrids.

Bacterial preparations had a positive effect on the height of sunflower plants. In the control variant, the plants were 3.6% shorter, while in the experimental variants treated with MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage, the plant height was 3.6% higher. In variants treated with AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 L/ha) at the 3-6 leaf stage, the hybrid was 1.2% shorter.

Foliar nutrition positively affected leaf number per plant and leaf surface area. The leaf number and leaf surface area increased by 6.7-9.6% and 4.5-9.3%, respectively, in variants where foliar nutrition was applied compared to the control.

The sunflower seed productivity coefficient was measured: seed number per head in the control variant (without foliar feeding) was 1,540, seed mass per head was 54.0 g, and 1,000-seed weight was 35.1 g lower than in the variants treated with foliar fertilizers AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 L/ha) at the 3-6 leaf stage, where these indicators increased to 1,547 seeds, 58.4 g per head, and 1,000-seed weight of 37.8 g, respectively.

The P64LE25 hybrid showed a significant advantage when sprayed with MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 L/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage, thanks to the balanced content of macro- and micronutrients that are quickly absorbed by the plant. This hybrid had 67 seeds per head more than the control variant, which had 1,607 seeds. The seed mass per head and 1,000-seed weight were 8.3 g and 3.7 g higher than the control, respectively.

The influence of foliar nutrition on sunflower growth and development, as well as increased resistance to adverse weather conditions, contributed to a higher yield compared to the control. When MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 L/ha) + HELPROST Boron (2 L/ha) were applied at the 3–6 leaf stage, the yield increased by 0.79 t/ha to 3.39 t/ha. When AZOTOFIX (0.3 L/ha) + ORGANIC-BALANCE Monophosphorus (0.5 L/ha) + HELPROST Boron (2 L/ha) were applied at the same stage, the yield increased by 0.67 t/ha to reach 3.27 t/ha.

Keywords*: sunflower, foliar nutrition, bacteria, application rates, MYCOFRIEND, GROUNDFIX, HELPROST Boron, AZOTOFIX, ORGANIC-BALANCE Monophosphorus, pests, diseases, nitrates, yield.*

Table 3. Ref. 16.

Statement of the problem. Modern farming systems show a certain instability in the effectiveness of basic fertilization resulting from imbalanced prices for agricultural products and chemical industry inputs, predominant use of minimal soil tillage systems, and almost complete lack of a stable crop rotation structure. A partial solution to the problem of insufficient plant nutrition is the application of foliar fertilization, which, according to many researchers, is effective for the cultivation of most crops [1, 3, 10].

Foliar nutrition is especially effective under unfavourable weather conditions and other factors that reduce the availability of nutrients from the soil, such as moisture and temperature levels, soil pH, etc. In such cases, foliar nutrition stimulates the absorption of nutrients from the soil. It enhances the synthesis of chlorophyll in the leaves, which contributes to a rich green coloration. This, in turn, stimulates root growth, sugar exudation, and an increase in the population of microorganisms that synthesize auxins and other root-stimulating substances. As cellular gas exchange intensifies, the amount of moisture absorbed by the roots increases, which activates the process of nutrient uptake from the soil solution.

In most cases, foliar fertilization is more effective when applied multiple times – at the beginning and during the vegetation period of crops [1, 9].

Foliar nutrition has gained special significance for sunflower as the main oilseed crop, which is highly sensitive to boron deficiency that is a problem that becomes especially acute during drought conditions and on calcareous soils [2, 6].

Foliar nutrition of sunflower with micronutrients helps to increase the yields by promptly and effectively regulating nutrient uptake during the growing season, in accordance with the specific conditions of each year. A well-balanced ratio of micronutrients plays a crucial role in this process. All nutrients are interconnected within unified biochemical pathways, and each element is essential. Therefore, it is advisable to combine micronutrient nutrition with the application of primary nutrients (NPK). Nutrient absorption occurs through all above-ground plant organs, including leaves and stems. This allows nutrients to be delivered directly to the parts of the plant where physiological processes are the most intensive and where deficiencies are often the most evident. The use of micronutrient fertilizers is especially important during the so-called critical stages of crop development when it is essential to ensure a balanced supply of micronutrients to the sunflower. This promotes root formation and the development of flower heads (capitula), ultimately leading to increased productivity [5, 7, 16].

Analysis of recent research and publications. Sunflower is the most important oilseed crop in Ukraine, accounting for over 70% of all oilseed cropping areas [5]. According to the State Statistics Service of Ukraine, in 2022, sunflower was harvested from the area of 52.38 million hectares. The average yield was 2.16 t/ha, and the total yield of commercial sunflower seed was 11.33 million tons [2, 8].

The biological and genetic traits of sunflower, along with the diversity of natural growing conditions and the demands of the oil, food, and paint industries, define the range and specificity of breeding objectives for this crop, as well as the development of farming practices to ensure high seed (raw material) quality [10-12].

Sunflower is used not only for oil production but also in the manufacture of confectionery products, decorative purposes, and bird feed [9, 13]. The confectionery industry has set an objective for agronomy science to grow large-seeded sunflower varieties and hybrids with favorable physical and mechanical seed properties, high protein content, technical potential for processing, and a dehulling efficiency (kernel yield) of no less than 0.6-0.7 [14-17].

Confectionery sunflower varieties and hybrids are characterized by well-filled seeds with 1,000-seed weight close to 100 grams [8, 10]. This type of sunflower has gained consumer interest due to its excellent taste and nutritional value (high in minerals and a good source of protein) [2-3]. Seed size, flavor, and shelf life are the most important quality traits for the confectionery industry. They are mainly determined by 1,000-seed weight, linear seed dimensions, and the specific content of fatty acids and vitamin E [5]. Sunflower seeds can successfully serve as a substitute for peanuts, sesame seeds, and nuts [24]. The desired protein content for confectionery applications is 22-23%, which is crucial for producing high-quality sweets, artificial almond milk, and almond meal [13, 16]. The protein in new high-protein confectionery sunflower varieties competes well with that of animal origin [2, 7].

The area under confectionery sunflower cultivation is steadily increasing and now accounts for about 4% of total sunflower sowing area [1]. The largest producer of confectionery (large-flowered) sunflower is China, with estimated planting areas of 1.32-1.64 million acres (5.34-6.64 million hectares), and an annual roasted seed consumption worth 40 billion yuan [17]. In Turkey, confectionery sunflower is grown on approximately 50,000-60,000 hectares, with an annual production volume of nearly 100,000 tons [11]. While there is not exact data on the cropping areas under confectionery sunflower varieties and hybrids in Eastern Europe, market demand and production areas are constantly increasing due to the high nutritional value of confectionery sunflower and its role in traditional diets. It is expected that in Eastern European countries, the area under this crop will continue to grow as varieties are replaced by high-yielding confectionery hybrids [12]. In Ukraine, this sector of agricultural production is highly attractive for 9% of agricultural enterprises, where confectionery sunflower accounts for 6-100% of the total sunflower acreage [3]. Due to the Ukrainian climate, confectionery sunflower yields are high and 1,000 seeds weigh over 120 g, with some samples reaching 150 g [3, 14]. In the climatic and soil-climatic conditions of the Eastern Forest-Steppe zone of Ukraine, confectionery sunflower hybrid yields reach up to 3.97 t/ha, and 1,000-seed weight is up to 123 g [6].

A modern element of plant cultivation technology is the use of growth regulators. Since key metabolic processes such as growth and development, photosynthesis, respiration, and water exchange regulation are controlled by growth hormones, knowledge and understanding of their molecular action in plants is crucial, just like the effect of synthetic analogues used to relieve stress and improve product quality [16].

The use of auxin-like preparations increases the intensity of photosynthesis by increasing the concentration of chlorophyll in the leaves of soybean, alfalfa, and sunflower. However, it is also known that photosynthesis intensity in sunflower may decrease after the application of heteroauxins [5, 10]. A range of auxin stimulators and their analogues are used to enhance crop productivity and improve quality.

Plant growth regulators include a wide range of chemical compounds commonly used to regulate plant growth at various stages of organogenesis. They are widely applied in agriculture primarily to increase lodging resistance [15, 17]. Retardants have been tested on various field crops to reduce stem length, increase lodging resistance, and boost yields. Preliminary data on the use of retardants mainly relates to cereal crops [2], as well as flax, cotton, and peas [14]. However, the effects of retardants on crops can often be unpredictable and may, in some cases, negatively affect yield.

Materials and methods. 23-2024 under the conditions of «Novomykilske» LLC on grey forest soils with a light loamy mechanical composition. The climatic conditions of the study area are generally quite favourable for the cultivation of all agricultural crops. In 2023, spring was prolonged with low temperature levels, which affected the terms of early sunflower sowing. An unfavourable weather factor was a sharp temperature drop, which became a limiting factor for sunflower development. In 2024, high temperatures and uneven precipitation distribution were observed. That year showed significant deviations in temperature and precipitation levels from the long-term average. The moisture deficit and excessive heat negatively impacted sunflower yield formation.

The experimental scheme. During pre-sowing cultivation, the following treatments were applied: GROUNDFIX (3 l/ha) combined with the mycorrhizal preparation MYCOFRIEND (0.125 kg/ha), or AZOTOFIX (0.3 l/ha) with ORGANIC-BALANCE Monophosphorus (0.5 l/ha). During the 3-6 leaf stage (BBCH 10-19), HELPROST Boron (2 l/ha) was additionally applied.

The soil of the experimental plot was grey forest with the following agrochemical characteristics: humus content (according to Tyurin) – 1.9-2.11%, available nitrogen (according to Kornfield) – 74.5-97.2 mg/kg of soil, mobile forms of phosphorus and exchangeable potassium (according to Kirsanov) – 109-124 and 140-154 mg/kg of soil, respectively; soil pH (salt extract) – 5.1-5.5. The total experimental area was 0.55 ha, with the recording area of 10.5 m² under threefold replication.

Winter wheat was a preceding crop in the experiment. After harvesting the predecessor, stubble cultivation was performed using heavy disk harrows (BDT-7), followed by ploughing to a depth of 25 cm.

Presentation of the main research material. Sunflower is highly sensitive to micronutrient deficiencies, and it is crucial to apply nutrition at the right time to prevent visible deficiency symptoms. If not addressed promptly, such deficiencies can not only reduce the plant's resistance to infectious diseases but also negatively affect flowering processes and the filling of the sunflower head.

Micronutrient fertilization of sunflower crops must be carried out at specific growth and development stages to ensure better nutrient uptake. In general, sunflower nutrition involves two key growth period, excluding seed pre-treatment, during which foliar nutrition is the most effective.

In field experiments, biometric indicators of sunflower were measured during the flowering stage. Foliar fertilization showed a positive trend. Micronutrients influenced plant height: on the control plot, height was 3.6% lower compared to the experimental plot where MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) were applied at the 3-6 leaf stage. It was also 1.2% lower than on the plot treated with AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) at the same growth stage (Table 1).

Table 1

Biometric indicators of sunflower plants depending on the application of micronutrient fertilizers

Variant	Leaf number per plant, pieces	Stem diameter, cm	Plant height, cm
Control (without foliar nutrition)	20.8	2.73	168
MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf phase	22.8	2.83	174
AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf stage	22.2	2.82	170

The source was obtained as a result of own research results

Thus, it was established that the tallest plants, with heights ranging from 170 to 174 cm, were observed in the variants where foliar nutrition was applied. In addition, stem diameter in these variants ranged between 2.82 and 2.83 cm. Foliar nutrition had a positive effect on both the number of leaves per plant and the leaf surface area. In the variants where foliar nutrition was applied, leaf number per plant was 6.7-9.6% higher, and the leaf surface area was 4.5-9.3% higher compared to the control.

The results also showed that the head diameter was 7.8% lower on the control site and 5.9% lower on the experimental site where AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) were applied at the 3-6 leaf stage, compared to the site where MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) were applied at the same stage. In other words, foliar nutrition increased the average head diameter to 16.2-16.5 cm.

In terms of sunflower productivity indicators, seed number per head (1,540), seed weight per head (54.0 g), and 1,000-seed weight (35.1 g) were lower in the control variant than in the variant where foliar nutrition was applied (Table 2).

Foliar nutrition with AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage increased these values to 1,547 seeds, 58.4 g of seed weight per head, and a 1,000-seed weight of 37.8 g, respectively.

Table 2

Elements of sunflower yield structure depending on foliar nutrition

Variant	1,000-seed weight, g	Seed weight per head, g	Head diameter, cm	Seed number per head, pcs.
Control (without foliar nutrition)	35.1	54.0	15.3	1,540
MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf phase	38.8	62.3	16.5	1,607
AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus(0.5 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf phase	37.8	58.4	16.2	1,547

The source was obtained as a result of own research results

The variant, which involved foliar nutrition with MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage, showed substantial benefits due to the balanced content of macro- and micronutrients that were quickly absorbed by plants. In this variant, compared to the control, the number of seeds per head was 67 more, reaching 1,607 seeds. The seed weight per head and 1,000-seed weight exceeded the control by 8.3 g and 3.7 g, respectively.

Yield is the most important indicator of the efficiency of crop production and agricultural output in general. Yield levels are reflected in economic indicators that characterize the profitability of agriculture as well as the quality of the organizational and economic performance of the enterprise.

Yield is defined as the average amount of plant product per unit area of a given crop (t/ha or c/ha). It represents the productivity of an agricultural crop under specific growing conditions. A distinction is made between biological and economic yield.

Under favorable weather conditions in the year of study, sunflower achieved a fairly high yield level, ranging from 2.60 to 3.39 t/ha, compared to the control variant, where foliar nutritopn was not applied (Table 3).

Due to the application of foliar nutrition, the growth and development of the P64LE25 hybrid improved, reducing plant stress caused by unfavorable weather conditions during the 2023 growing season. The use of these foliar nutrition led to an increase in yield compared to the control**.**

Table 3

Sunflower seed yield when applying foliar nutrition, t/ha

Variant	Years		Average over the years of research	± before control
	2023	2024		
Variant	2.64	2.55	2.60	-
MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf phase	3.53	3.25	3.39	0.79
AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf phase	3.42	3.12	3.27	0.67

The source was obtained as a result of own research results

The treatment with MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage contributed to a yield increase of 3.53 t/ha**,** which was 0.79 t/ha more than in the control variant. It was less effective to apply AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage. This treatment provided a yield gain of 0.67 t/ha, increasing the total yield to 3.42 t/ha**.**

Foliar nutrition improves the conditions for sunflower growth, which is reflected in enhanced biometric parameters of the plants. Based on the two-year research results, the farms of the Left Bank Forest-Steppe of Ukraine are recommended to apply three foliar treatments using a combination of macronutrients and boron-based foliar nutrition to increase sunflower seed yields.

In the context of climate change and increasing moisture deficits during the sunflower growing season, it is effective to apply a macro- and micronutrient complex combined with **g**rowth stimulators based on amino acids**.** This strategy enhances plant stress resistance and ensures consistently high yields of this major oilseed crop.

Conclusions and Prospects for Further Research. Based on the results of experimental research, the following conclusions can be drawn.

Foliar nutrition had a positive effect on the height of sunflower plants. In the control variant, plant height was 3.6% lower compared to the experimental variants where MYCOFRIEND (0.125 kg/ha) + GROUNDFIX (3.0 l/ha) + HELPROST Boron (2 l/ha) were applied at the 3-6 leaf stage. In the variant where AZOTOFIX (0.3 l/ha) + ORGANIC-BALANCE Monophosphorus (0.5 l/ha) + HELPROST Boron (2 l/ha) were applied at the same stage, plant height was 1.2% lower.

Foliar nutrition also had a positive effect on the leaf number per plant and total leaf surface area. In the treated variants, the number of leaves increased by 6.7-9.6%, and the leaf surface area increased by 4.5-9.3% compared to the control.

The coefficient of sunflower seed productivity was measured. In the control variant (without foliar nutrition), seed number per head was 1,540, seed mass per head was 54.0 g, and 1,000-seed weight was 35.1 g less than in the variant treated with AZOTOFIX (0,3 l/ha) + ORGANIC-BALANCE Monophosphorus (0,5 l/ha) + HELPROST Boron (2 l/ha) in the 3-6 leaf stage. These indicators increased to 1,547 seeds, 58.4 g per head, and 1,000-seed weight of 37.8 g, respectively.

A significant advantage was observed in the P64LE25 hybrid treated with MYCOFRIEND (0,125 kg/ha) + GROUNDFIX (3,0 l/ha) + HELPROST Boron (2 l/ha) at the 3-6 leaf stage due to a balanced content of macro- and microelements, which were quickly absorbed by the plants. In this hybrid, seed number per head was 67 more compared to the control, totalling 1,607 seeds. Seed mass per head and 1,000-seed weight were 8.3 g and 3.7 g higher than in the control, respectively.

A positive effect of foliar nutrition on the growth and development of sunflower, along with improved resistance to adverse weather conditions, led to an increase in yield compared to the control. When MYCOFRIEND (0,125 kg/ha) + GROUNDFIX (3,0 l/ha) + HELPROST Boron (2 l/ha) were applied at the 3-6 leaf stage, the yield increased by 0.79 t/ha, reaching 3.39 t/ha. In the variant treated with AZOTOFIX (0,3 l/ha) + ORGANIC-BALANCE Monophosphorus (0,5 l/ha) + HELPROST Boron (2,0 l/ha), the yield increased by 0.67 t/ha, reaching 3.27 t/ha.

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Відомості про авторів

Колісник Олег Миколайович − кандидат сільськогосподарських наук, доцент кафедри ботаніки, генетики та захисту рослин Вінницького національного аграрного університету (21008, м. Вінниця, вул. Сонячна, 3, e-mail: ooov@i.ua).

Kolisnyk Oleg − Candidate of Agricultural Sciences, Associate Professor of the Department of Botany, Genetics and Plant Protection, Vinnytsia National Agrarian University (21008, Vinnytsia, Soniachna St. 3, e-mail: ooov@i.ua).

Суржиков Микола Андрійович – аспірант Вінницького національного аграрного університету (21008, м. Вінниця, вул. Сонячна, 3, e–mail: Mukolasks@ukr.net).

Surzhykov Mykola – post-graduate student of National Agrarian University (21008, Vinnytsia, 3 Soniachna Street, e-mail: Mukolasks@ukr.net).