

EFFICACY OF FOLIAR BORON-CONTAINING FERTILISERS ON SUNFLOWER PLANTS

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This paper explores the effectiveness of boron-containing fertilisers on the structural elements of sunflower yield, and the economic benefits associated with their use. It is recognised that farmers often apply such fertilisers to sunflower seeds either as part of mono- or multi-element compound fertilisers or through foliar feeding. The fertiliser market is oversaturated with various microfertilisers with different boron concentrations. The effectiveness of these fertilisers must be assessed across multiple soil types, climatic conditions, and farming practices. Consequently, researching boron-containing fertilisers is highly relevant because of the increasing availability of such products on the global market. These fertilisers come with varying percentages of boron and pH indicator, often including nitrogen and other macro- and microelements. Our experiment was conducted in the fields of Sumy National Agrarian University, Sumy, Ukraine. There have been studies on the effectiveness of using three fertiliser types in the foliar feeding of sunflowers plants in the phase of 5-6 pairs of leaves: in liquid form, polyborates Quantum Boron 14% B and Speedfol Boron 17% (acidify the solution) and in crystalline granular form CrystallMax 20.8% B (neutral and alkaline pH). The mid-early sunflower hybrid LG 50479 SX (Limagrain) was sown on the experimental plots. It was determined that applying foliar boron-containing fertilisers influenced the height of plants. The tallest plants were recorded using Quantum boron active, resulting in a 4.85 % increase compared to the control treatment. Boron fertilisers enhanced the weight of seeds produced by the plant, with the most significant increase observed after applying Quantum boron, yielding an additional 10.5 g. The weight of the thousand seeds from the experimental plants ranged from 70 g to 75 g, and with the use of Quantum Boron, this indicator was the highest. It was the lowest among the boron-fertilised treatments (increase from the control of 3.4 g) with the application of Speedfol. Furthermore, it was established that boron fertilisers positively impact sunflower yields. The yield was 2.84 t/ha on the control plots, without fertilisers, while Quantum boron active increased it to 3.18 t/ha. Quantum boron active was the most cost-effective option for plant nutrition with boron-containing fertilisers, with a cost-effectiveness rate of 75.6 %. In comparison, Avangard CrystallMax achieved a rate of 74.7 %, and Speedfol reached 70.2 %.

Key words: sunflower, yield, seeds, micronutrients, boron, foliage, fertilisation, profitability, productivity, biometric parameters.

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Introduction. Sunflower is a primary source of high-quality edible oil, and the growing global population further fuels the demand for edible oil (Phonglosa et al., 2023). The seed yield is currently insufficient, which requires the improvement of modern agricultural technologies for growing crops (Sydiakina & Pavlenko, 2021). Boron plays a crucial role in various physiological processes in sunflower plants, including cell division, water metabolism, ion uptake, carbohydrate

metabolism, sugar translocation, and seed development (Figueira et al., 2024). A boron deficiency can negatively impact all these functions (Greena et al., 2023; Kovalenko et al., 2020; Reguera & Camacho-Cristóbal, 2023). Deficiency in sunflower nutrition typically occurs in sandy soils, particularly those with high nitrogen or calcium content and lower temperatures (Chorna & Wagner, 2017; Degryse, 2017). When applied to the soil, boron enhances crop index

and seed yield while increasing oil content in sunflower (Zahoor et al., 2011; Zapletalová et al., 2024). Boron is also essential for pollen germination and the growth of pollen tubes (Kundu et al., 2023). However, excessive boron can be toxic to crop growth, depending on the soil conditions and dosage applied (Brdar-Jokanović, 2020; Maqbool et al., 2023). Many plants are believed to require significantly more boron during their reproductive growth compared to the vegetative phase (Tkalych et al., 2017), as recently highlighted in sunflower.

The functional role of boron in plants is closely linked to water availability, the translocation of sugars, the uptake of cations and anions, and the metabolism of nitrogen, phosphorus, carbohydrates, and fats (Palamarchuk, 2020; Trotsenko et al., 2016). Due to boron deficiency, sunflower growth is often hindered under drought conditions. Foliar application of boron is beneficial in enhancing sunflower growth, yield, and water use efficiency in water-deficient conditions (Shevchenko et al., 2019).

Boron compounds must dissolve well and quickly in the solution for better absorption by the plant's leaves (Kohli et al., 2023). The dissolution rate of different crystalline boron compounds is quite different. For example, boric acid, especially borax, is poorly soluble. Therefore, fertilisers containing pure boric acid or borax will be less technological than other boron fertilisers. In addition, the low dissolution rate of these substances cannot guarantee 100 % availability of boron to the plant, since nutrients are available only if they are completely dissolved. Abat et al. (2015) found that co-granulating boron with other macronutrients, such as mono-ammonium phosphate, can obtain a good concentration of B in fertiliser and eliminate deficiency symptoms.

It is important to note that fertilisers containing disodium octaborate provide boron and have a significant sodium content, which can be toxic to many crops (Klymchuk & Dumych, 2021). Boron, by nature, is not a highly mobile element; its compounds with sodium and potassium exhibit a moderate level of mobility, while those with calcium and magnesium are poorly soluble.

Unlike trace metal elements, boron does not form chelates. A reaction with monoethanolamine is common to enhance the solubility of boron. All liquid boron fertilisers are formulated based on this compound (Kovalenko et al., 2022).

Materials and Methods. This study used the hybrid of LG 50479 SX (Limagrains company), which is classified as a mid-early sunflower hybrid. The experimental site is situated at the coordinates of 50°52'41.0" N and 34°12'07.5" E in the Sumy district of the Sumy region. Sowing was conducted on a plot of typical low-humus, slightly leached chernozem on loam loess. The primary agrochemical indicators of the soil are: humus content (as measured by Tyurin) at 3.75 %, pH in water at 6.41, and pH in KCl at 5.95. Humus content is 3.7 %, content of easily hydrolysed nitrogen is 106.3 mg/kg (very low), mobile phosphorus is 77.82 mg/kg (average level), exchangeable potassium is 7.61 mg/kg (average), and boron – 0.17 mg/kg (low). The predecessor of sunflower was corn.

The experimental scheme was as follows: 1. Control (water treatment). 2. Quantum boron active. 3. Avangard

Crystalmax B-21. 4. Speedfol boron. Foliar feeding with boron-containing fertilisers was conducted during the growth phase of 5-6 leaves. The application rate was 1.5 litres per hectare of active substance diluted in 200 litres of water, with three repetitions per treatment across plots of 1 hectare each.

The Quantum boron active fertiliser (Quantum company) contains 14 % boron, 5.5 % nitrogen, and trace amounts of copper and molybdenum in liquid form. Speedfol boron, produced by LLC "Agrokhimtsentr TD," boasts a boron content of 17 % in polyborate, with a solution pH of 5.0, indicating acidity. Avangard CrystalMax B from Ukravit contains the highest percentage of boron among the three fertilisers, at 20.8 %, and is available in crystalline powder form.

Sunflower sowing was carried out in May of 2022 and 2023, with a seeding density of 60,000 plants per hectare to the depth of 4-5 cm. The sowing was conducted with a pneumatic eight-row precision seed drill, Veles-Agro SPM-8, utilising a row spacing of 70 cm, and was operated with a CLAAS tractor. Alongside the sowing process, a complex fertiliser nitroammophoska (15-15-15) was applied at 110 kg/ha in physical weight. Subsequent crop management included the use of herbicides as well as nitrogen and boron foliar feeding. At the end of September, the accounting plots were harvested, and plants were analysed (three replicates from each plot, a total of 12). Statistical analysis was carried out using the Agrostat program.

Results. Biometric and yield data presented in Table 1, showed the results of plant morphology measurements as well as their corresponding yield. The plant height was influenced by applying boron-based fertilisers during foliar feeding. The tallest plants, 190 cm, were observed in the Quantum Boron Active treatment, resulting in a 4.85 % increase compared to the control. The use of Avangard B led to a 3.4% increase, while Speedfol resulted in a 2.9 % growth; however, no significant difference was noted between these two treatments. Boron-containing fertilisers also enhanced the seed weight per plant, with the heaviest seeds recorded in the Quantum Boron treatment at +10.5 g. No significant differences were observed between Avangard and Speedfol in this regard.

The weight of 1000 seeds at the experimental treatments ranged between 70.4 g and 75.7 g, with Quantum Boron showing the highest weight, while Speedfol yielded the lowest at 73.8 g. Notably, the number of seeds collected from the plant heads fell within the 697 (control) to 713 (Quantum) seed range, and no significant differences were detected between the variants treated with Speedfol and Avangard, indicating their comparable effectiveness under the study conditions.

The experimental plots produced an average sunflower seed yield of 3.05 tons per hectare, while the control group yielded 2.84 t/ha, demonstrating a measurable difference. The most remarkable results were noted in plots treated with Quantum Boron Active, which yielded 3.18 t/ha. The treatments with Avangard Crystalmax B and Speedfol showed no statistically significant differences in yield.

The cost-effectiveness of boron fertilisers in foliar applications was presented in Table 2. We have set the price

of sunflower seeds at UAH 13,000 (October – December 2023). However, it is worth noting that prices can fluctuate based on market conditions observed on various traders' websites. This economic assessment provides valuable insights into the financial benefits of integrating boron fertilisers into sunflower cultivation practices.

The costs associated with the additional production resulting from the application of boron fertilisers in the experiment ranged from UAH 2,990 to UAH 4,420; this indicates that we achieved higher returns when selling sunflower seeds treated with Quantum Boron Active. The total production expenses for boron fertiliser application and harvesting the additional sunflower seed crop amounted to between UAH 754 and UAH 1,076. Consequently, the additional profit generated was between UAH 2,236 and UAH 3,344. As a result, the highest profitability was observed with Quantum Boron Active at 75.6%, followed by Speedfol at 70.2 %, and Avangard Crystallmax B at 74.7 %.

Selling harvested crops has presented challenges due to the complexities of exporting from Ukraine (Ivanenko & Markovska, 2023). Specifically, sunflower yields have been observed to be 20-25% lower than expected. The Department of Agroindustrial Development in the Sumy region in 2023 reported that farmers are hesitant to sell their grain and choose to store it in anticipation of better prices.

Discussion. Various factors influence sunflower yields, including weather conditions during the growing season, soil fertility, and cultivation technology. Our results confirm the data of Kovalenko et al. (2022), who indicated the effect of the applied Quantum in foliar feeding in the 6-8 leaf phase on the growth of the 1000 seed weight (by 2.6 %), increasing seed yield and oil yield. However, scientists emphasise

that the data fluctuates depending on the selected hybrid and the weather conditions of the year. Kharchenko et al. (2019) and Garbar & Knap (2021) indicated the importance of the variety role. Enhancing biomass translocation to the seed crop can significantly impact productivity and improve the distribution of assimilation from vegetative to reproductive organs, potentially resulting in a 50 % increase in seed yield (Mehmood et al., 2018). Boron can exert beneficial and detrimental effects on yield and the various components of both the vegetative and reproductive stages of sunflower growth, depending on the dosage of fertiliser applied (Nikitenko et al., 2021). So we confirm the beneficial effect of boron fertilisers under the conditions of the Left-Forest of Ukraine.

Need to say, that the search for the best source of boron and its application method has been ongoing for a long time. Many scientists have published the results of studies on using boron nanoparticles (Al-kakayie & Al-Juhayshi, 2024; Pruthviraj et al., 2025). It was proven that foliar feeding was more effective than seed treatment and positively affected the plant's ability to absorb nutrients and increased pollen fertility, ultimately increasing seed yield. The effectiveness of the combined use of boron, sulphur (elemental sulphur 90%) – nitrogen-containing fertilisers, in particular nanourea together with Bortrak (15% boron, effective 200 mg/ha) for plant nutrition in the conditions of Pidzhaba, India, has also been proven (Roy A., Singh M.2024; Kumar et al., 2024). That is why we chose to use boron fertilisers for the foliar feeding, but the boron content was different, and some additional compounds were in the investigated fertilisers.

In 2024, sunflower seed prices doubled due to deteriorating logistics, the high cost of fuel, fertilisers, pesticides,

Table 1

Structural analysis of sunflower yield (average for 2022-2023)

Treatment	Structural elements of yield				
	Plant height, cm	Seed weight per plant, g	1000-seed weight, g	Total number of seeds per head, psc	Yield, t/ha
Control (water treatment)	181,2	41,3	70,4	697	2,84
Quantum boron active	190,0	48,5	75,7	713	3,18
Avangard CrystallMax	187,4	44,6	74,4	705	3,07
Speedfol	186,4	44,9	73,8	704	3,10
LSD ₀₅	1,3	1,9	1,3	1,11	0,5

Table 2

Economic efficiency of boron fertilisers application in sunflower cultivation

Indicators	Treatments		
	Quantum boron active	Avangard CrystallMax	Speedfol
Yield increase, t	0,34	0,23	0,26
Price for 1 ton seed, UAH	13000		
Cost of additional products, UAH	4420	2990	3380
Total additional costs, UAH	1076	754	1007
Additional profit, UAH	3344	2236	2373
Profitability of boron fertiliser application, %	75,6	74,7	70,2

seed drying and storage, transportation, etc. As we pointed out in our last paper (Kysylchuk et al., 2024), the area under sunflower crops is decreasing.

Conclusions. The application of boron-containing fertilisers as foliar nutrition during the 5-6 leaf phase has been shown to increase the growth of plant height by 2.9-4.85 %, as well as improve seed weight per plant, the weight of 1000 seeds, and the number of achenes per head. Notably, no significant differences were observed between the variants

treated with Speedfol and Avangard B. Sunflower seed yields in the experimental plots ranged from 2.84 t/ha in the control to 3.18 t/ha with Quantum Boron Active. A boron-containing liquid fertiliser with 14 % boron and 5.5 % nitrogen significantly boosted yields compared to other boron-containing fertilisers with higher concentrations. The profitability of boron-containing fertiliser is quite favourable, varying between 70.2 % and 75.6 %, with the highest profitability recorded for Quantum Boron Active.

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Ефективність борвмісних добрив у позакореневе внесення при вирощуванні соняшнику

У статті наведено ефективність впливу борвмісних добрив на структурні елементи врожаю соняшнику та економічну доцільність їх застосування. Відомо, що аграрії застосовують борвмісні добрива для обробки насіння соняшнику у складі моно- або поліелементного добрива або при позакореневому підживленні. Наразі ринок переповнений різними мікродобривами з різною концентрацією бору. Ефективність цих добрив необхідно оцінювати за різними типами ґрунтів, кліматичними умовами та методами землеробства. Отже, дослідження борвмісних добрив є актуальним, особливо зважаючи на зростання доступності таких продуктів на світовому ринку. Ці добрива містять різний відсоток бору та мають різну реакцію розчину, часто включають азот та інші макро- та мікроелементи. Наш експеримент проводився на полях Сумського національного аграрного університету, Суми, Україна. Було проведено дослідження ефективності використання трьох видів добрив при позакореневому підживленні соняшнику у фазі 5-6 пар листків: у рідкій формі поліборатів Квантум Бор 14% В і Спідфол Бор 17% (підкислюють розчин) і в кристалічній гранульованій формі Авангард КристалМакс Бор 20,8% В (нейтральний і лужний рН). На дослідних ділянках був посіяний середньоранній гібрид соняшнику LG 50479 SX (Лімагрейн). При виконанні досліджень встановлено, що внесення позакореневих борвмісних добрив впливає на висоту рослин соняшнику. Найвищі рослини були зареєстровані з використанням Квантум бор, що призвело до збільшення на 4,85 % порівняно з контрольною обробкою рослин водою. Борні добрива збільшували масу насіння кошику, причому найбільш значне зростання спостерігали після застосування Квантума, що забезпечило додаткові 10,5 г. Маса тисячі насінин з дослідних рослин була в межах від 70 г до 75 г, причому при застосуванні Квантум Бор цей показник був найвищим, а при застосуванні Спідфол – найнижчим серед варіантів досліду (приріст від контролю – 3,4 г). Встановлено, що борні добрива позитивно впливають на врожайність соняшнику. На контрольному варіанті без борвмісних добрив було досягнуто врожайності 2,84 т/га, а Квантум бор актив підвищив врожайність до 3,18 т/га. Квантум бор актив виявився найбільш рентабельним варіантом підживлення рослин борвмісними добривами з показником економічної ефективності (рентабельності) 75,6 %. Для порівняння, Авангард КристалМакс Бор досяг показника 74,7%, а Speedfol – 70,2 %.

Ключові слова: соняшник, урожайність, мікроелементи, бор, листкове підживлення, насіння, удобрення, рентабельність, продуктивність, біометричні показники.