

**INFLUENCE OF PLANT GROWTH STIMULANTS AND NUTRITION BACKGROUND
ON THE FORMATION OF BIOMETRIC INDICATORS OF WINTER WHEAT
IN THE EASTERN PART OF THE NORTHERN STEPPE OF UKRAINE**

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Topicality. The introduction of growth stimulants of various origins into the technological process of growing winter wheat contributes to a more rational utilisation of nutrients by plants during the growing season due to the development of root and vegetative systems. Adjustment of technology elements during different organogenesis stages allows us to predict the course of physiological processes of plants at the following developmental stages and to influence them in a timely manner. **Purpose.** To study the influence of plant growth stimulants and nutritional status on the formation of biometric indicators by winter wheat plants during different periods of organogenesis. **Methods.** Field, laboratory, measuring, calculation and comparative, and mathematical statistics methods. **Results.** In 2021–2023, the research was carried out in the field crop rotation of the Donetsk State Agricultural Research Station of NAAS of Ukraine on two nutritional statuses: mineral ($N_{30}P_{30}$) and organic (biohumus at a rate of 1,000 kg/ha). The application of microbiological preparations Microhumin and Baikal for treating winter wheat seeds contributed to more effective preparation of plants to overwintering, regardless of the nutritional status. Thus, the number of secondary roots in winter wheat plants at the time of cessation of autumn vegetation exceeded by 0.4 pcs (mineral background) and 0.6 pcs (organic background) compared to the control variants. Comparing the nutrition status, it was found that the mineral background contributed to an increase in the amount of accumulated sugars in tillering nodes by 2.5% compared to the organic background. Regardless of the nutritional status, the highest percentage of sugars was provided by variants with the application of Baikal for seed treatment. The best effect on the indicators of general and productive tillering of winter wheat plants was found at the mineral background of nutrition after seed treatment with Microhumin. Microhumin in combination with other preparations increased the coefficient of general tillering by 0.1–0.3 and the coefficient of productive tillering by 0.2–0.5 compared to the control variant. The highest coefficients of general and productive tillering of winter wheat plants of Peremoha variety on mineral (2.5 and 2.2, respectively) and organic (2.2 and 1.9, respectively) nutrition backgrounds were provided by application of Microhumin (seed treatment) + Ecostimul (tillering stage). **Conclusions.** The studied microbiological preparations contributed to the increase of tillering in winter wheat plants regardless of the nutritional status. The mineral background provided an advantage in the formation of biometric parameters in winter wheat plants.

Key words: winter wheat, fertilizer system, microbiological preparations, periods of organogenesis, development of root and vegetative systems

Introduction. The key challenge for the Ukrainian agricultural sector is the significant growth and stabilisation of grain production. Climate changes, environmental degradation and frequent droughts require identifying opportunities to counteract these phenomena, including through biologisation of cultivation technologies, considering hydrothermal conditions and the response of modern varieties to them. One of the main focuses of agricultural science is to enhance the grain yields of spiked crops by improving existing cultivation technologies and developing new, more rational and environmen-

tally friendly agricultural practices [1, 2].

Among the environmental factors, the formation of a plant organism is most strongly influenced by the nutritional regime, which is created by proper crop rotations and balanced application of macro- and micronutrients [3, 4].

Mineral fertiliser application in winter wheat cultivation has a significant effect on the profitability of this crop. The payback of fertilisers depends on the combined effect of both biotic and abiotic factors. Unbalanced fertiliser application leads to a lower efficiency of nutrient consumption by plants in the early ontoge-

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nesis, unproductive loss of soil moisture, a few quantitative composition of soil biota and plant resistance to diseases. Excessive application of mineral fertilisers ultimately decreases the productivity of winter wheat plants.

The organic fertilisers used in cultivation technology stabilises the development of beneficial soil biota and physiological activity aimed at the natural enrichment of the soil with essential micro- and macronutrients. A deficit-free humus balance in the soil requires constant introduction of organic fertilisers [5, 6]. Significant number of studies are aimed at enhancing soil fertility with vermicompost organic fertilisers produced by industrial compost processing, using vermicompost produced with the help of Red Californian earthworms (*Eisenia foetida andrei*) [7].

Analysis of the literature shows that an integral part of the modern technological process of growing crops is the application of biostimulants of various origins, which increase the efficiency of fertilisers, improving plant nutrition and productivity [8–14]. The implementation of growth stimulants of various origins in the winter wheat cultivation technology contributes to a more rational assimilation of nutrients by plants during the growing season due to the development of a powerful root system and vegetative mass of plants.

Understanding and knowledge of the factors that influence the growth and development of winter wheat plants makes it possible to adjust the elements of technology during different organogenesis stages. The analysis of biometric parameters helps to predict the course of plant physiological processes during the growing season and to influence them in a timely manner.

The research is aimed at studying the influence of growth stimulants and nutrition backgrounds on the formation of biometric parameters of winter wheat plants in different periods of organogenesis.

Materials and Methods. The research was carried out in the field crop rotation of the Donetsk State Agricultural Research Station of NAAS of Ukraine in 2021–2023 on two nutrition backgrounds: mineral ($N_{30}P_{30}$) and organic (vermicompost – 1000 kg/ha). The sown area of the plot is 84 m², the registration area is 76.9 m². The research was carried out in multifactorial field experiments, laid out by the se-

quential plot method in a systematic way. The experiments were repeated three times.

The main research method was field, which was supplemented by analytical studies, measurements, calculations and observations in accordance with generally accepted methods and guidelines in crop production. The experimental data were statistically processed according to the field experiment methodology [15].

The soil cover of the experimental plot is ordinary low-humus heavy loamy chernozem. The humus content in the topsoil is 4.5 %. Gross content of main nutrients: N – 0.28–0.31 %, P₂O₅ – 0.16–0.18 %, K₂O – 1.8–2.0 %.

The weather conditions in terms of moisture availability during the years of research were favourable for the development of grain crops, and different nutrition backgrounds and physiologically active preparations created additional conditions for the effective development of winter wheat during the first organogenesis stages.

Cultivation technology was generally accepted for the eastern part of the Northern Steppe of Ukraine, except for the questions posed for the study, and corresponded to zonal and regional recommendations. The predecessor of winter wheat is black fallow. Mineral and organic fertilisers were during sowing. Experimental variants are shown in Table 1.

In their research, inoculation of seeds and spraying of winter wheat crops of Peremoha variety in the tillering stage with microbiological preparations was carried out to establish their effect on the biometric parameters of plants under different nutrition backgrounds at the cessation of autumn vegetation, at the end of the tillering stage and in the full maturity stage.

Microhumin (1 kg/t) is a multifunctional biological product for bacterisation of grain crop seeds to improve root nutrition of plants. The product contains specially prepared peat with bacterial cells of *Azospirillum brasilense* 410, physiologically active substances of biological origin (auxins, cytokinins, amino acids, and humic acids), trace elements in chelated form and macroelements in starting concentrations.

Baikal (1 ml/l of water) is a unique microbiological product containing a wide range of effective soil microorganisms (more than 80 strains in total). Baikal promotes plant nutrition, stimulates the formation of new shoots and

roots, increases the plant resistance to pathogenic organisms and suppresses pathogenic soil microflora (bacteria, fungi, viruses), accelerates the decomposition of organic matter, improves air and water permeability in the soil.

Ecostimul (2 l/ha) is an organic fertiliser for increasing yields, providing plants with adequate nutrition, compensating the deficiency of macro- and microelements, and improving disease resistance.

Biorhythm (2 l/ha) is a complex of natural environmentally friendly nutrients, humic substances and plant growth stimulants.

Results. At the time of cessation of autumn vegetation of winter wheat plants, the effectiveness of the proposed agrotechnical measures for the formation of vegetative mass and root system and preparation of plants for the period of winter dormancy can be observed by biometric indicators (Table 1).

Table 1. Biometric parameters and sugar content in winter wheat plants at the cessation of autumn vegetation, 2021–2023

Variant	Plant height, cm	Number of shoots per plant, pcs.	Number of nodal roots per plant, pcs.	Sugar content, %
Mineral nutrition background (N ₃₀ P ₃₀)				
Control	14.4	2.0	2.8	23.98
Microhumin (seed treatment)	14.8	2.1	3.1	26.82
Microhumin + Baikal (seed treatment)	15.0	2.2	3.6	28.18
Microhumin (seed treatment) + Biorhythm (tillering stage)	15.0	2.1	3.0	25.32
Microhumin (seed treatment) + Ecostimul (tillering stage)	14.9	2.3	3.1	25.34
Baikal (seed treatment) + Biorhythm (tillering stage)	15.0	2.1	3.3	27.75
Baikal (seed treatment) + Ecostimul (tillering stage)	15.1	2.1	3.4	27.86
Baikal (tillering stage)	14.4	2.0	2.7	23.54
Biorhythm (tillering stage)	14.5	2.0	2.8	23.48
Ecostimul (tillering stage)	14.5	1.9	2.7	23.66
LSD ₀₅	0.03	0.01	0.09	1.3
Organic nutrition background (vermicompost of 1000 kg/ha)				
Control	13.3	1.5	2.0	23.38
Microhumin (seed treatment)	13.9	1.8	2.5	23.31
Microhumin + Baikal (seed treatment)	13.9	1.8	2.8	26.98
Microhumin (seed treatment) + Biorhythm (tillering stage)	14.0	1.7	2.6	23.12
Microhumin (seed treatment) + Ecostimul (tillering stage)	13.8	1.8	2.5	23.48
Baikal (seed treatment) + Biorhythm (tillering stage)	13.9	1.7	2.7	25.59
Baikal (seed treatment) + Ecostimul (tillering stage)	13.9	1.8	2.7	23.54
Baikal (tillering stage)	13.2	1.4	2.1	22.95
Biorhythm (tillering stage)	13.3	1.4	2.1	20.57
Ecostimul (tillering stage)	13.3	1.5	2.2	23.01
LSD ₀₅	0.02	0.02	0.08	1.6

Depending on the experiment variants and nutrition backgrounds, the plant height of winter wheat varied from 13.2 cm to 15.1 cm. The tal-

lest plants (15.0 cm on average) were in the variants with the application of Baikal and Microhumin for seed treatment on the mineral nutri-

tion background. On the variants without seed treatment, the plant height was 0.6 cm less on average. A similar tendency was observed on the organic nutrition background, but the plants were shorter on average by 1 cm compared to the mineral nutrition.

Seed treatment with microbiological preparations had a positive effect on the shoot formation by plants. Thus, in the variants with seed treatment, the values of this indicator were on average 0.1 shoot (with mineral background) and 0.3 shoot (with organic background) higher than the corresponding values in the control.

The number of secondary roots demonstrates the adaptability of plants to environmental conditions. The application of a mixture of Microhumin and Baikal for seed treatment contributed to the formation of the largest number of secondary roots in winter wheat plants regardless of the nutrition background (on average 3.6 pcs on mineral; 2.8 pcs on organic).

Based on the comparative study of biometric parameters of winter wheat plants at the initial organogenesis stages under different nutrition backgrounds, we can conclude that the use of mineral fertilisers promotes more intensive growth and development of both vegetative mass and root system of plants. Comparison of

nutrition backgrounds revealed that mineral fertiliser contributed to an increase in the content of accumulated sugars in tillering nodes by 2.5 % versus organic fertiliser. Regardless of the nutrition background, the highest content of sugars in the tillering nodes was provided by the variants of seed treatment with Baikal. During the research, the weather conditions of winter period were favourable for overwintering of winter wheat plants, which contributed to the rapid resumption of spring vegetation, as well as their stable development during the spring organogenesis stages.

The influence of agrotechnological elements on the growth and development of winter wheat plants is indicated by biometric parameters that were formed before the end of the tillering stage.

One of the main biometric indicators is the number of formed and preserved shoots per plant. This indicator shows the plant's resistance to the influence of a complex of environmental factors during the stages of organogenesis. The mineral background increases the ability of plants to generate shoots by an average of 0.5–0.6 per plant compared to the organic background (Fig. 1).

Regardless of the nutrition background, the



Fig. 1 Effect of microbiological preparations on shoot formation in winter wheat plants at the end of the tillering stage, 2021–2023.

largest number of shoots per plant was obtained in the variant with the seed treatment with Microhumin and spraying of crops with Ecostimul at the

beginning of the tillering stage.

The development of the secondary root system demonstrates the adaptability of plants

to environmental conditions. For this reason, the number of secondary roots per plant was recorded at the end of the tillering stage. The mineral background contributed to a more intensive

formation of secondary roots in winter wheat plants compared to the organic background (Fig. 2).

Seed treatment with microbiological pre-



Fig. 2 Effect of microbiological preparations on the formation of secondary roots by winter wheat plants at the end of the tillering stage, 2021–2023.

parations, regardless of the nutrition background, increased the number of secondary roots per plant on average from 0.4 to 0.8 pcs.

The final effect of microbiological preparations on the formation of biometric parameters of winter wheat plants was determined in the full maturity stage.

Nutrition backgrounds had different effects on the biometric parameters of plants during the growing season. Thus, under the mineral background, wheat plants on the control were 2 cm taller than plants on the organic background (Table 2).

The variants with seed treatment with the microbiological preparation Microhum in combination with Baikal, Biorhythm and Ecostimul contributed to the formation of the tallest plants compared to the control. A similar result was achieved with a single application of Baikal at the beginning of the tillering stage.

On the organic background, there was a similar trend in the plant height of winter wheat. The tallest plants in the full maturity stage were obtained with application of Microhum (seed treatment) in combination with Ecostimul (spraying in the tillering stage) (+5 cm com-

pared to the control). Comparison of the influence of nutrition backgrounds revealed a pattern – greater effectiveness of physiologically active substances on plants was observed in the organic background. The increase in plant height in the variants with the microbiological preparations compared to the control was on the organic background, although in general, plants were taller on the mineral background.

The significant effect of nutrition backgrounds and microbiological preparations on the winter wheat growth and development during the first organogenesis stages, namely on the formation of general and productive tillering shoots. On the mineral background, the best efficiency was achieved in the variants with seed treatment of Microhum in combination with other preparations, in which the number of shoots of general tillering increased from 0.1 to 0.3, and shoots of productive tillering – from 0.2 to 0.5. The highest intensity of general and productive tillering of winter wheat (tillering coefficient 2.5 and 2.2, respectively) was provided by the application of Microhum (seed treatment) and Ecostimul (spraying of crops at the beginning of the tillering stage). The organic nut-

Table 2. Biometric parameters of winter wheat plants in the full maturity stage, 2021–2023

Variant	Plant height, cm	Number of shoots, pcs/m ²		Total tillering coefficient, %	Productive
		total	productive		
Mineral nutrition background (N ₃₀ P ₃₀)					
Control	86	990	765	2.2	1.7
Microhumin (seed treatment)	87	1035	900	2.3	2.0
Microhumin + Baikal (seed treatment)	90	1080	945	2.4	2.1
Microhumin (seed treatment) + Biorhythm (tillering stage)	90	1035	855	2.3	1.9
Microhumin (seed treatment) + Ecostimul (tillering stage)	90	1125	990	2.5	2.2
Baikal (seed treatment) + Biorhythm (tillering stage)	89	990	810	2.2	1.8
Baikal (seed treatment) + Ecostimul (tillering stage)	89	1035	810	2.3	1.8
Baikal (tillering stage)	90	990	765	2.2	1.7
Biorhythm (tillering stage)	88	1035	900	2.3	2.0
Ecostimul (tillering stage)	89	945	765	2.2	1.7
LSD ₀₅	0.9	12	7	0.06	0.03
Organic nutrition background (vermicompost of 1000 kg/ha)					
Control	84	765	630	1.7	1.4
Microhumin (seed treatment)	87	855	720	1.9	1.6
Microhumin + Baikal (seed treatment)	88	855	675	1.9	1.5
Microhumin (seed treatment) + Biorhythm (tillering stage)	88	900	630	2.0	1.7
Microhumin (seed treatment) + Ecostimul (tillering stage)	89	990	855	2.2	1.9
Baikal (seed treatment) + Biorhythm (tillering stage)	86	945	855	2.1	1.9
Baikal (seed treatment) + Ecostimul (tillering stage)	87	855	720	1.9	1.6
Baikal (tillering stage)	88	855	720	1.9	1.6
Biorhythm (tillering stage)	87	810	630	1.8	1.4
Ecostimul (tillering stage)	87	765	585	1.7	1.3
LSD ₀₅	1	11	5	0.04	0.05

rition background created other conditions for revealing the potential of the microbiological preparations.

Spraying only with Ecostimul at the beginning of the tillering stage resulted in the total and productive tillering coefficients similar to the control. The highest coefficients of total and productive tillering (2.2 and 1.9) were obtained under seed treatment with Microhumin and spraying of crops with Ecostimul at the beginning of the tillering stage.

Comparison of nutrition backgrounds demonstrates the advantage of mineral back-

ground in the formation of biometric parameters in winter wheat plants.

Conclusions. The pattern of influence of nutritional backgrounds and studied microbiological preparations on the formation of biometric parameters in winter wheat plants at different organogenesis stages was determined.

Seed treatment (inoculation) of winter wheat with microbiological preparations Microhumin and Baikal contributed to a more effective preparation of plants for overwintering, regardless of the nutritional background. Thus,

the number of secondary roots at the cessation of autumn vegetation exceeded the control by an average of 0.4 (mineral background) and 0.6 (organic background).

A comparison of nutrition backgrounds revealed that mineral nutrition increased the content of accumulated sugars in tillering nodes by 2.5 % compared to organic nutrition. Regardless of the nutritional background, the highest sugar content in the tillering nodes was obtained in the variants with seed treatment with Baikal.

Under the mineral nutrition background,

the highest coefficients of total and productive tillering were found when using Microhumin for seed treatment, which in combination with other preparations contributed to an increase in the number of shoots from 0.1 to 0.3 compared to the control.

The highest coefficients of total and productive tillering of winter wheat plants on mineral (2.5; 2.2) and organic (2.2; 1.9) nutrition backgrounds, respectively, were obtained when using Microhumin (seed treatment) + Ecostimul (tillering stage).

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Актуальність. Введення у технологічний процес вирощування пшениці озимої стимуляторів росту різного походження сприяє більш раціональному використанню рослинами поживних елементів протягом вегетації, за рахунок розвитку кореневої та вегетативної систем. Коригування елементами технології протягом різних етапів органогенезу дозволяє прогнозувати перебіг фізіологічних процесів рослин на наступних стадіях розвитку та своєчасно впливати на них. **Мета.** Вивчити вплив стимуляторів росту та фонів живлення на формування рослинами пшениці озимої біометричних показників у різні фази розвитку. **Методи.** Польовий, лабораторний, вимірвальний, розрахунково-порівняльний, методи математичної статистики. **Результати.** Дослідження виконувались у польовій сівозміні Донецької державної сільськогосподарської дослідної станції НААН України у 2021–2023 рр. на двох фонах живлення: мінеральному ($N_{30}P_{30}$) і органічному (біогумус – 1000 кг/га). Використання мікробіологічних препаратів Мікрогумін та Байкал для обробки насіння пшениці озимої сприяло більш ефективній підготовці рослин до зимового періоду незалежно від фону живлення. Так, кількість вторинних коренів у рослин пшениці озимої на час припинення осінньої вегетації перевищувала контроль на 0,4 шт. (мінеральний фон) та 0,6 шт. (органічний фон). При порівнянні фонів живлення було встановлено, що мінеральний фон сприяв збільшенню вмісту накопичених цукрів у вузлах кущіння на 2,5 % порівняно з органічним. Незалежно від фону живлення найбільший вміст цукрів забезпечили варіанти з використанням для обробки насіння препарату Байкал. За мінерального фону живлення найкращі показники загального та продуктивного кущіння рослин пшениці озимої отримали за обробки насіння препаратом Мікрогумін, який у поєднанні з іншими препаратами, порівняно з контролем, забезпечив підвищення коефіцієнтів загального кущіння на 0,1–0,3, продуктивного кущіння – на 0,2–0,5. Найвищі коефіцієнти загального та продуктивного кущіння рослин пшениці озимої сорту Перемога на мінеральному (2,5 та 2,2, відповідно) та органічному (2,2 та 1,9, відповідно) фонах живлення забезпечив варіант Мікрогумін (обробка насіння) + Екостимул (фаза кущіння). **Висновки.** Застосування мікробіологічних препаратів, що вивчались, сприяло підвищенню кущіння у рослин пшениці озимої незалежно від фону живлення. Мінеральний фон забезпечив перевагу при формуванні у рослин пшениці озимої біометричних показників.

Ключові слова: пшениця озима, система удобрення, мікробіологічні препарати, періоди органогенезу, розвиток кореневої та вегетативної систем