

INFLUENCE OF FERTILIZER SYSTEM ON SPRING BARLEY PRODUCTIVITY

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Topicality. Spring barley is one of the key grain crops in Ukraine, the productivity of which can be enhanced through optimising plant nutrition in the fertiliser system. **Purpose.** The study was aimed to determine the effectiveness of fertilizer system and foliar feeding with microfertilizer Aidamin-complex for growing spring barley in the conditions of the Right-Bank Forest-Steppe of Ukraine. **Methods.** The research was carried out on the basis of Organic-D LLC in the Sutysky village of Vinnytsia region, Ukraine in 2020–2021. Field, laboratory, laboratory-field methods were used. **Results.** Microfertiliser Aidamin-complex at rates of 1 and 2 l/ha improves growth processes, which is manifested in an increase in line dimensions of plants by 1.7–2.1 cm and 5.4–6.1 cm, respectively, compared to the control variant. Optimisation of plant nutrition with macro- and microelements increased the lodging resistance. The combination of $N_{45}P_{45}K_{30}$ introduction with foliar feeding with Aidamin-complex microfertiliser at a rate of 2 l/ha provided the highest 1,000 grain weight and grain weight per spike (the increase in the number of grains was 0.2–1.3 seeds). This experimental variant had also the largest number of productive shoots and the highest grain yield of spring barley: Hetman variety – 396 shoots/m² and 3.12 t/ha, Helios variety – 398 shoots/m² and 3.72 t/ha, and Vakula variety – 392 shoots/m² and 3.14 t/ha, respectively. **Conclusions** The economically valuable traits and productivity of the studied spring barley varieties were significantly improved by applying mineral fertilisers at the rate of $N_{45}P_{45}K_{30}$ in combination with microfertiliser Aidamin-complex (2 l/ha), in particular, the plant height was increased; improvement of lodging resistance of plants were observed; the highest 1,000 grain weight, grain weight per spikelet, number of productive shoots were obtained, and the highest yields of Hetman, Helios and Vakula varieties of spring barley were 3.12 t/ha, 3.72 t/ha and 3.14 t/ha, respectively.

Key words: spring barley, grain, nutrients, microfertiliser, variety, lodging, yield, crop structure, plant height

Introduction. The problems of low yields and poor grain quality can affect the efficiency of barley cultivation. For the purpose of improving yields and grain quality, a lot of attention is paid to improving the varietal technology of growing the crop. One of the key aspects of this improvement is optimisation of the plant nutrition system, i.e. providing plants with the necessary nutrients for intensive growth and development [1].

Intensification of grain production is one of the ways of development of the agricultural sector of Ukraine, which involves the technologies increasing the resistance of cultivated plants to adverse environmental factors through the development of methods of stabilising adaptive responses of plants through the use of physiologically active substances of synthetic and natural origin and fertilisers [1]. The problem of low yields of spring barley requires improve-

ment of cultivation technology, with consideration of the peculiarities of plant growth and development and assimilation of macro- and microelements. This will help us understand how to optimise the cultivation process [2].

Micronutrients play an important role in plant nutrition and yield formation, ensuring optimal growth, development and functioning of plants. The main microelements (boron, iodine, cobalt, manganese, copper, molybdenum and zinc) perform a number of functions in plants. These microelements are key components of enzymes and factors regulating biochemical processes such as photosynthesis, respiration, nitrogen fixation, etc. A deficiency or insufficient amount of one of these micronutrients can significantly affect plant development, reduce their yield and quality.

Therefore, optimal nutrition of plants with both macronutrients and micronutrients is essen-

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tial [2, 3].

High-quality seeds and the full realisation of the genetic potential of high-intensity and intensive barley varieties require foliar feeding with microfertilisers at different stages of organogenesis. Foliar feeding includes the application of macro- and microelements not to the roots of the plant, but to the leaves or stem, which provides the plants with additional nutrients at a time when the root system is unable to provide the required amount of nutrients. Foliar feeding with microfertilisers improves photosynthesis, increases plant resistance to pests, diseases and stressful conditions (drought or low temperatures), which results in improved grain formation and quality, and can increase individual plant productivity [4].

Foliar feeding with microelements under high temperature conditions increases the content of colloidal-bound water, reduces the disruption of protein synthesis, the intensity of hydrolysis and the accumulation of ammonia and other harmful substances in plant tissues. Microelements have a positive effect on the redistribution of water in the plant, in particular, the amount of bound water increases by 12–50 %, which ensures plant resistance to drought and high temperature conditions [5]. They improve leaf watering, stimulate the acceleration of carbohydrate outflow from leaves to generative organs, reduce the formation of underdeveloped spikes by 35 % and increase pollen viability [1]. The application of microfertilisers helps to reduce protein hydrolysis in the leaves by 11–15 %. As a result, the protein is preserved in the leaves of the plant under the action of microelements, and is not converted into ammonium nitrogen during drought [6].

Barley is the most demanding crop in terms of soil fertility compared to other grain crops. The weakly developed root system of barley, which is very susceptible to salt concentrations in the soil solution, forms a significant amount of organic matter in a short period of time, especially at the first stage of growth and development [7]. Spring barley is considered one of the spring spiked crops that shows the best response to optimised fertilisation. However, fertilisation can have a significant impact on its growth and development, especially on lodging resistance, and for this reason, nitrogen fertilisation should be carried out in accordance

with the recommendations to avoid lodging [8–11].

Optimal fertilisation systems for spring barley are determined by various methods, the best of which is the calculation method. This method involves estimating the nutrient content of the soil and the crop's nutrient requirements. Usually, the results of agrochemical soil analysis are used to calculate the fertiliser dose. The fertiliser rate is calculated based on the nutrients that are not enough for optimal barley growth and development. The calculated rate of fertiliser is designed to provide the crop with the necessary amount of nutrients for the formation of a crop yield not lower than the recommended one. However, rate and cost of fertiliser application with the calculated fertiliser rate is significantly lower [8].

Therefore, research on the response of spring barley to agronomic cultivation practices is needed, in particular, studying the productivity of spring barley varieties depending on the fertilisation system and foliar feeding.

Research was aimed to investigate the effectiveness of fertilisation system and foliar feeding with microfertiliser Aidamin-complex for spring barley cultivation in the conditions of the Right Bank Forest-Steppe of Ukraine.

Materials and Methods. The experimental part of the research work to study the effect of fertilisation and foliar feeding on the spring barley productivity was carried out in the conditions of Organic-D LLC during 2020–2021.

The experimental plot has grey forest light loamy soil characterised by a slightly acidic reaction of the soil solution, low content of mineral nitrogen and mobile phosphorus compounds and medium content of mobile potassium compounds.

During the growing season of 2020, an increase in air temperature was observed in April and May, which exceeded the long-term average by +6.6 °C and +3.1 °C, respectively, in June – August – by +1.7 °C, as well as a significant decrease in precipitation by 175–179 mm in April – June and August. In March, the weather was unusually warm with poor precipitation and thick fog. At the end of May, a sharp short-term cold snap and rainy weather set in, this became a limiting factor for crop development. In 2021, there was an improvement in the moisture availability and optimisation of temperature conditions, as evidenced by the yields and growth and

development of spring barley plants this year. In March 2021, precipitation fell in the form of snow and sleet, with varying intensity, ranging from 6 to 11 mm, or 31–64 % of the long-term average. In April, there was an increase in the temperature regime, with rain and hail falling. In the first ten-day period of May, the weather was moderately warm with precipitation, and in the third ten-day period there was a decrease in temperature by (1.0–1.7 °C). In June and July, there was an increase in temperature and relative air humidity, and precipitation of various

intensities.

The experimental design included two factors: factor A – spring barley varieties Hetman, Helios and Vakula; factor B – foliar fertilisation: 1) control – without foliar feeding + N₄₅P₄₅K₃₀ (background), 2) background + Aidamin-complex in the tillering stage (1 l/ha), 3) background + Aidamin-complex in the tillering stage (2 l/ha).

Aidamin-complex is a liquid balanced complex microfertiliser on a chelate basis for foliar feeding (Table 1).

Table 1. Chemical composition of the microfertiliser Aidamin-complex

Indicator	N	K ₂ O	Zn	Fe	Mg	B	Cu	Mn	Mo	Co	SO ₄	Density, g/cm ³	pH
Content	39.6 g/l	12 g/l	2 g/l	4.6 g/l	9.6 g/l	6.6 g/l	0.6 g/l	5.6 g/l	0.2 g/l	0.2 g/l	122 g/l	1.15	2.4

The chelating agents in Aidamin-complex fertiliser are succinic, malic, aspartic, glutamic, citric, oxalic, oxalic-succinic, oxalic-acetic, ethylenediamine-succinic and other organic acids. The application rate is 1–2 l/ha for grain crops. The application of the fertiliser increases the growth and development of spring barley plants, especially during stressful periods, eliminates stress of cultivated plants caused by herbicide application, increases resistance to drought and low temperatures.

The registration area of spring barley plots was 25 m², trial was replicated four times. The cultivation technology is generally accepted for the Right-Bank Forest-Steppe, except for the factors studied.

The predecessor was winter wheat. Ploughing was carried out to a depth of 22 cm. Sowing was carried out with a Wintersteiger precision seeder with a seeding rate of 4.0 million seeds/ha at a seeding depth of 4 cm.

The seeds were dressed with Vitavax 200FF (2.5 l/t) 7 days before sowing. Crop care included weed control by applying the herbicide 2.4D amine salt (1 l/ha) in the tillering stage of spring barley, which ensured a clean field from weeds throughout the growing season. Mineral fertilisers were applied before sowing.

The plant resistance to lodging in plots was evaluated according to the methodology of state variety testing on a nine-point scale [12]. The plant height of barley was determined on

25 plants in the waxy ripeness stage, which were measured in different places along the diagonal of the registration plot and the average was calculated [13]. Among the yield attributes of spring barley varieties, the number of productive stems, spike length, and number of grains per spike were determined according to the generally accepted method [12]. Determining the 1000 grain weight in two 500-grain weights from each sample was performed with an accuracy of 0.1 g.

The harvest was threshed manually by selecting a trial sheaf [12]. The yield per plot, grain moisture content was determined during threshing.

Results. In grain crops such as barley, linear plant growth continues until the flowering stage. During this period, the plants gain vegetative mass and their linear dimensions increase. After this period, the plant activates its energy for the formation of spikes and grains, which becomes a priority for yield [14].

The research revealed that the highest plants were 87.5–92.9 cm in Helios variety at the wax ripeness stage (Table 2). Table 2 shows that the fertilisation system significantly affects the plant height of barley varieties.

On average, the plant height in the control was 77.6 cm for Hetman, 87.5 cm for Helios, and 84.1 cm for Vakula varieties. In general, the application of microfertiliser Aidamin-complex at a rate of 1 l/ha in the tillering stage increased

Table 2. Effect of fertilisation system on spring barley plant height, cm (2020–2021)

Experimental variant	Variety					
	Hetman		Helios		Vakula	
	plant height	± to control	plant height	± to control	plant height	± to control
Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	77.6	0.0	87.5	0.0	84.1	0.0
Background + Aidamin-complex, 1 l/ha	79.7	2.1	89.4	1.9	85.8	1.7
Background + Aidamin-complex, 2 l/ha	83.9	6.3	92.9	5.4	90.6	6.5

plant height by 1.7–2.1 cm, depending on the variety. The highest plants were observed in the variant with the highest rate of microfertiliser Aidamin-complex. In this case, the plant height increased by 5.4 cm in Hetman variety, 6.5 cm in Helios variety, and 6.1 cm in Vakula variety compared to the control.

The microfertiliser Aidamin complex has a positive effect on increasing plant height and leading to more active barley growth, especially at a rate of 2 l/ha: Hetman variety – 83.9 cm, Helios variety – 92.9 cm and Vakula variety – 90.2 cm. At the same time, the plant height was 5.4–6.5 cm higher than in the control variant.

Thus, the application of microfertiliser Aidamin-complex (2 l/ha) containing a complex of microelements (Zn, Fe, B, Cu, Mo, Co) in combination with N₄₅P₄₅K₃₀ improves the plant availability of nutrients, which leads to intensification of growth processes of the studied spring barley varieties.

Yields of spring barley can be reduced by lodging, which occurs due to the low lignin and tannin content of the stems, which provide them

with the essential strength and stability. There is a positive correlation between barley yields and lodging resistance, i.e. a more lodging resistant barley variety provides more opportunities for high yields. Improving plant resistance to lodging can be achieved with the application of microelements. They contribute to a uniform increase in the sclerenchymal (hard) layer in all internodes of the stem, which strengthens it and makes it less susceptible to environmental stressors such as wind and rain [14].

Lodging of grain crops, including spring barley, is a physiological response of plants to various environmental stressors (lack of light, waterlogging of soil, diseases, excessive nitrogen nutrition, strong winds, etc.) However, the determining factor in the resistance of spring barley varieties to lodging is the anatomical structure of the stem, plant height and genetic characteristics of the variety.

The lodging resistance of spring barley plants ranged from 7.6 to 8.9 points on average over the two years of research, depending on the variety and fertilization system (Table 3).

Table 3. Effect of fertilisation system on lodging resistance of spring barley, points (2020–2021)

Spring barley variety	Lodging resistance, points		
	Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	Background + Aidamin-complex, 1 l/ha	Background + Aidamin-complex, 2 l/ha
Hetman	7.6	7.7	8.6
Helios	8.0	8.7	8.9
Vakula	8.3	8.6	8.9

Variety is one of the most important elements for modern cultivation technologies of spring barley. The highest resistance to lodging (8.6–8.9 points) was observed in spring barley plants on the variant with application of N₄₅P₄₅K₃₀ and foliar feeding with microfertiliser Aidamin-complex at a rate of 2 l/ha. The best legumes) [15].

The application of microfertiliser Aidamin-complex has a positive effect on reducing the number of lodging plants. This technique

resistance to lodging was shown by the Vakula variety (8.3–8.9 points) and the lowest by the Hetman variety (7.6–8.6 points) on average over two years of research. Determination of lodging resistance was carried out according to the methodology of state variety testing of agricultural crops (grain, groat crops and grain increases lodging resistance by 0.1–1.0 points compared to the control, which is a fairly high indicator. Lower lodging increases yields and improves the harvested grain quality.

The main yield attributes of spring barley also include the number of productive stems per unit area, grain weight per spike, grain content of the spike and 1000 grain weight (Table 4).

Table 4. Yield attributes of spring barley depending on fertilisation system, (2020–2021)

Experimental variant	Number of productive shoots, pcs/m ²	Number of grains per spike, pcs	1000 grain weight, g	Grain weight per spike, g
Hetman				
Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	393	21.9	45.0	1.09
Background + Aidamin-complex, 1 l/ha	395	22.1	46.3	1.11
Background + Aidamin-complex, 2 l/ha	396	22.2	46.7	1.12
Helios				
Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	395	23.3	47.0	1.12
Background + Aidamin-complex, 1 l/ha	396	24.4	48.4	1.14
Background + Aidamin-complex, 2 l/ha	398	24.5	48.5	1.14
Vakula				
Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	389	227	44.3	1.08
Background + Aidamin-complex, 1 l/ha	391	23.0	45.0	1.10
Background + Aidamin-complex, 2 l/ha	392	23.1	45.3	1.12

Based on the analysis of the data obtained (Table 4), we can see that the grain weight per spike also changed under the impact of fertilisation systems and foliar feeding with the micro-fertiliser Aidamin complex. However, the importance of varietal characteristics of a particular variety of spring barley for the formation of grain weight per spike should be noted. Thus, it was found that the highest grain weight of the spike was formed in the variant with the introduction of N₄₅P₄₅K₃₀ in combination with foliar feeding with microfertiliser Aidamin-complex (2 l/ha) by Hetman variety (1.11 g), Helios variety (1.14 g) and Vakula variety (1.11 g), while in the control variant (without feeding) it was 1.08 g, 1.11 and 1.07 g, respectively.

Reducing the stem height can have a positive effect on plant productivity, increasing grain yields and is accompanied by increased spike growth and grain filling.

Foliar feeding is an important factor in increasing yields by supplying additional nutrients that meet the energy and building materials needs of plants, growth and development, in particular, of reproductive organs, which helps to reorient the flow of assimilants into the reproductive organs of the plant.

The tillering of grain crops is a characteristic effect of the fertilisation system and foliar feeding on the number of productive shoots of spring barley. In particular, it was found that the number of productive shoots increased significantly in the variant with foliar feeding with

istic and valuable biological trait. This ability significantly affects the yield and overall efficiency of agricultural production and depends on the genetic characteristics of the variety, soil nutrients, the duration of the period from seedling to stem elongation, agro-climatic factors, etc.

The foliar feeding contributed to an increase in the 1000 grain weight in different varieties of spring barley: Hetman variety – by 1.3–1.7 g, Helios variety – by 1.4–1.5 g and Vakula variety – by 0.7–1.0 g, compared to the control variant. The highest 1000 grain weight was obtained in the variant with N₄₅P₄₅K₃₀ + Aidamin complex (2 l/ha) for Hetman variety – 46.7 g, Helios variety – 48.5 g and Vakula variety – 45.3 g (see Table 4). In our opinion, increasing the lodging resistance of crops along with optimising the nutrient supply is the factor that increases the 1000 grain weight.

Our research has revealed that the application of the microfertiliser Aidamin-complex in foliar feeding had a slight effect on the number of grains in the spike; the increase in the number of grains was 0.2–1.3 grains. This indicator was largely determined by the morphological characteristics of a particular variety.

The experimental studies also indicate the micro-fertiliser Aidamin-complex and the introduction of mineral fertiliser N₄₅P₄₅K₃₀. In the control (without feeding), the number of productive shoots was 393 pcs./m² in Hetman variety, 395 pcs./m² in Helios variety, and

389 pcs./m² in Vakula variety on average for two years. Foliar feeding with microfertiliser Aidamin-complex (1 l/ha) + background N₄₅P₄₅K₃₀ increased the number of productive shoots in Hetman variety by 0.5 %, Helios variety – 0.25 % and in Vakula variety by 0.51 %, and for 2 l/ha of microfertiliser, the growth of this indicator was 0.76 %, 0.75 and 0.77 % compared to the control (background N₄₅P₄₅K₃₀).

The cultivation technology of spring barley can differ depending on various factors, such as climatic conditions, soil cover, available inputs and barley varieties sown. The optimal levels of technological practices will depend on different regions and growing conditions. The application of these technological practices will ensure a guaranteed spring barley harvest with high quality indicators that correspond to the potential of each variety.

The analysis of the data (Table 4) shows that in the control (background N₄₅P₄₅K₃₀), the yield of Hetman variety was 2.87 t/ha, Helios

variety – 3.44 t/ha and Vakula variety – 2.97 t/ha on average for two years of research.

The deviation of the actual yield from the biologically possible yield (based on calculation of the yield attributes) is explained by the delay in harvesting as we assessed the lodging resistance of the varieties.

The application of mineral fertilisers in combination with foliar feeding with microfertiliser Aidamin-complex increased the yield of Hetman, Helios and Vakula varieties. In particular, foliar feeding with microfertiliser Aidamin-complex (1 l/ha) in the tillering stage ensured the yield of the varieties Hetman (3.01 t/ha), Helios (3.65 t/ha) and Vakula (3.04 t/ha). However, the highest grain yields for the Hetman, Helios and Vakula varieties (3.12 t/ha, 3.72 and 3.14 t/ha, respectively) were obtained in the variant with background fertiliser (N₄₅P₄₅K₃₀) and the maximum rate (2 l/ha) of microfertiliser Aidamin-complex in feeding.

Thus, the application of the microfertiliser

Table 5. Spring barley yield depending on the fertilisation system, t/ha, (2020–2021)

Variety (A)	Variant of fertilisation (B)	Yield, t/ha		
		2020	2021	average
Hetman	Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	2.17	3.57	2.87
	Background + Aidamin-complex, 1 l/ha	2.23	3.78	3.01
	Background + Aidamin-complex, 2 l/ha	2.39	3.85	3.12
Helios	Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	2.56	4.32	3.44
	Background + Aidamin-complex, 1 l/ha	2.75	4.55	3.65
	Background + Aidamin-complex, 2 l/ha	2.77	4.67	3.72
Vakula	Control (no feeding + N ₄₅ P ₄₅ K ₃₀ (background))	2.25	3.68	2.97
	Background + Aidamin-complex, 1 l/ha	2.32	3.75	3.04
	Background + Aidamin-complex, 2 l/ha	2.38	3.89	3.14
LSD ₀₅ , t/ha	Factor A	0.07	0.12	–
	Factor B	0.15	0.21	
	Interaction AB	0.19	0.26	

Aidamin-complex + background (N₄₅P₄₅K₃₀) resulted in a 9–16 % increase in yield. Consequently, the application of these fertilisers in combination provides an environmentally safe and high yield of spring barley.

Conclusions. The integrated effect of hyd-rothermal conditions and fertilisation system on the processes of growth and development and productivity of spring barley varieties was established. In particular, the application of

background fertiliser N₄₅P₄₅K₃₀ in combination with microfertiliser Aidamin-complex (2 l/ha) contributes to the formation of the best plant architectonics of spring barley varieties, resistant to lodging, yield attributes such as 1000 grain weight, grain weight per spike, number of productive shoots and provides the highest yields in Hetman, Helios and Vakula varieties 3.12 t/ha, 3.72 and 3.14 t/ha, respectively.

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Актуальність. Ячмінь ярий це одна із основних зернових культур України, збільшення продуктивності якої можливе за рахунок оптимізації живлення рослин у системі удобрення. **Метою досліджень** було встановлення ефективності системи удобрення та позакоренових підживлень мікродобрином Айдамін-комплексний для вирощування ячменю ярого в умовах Правобережного Лісостепу України. **Методи.** Польовий, лабораторний, лабораторно польовий. Дослідження проводились протягом 2020–2021 років на базі ТОВ «Органік-Д» с. Сутиски Вінницької області, Україна. **Результати.** Застосування мікродобрива Айдамін-комплексний забезпечує поліпшення ростових процесів, це проявляється збільшенням лінійних розмірів рослин, на 1,7–2,1 см та 5,4–6,1 см відповідно за дози внесення 1 та 2 л/га, порівняно із контрольним варіантом. Оптимізація живлення рослин макро- і мікроелементами сприяла покращенню стійкості до вилягання. У варіанті за $N_{45}P_{45}K_{30}$ у поєднанні із позакореновим підживленням мікродобрином Айдамін-комплексний дозою 2 л/га отримали найвищу масу 1000 зерен та масу зерна з колосу, а також кількість зерен зросла на 0,2–1,3 шт. Цей варіант забезпечив зростання показників кількості продуктивних пагонів та

урожайності ячменю: сорт Гетьман – 396 шт./м² та 3,12 т/га, Геліос – 398 шт./м² та 3,72 т/га і Вакула – 392 шт./м² та 3,14 т/га, відповідно. **Висновки.** Господарсько-цінні ознаки і продуктивність досліджених сортів ячменю ярого істотно покращувалися за рахунок внесення мінеральних добрив N₄₅P₄₅K₃₀ у поєднанні з мікродобривом Айдамін-комплексний (2 л/га), зокрема, відмічене збільшення висоти рослин, покращення стійкості рослин до вилягання, найвище значення маси 1000 зерен, маси зерна з колоса, кількості продуктивних пагонів та найвищу урожайність – 3,12 т/га, 3,72 та 3,14 т/га, відповідно для сортів ячменю ярого Гетьман, Геліос і Вакула.

Ключові слова: ячмінь ярий, зерно, елементи живлення, мікродобриво, сорт, вилягання, урожайність, структура врожаю, висота рослин