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BIOCHEMICAL COMPOSITION OF SPRING WHEAT GRAIN UNDER PRE-SOWING TREATMENT WITH METABOLICALLY ACTIVE SUBSTANCES

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Problem statement. Grain crops play a significant role in the agro-industrial complex of Ukraine, and spring wheat takes an important place in it. This crop serves as a reserve for obtaining high-quality food grain, especially in years when winter grain crops perish due to unfavourable environmental conditions [1]. Considering scientific forecasts of climate change, spring wheat grain has high baking qualities and contains more protein and gluten than winter wheat. It allows this flour to be used as an improver in bread baking. Spring wheat grain is also used in the production of high-quality semolina and pasta [2].

At the current stage of grain farming development, it is important not only to increase yields but also to improve grain quality while reducing material, labour, and financial costs for producing a unit of output. To achieve this goal, it is necessary to apply not only traditional agro-technologies but also to introduce new approaches, among which safe plant growth regulators play a significant role [3]. Promising among them are combinations of metabolically active substances, in particular, para-hydroxybenzoic acid (PHBA), $MgSO_4$, methionine, ubiquinone-10, and vitamin E.

Analysis of recent studies and publications. The biochemical composition of grain is a crucial indicator of its nutritional value, determining both crop quality and suitability for various types of processing. It is known that the main components of wheat grain are proteins, carbohydrates – particularly starch – as well as carotenoids and antioxidant enzyme. They influence the technological properties of the grain. The content of these biochemical substances is determined by the genetic characteristics of the variety [5], growing conditions, and the influence of agro-technical measures such as pre-sowing seed treatment with biologically active substances [6].

The authors have proved [6] that pre-sowing treatment of wheat seeds with the K-1317 variety with biological, chemical, or hormonal solutions at a 1:1 concentration for 12 and 24 hours led to an increase in grain protein content. The authors [7] have also reported improvements in grain quality indicators following pre-sowing treatment of winter wheat seeds with the BioZern fertilizer, the Medax Top growth regulator, the Turbo micronutrient, and $MgSO_4$ against the background of standard fertilization. Therefore, the search for new environmentally safe and effective preparations for pre-sowing treatment of wheat seeds that will improve the biochemical composition of wheat grain is a pressing issue today.

The purpose of the research is to investigate the effect of pre-sowing seed treatment with combinations of metabolically active substances on the biochemical composition of spring wheat grain.

Materials and methods. Field experiments were conducted at the educational and research agrobio-station of Nizhyn Mykola Gogol State University (Chernihiv region) during the period from 2022 to 2024. For plot preparation, cultivation was carried out, the area was measured, divided into variants and replications, and wheat seeds were treated with the following substances:

1. Control – seeds without treatment (treated with distilled water).
2. EQ – seeds treated with a combination of vitamin E (10^{-8} M) and ubiquinone-10 (10^{-8} M).
3. EMP – seeds treated with a combination of vitamin E (10^{-8} M), methionine (0.001 %), and para-hydroxybenzoic acid (PHBA) (0.001 %).
4. EMPMg – seeds treated with a combination of vitamin E (10^{-8} M), methionine (0.001 %), PHBA (0.001 %), and $MgSO_4$ (0.001 %).
5. EPMg – seeds treated with a combination of vitamin E (10^{-8} M), PHBA (0.001 %), and $MgSO_4$ (0.001 %).

The duration of wheat seed treatment with metabolically active substances was 2 hours. The research was carried out in accordance with the methodology of field experiments [8]. After treatment, the seeds were sown in the field using a narrow-row method (row spacing – 15 cm) in podzolized, low-humus black soil.

The soil was relatively homogeneous in granulometric and total chemical composition, with a high content of nutrients in the humus horizon. The humus content in the arable layer was 3.5 %, the base saturation – 90.8–91.1 %, and the soil solution reaction was slightly acidic (pH 6.0–6.3). The hydrolytic acidity was 2.42 mg/100 g of soil. The content of available phosphorus compounds was 118 mg/kg, exchangeable potassium – 99 mg/kg (according to Chyrykov – increased supply), and nitrogen – 64 mg/kg (according to Kornfield – medium supply).

There was no need for the application of mineral fertilizers. The total area of the experimental plot was 98 m^2, and the experiment was conducted in triplicate.

For the research, the seeds of soft spring wheat of the variety Panianka were used. This variety is high-yielding, mid-ripening, and resistant to diseases, lodging, drought, and shattering [9]. Sowing was carried out using calibrated seeds with high fertility. The seeding rate was 5.5 million seeds per hectare, and the sowing depth was 3–5 cm.

The protein content in plant material was determined using the Lowry method [10]. The carotenoid content was measured by the spectrophotometric method [11], while the starch content was determined colorimetrically at a wavelength of 590 nm [12].

Statistical and mathematical data processing was performed using Excel 16.0 for Windows. Statistical evaluation was carried out using the Student's t-test at a significance level of $p \leq 0.05$.

Research results. In most countries throughout the world, grain products form the basis of the human diet, providing 60–80 % of daily caloric intake [3]. One of the global challenges facing humanity today is unbalanced nutrition, particularly vitamin and mineral deficiencies. Among the main consequences of this disbalance is the insufficient intake of carotenoids. Carotenoids belong to a large group of natural pigments that perform essential biological functions: they exhibit strong antioxidant activity and serve as precursors of vitamin A in the human body [4].

The conducted research showed that pre-sowing seed treatment with metabolically active substances contributed to an increase in the carotenoid content in the grain of spring wheat of variety Panianka. The highest carotenoid accumulation levels were recorded in the variants with pre-sowing seed treatment using the EMPMg and EQ combinations – exceeding the control variant by 24.3 % and 24.0 %, respectively. When the EMP combination was applied, the carotenoid content in the grain reached 39.09 mg/g of fresh weight, which was 17.9 % higher than the control value (Table 1).

Table 1

Carotenoid content in the grain of spring wheat variety Panianka under pre-sowing seed treatment with combinations of metabolically active compounds (average for 2022–2024).

Variant	Carotenoid content, mg/g of fresh weight	% of control
Control	33,14 ± 1,81	100,0
EPMg	35,73 ± 3,10	107,8
EMPMg	41,22 ± 2,56*	124,3
EMP	39,09 ± 2,23*	117,9
EQ	41,09 ± 1,74*	124,0

*Note: * – the difference is significant compared to the control, $p < 0.05$.*

Protein is the main structural and functional component of all living cells, and its quantity, amino-acid composition, and physicochemical properties determine the technological and nutritional value of grain products [4, 5].

Plant-derived proteins are an important source of nutrients in the human diet. They participate in processes of growth, development, and tissue regeneration, and are essential for the synthesis of enzymes, hormones, and other biologically active compounds. In addition, plant proteins contribute to improved digestion, reduced risk of cardiovascular diseases, and exhibit antioxidant properties, protecting body cells from damage [4].

The proteins of spring wheat are one of the key factors determining grain quality and its suitability for various processing purposes. The protein content in wheat grain varies depending on the genetic characteristics of the variety, growing conditions, and the agro-technical practices applied [4].

The research results indicate that pre-sowing seed treatment of spring wheat with combinations of metabolically active compounds has contributed to the increase in protein content in the grain by 13.6–24.3 % compared to the control. The highest protein content was observed in the variant with pre-sowing seed treatment using the EMPMg combination, reaching 4.45 mg/g of fresh weight, which exceeded the control values by 24.3 % (Table 2).

Table 2

Protein content in the grain of spring wheat variety Panianka under pre-sowing seed treatment with combinations of metabolically active compounds (average for 2022–2024)

Variant	Protein content, mg/g of fresh weight	% of control
Control	3,58 ± 0,15	100,0
ЕПMg	4,07 ± 0,16	113,6
ЕМПMg	4,45 ± 0,13*	124,3
ЕМП	4,12 ± 0,14	115,1
EQ	4,29 ± 0,15*	119,8

*Note: * – the difference is significant compared to the control, $p < 0.05$.*

Starch is one of the main components of wheat grain, consisting of polymeric chains of glucose and serving as a primary energy source for both plants and humans. Its content in the grain depends on the biological characteristics of the variety, agro-technical cultivation conditions, and a range of environmental factors [4, 5].

As a key structural component of wheat flour, starch plays an important role in shaping its technological and baking properties. The nutritional value, taste, texture, and shelf life of finished products largely depend on the quantitative and qualitative composition of starch. Starch is the main source of carbohydrates that meet the energy needs of the human body [4].

Pre-sowing seed treatment of spring wheat with combinations of metabolically active substances contributed to the increase in starch content in the grain by 6.2–12.4 % compared to the control. The highest starch content in the grain of the Panianka variety was observed under pre-sowing seed treatment with the EMPMg combination, reaching 329.12 mg/g of fresh weight, which exceeded the control variant by 12.4 % (Table 3).

Summarizing the research results, it can be stated that the increase in carotenoid, protein, and starch content in the grain of spring wheat of the variety Panyanka is due to the activation of biosynthetic processes of these compounds under the influence of the components of the

Table 3

Starch content in the grain of spring wheat variety Panianka under pre-sowing seed treatment with combinations of metabolically active compounds (average for 2022–2024)

Variant	Starch content, mg/g of fresh weight	% of control
Control	292,92 ± 7,05	100,0
EPMg	310,99 ± 10,11	106,2
EMPMg	329,12 ± 16,01*	112,4
EMP	321,54 ± 11,09*	109,8
EQ	319,15 ± 9,98*	109,0

*Note: * – the difference is significant compared to the control, $p < 0.05$.*

studied combinations and their dosage during pre-sowing seed treatment.

Vitamin E and ubiquinone-10 participate in bioenergetic processes and act as powerful antioxidants, providing protection of plants against oxidative stress [13,14]. Para-hydroxybenzoic acid (PHBA) is a natural phenolic compound characterized by both antioxidant and prooxidant properties; it stimulates alternative oxidase activity and regulates antioxidant enzyme functions. Moreover, it performs a signalling role in plant cells, activating defense responses and enhancing plant tolerance to stress conditions [15].

Methionine serves as a precursor in the biosynthesis of phytohormones that regulate plant growth and development [16]. Magnesium sulfate is of an important role in cellular metabolism: magnesium is a constituent of enzymes involved in protein synthesis, while sulfur is a component of amino acids (methionine, cystine, cysteine), vitamins (thiamine, biotin), and enzymes (dehydrogenases, etc.) [17].

Conclusions. It has been established that pre-sowing seed treatment with combinations of metabolically active compounds – EMPMg, EQ, and EMP – contributed to the increase in protein, carotenoid, and starch content in the grain of spring wheat variety Panianka. Among the tested variants, the EMPMg combination has proved to be the most effective in improving the biochemical composition of spring wheat grain. The high efficiency of the above-mentioned treatments can be explained by the synergistic action of the components within the studied combinations and their optimal dosage during pre-sowing seed treatment.

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Havii V. M., Trybel A. G. Biochemical composition of spring wheat grain under pre-sowing treatment with metabolically active substances

Grain crops play a significant role in the agro-industrial complex of Ukraine, and spring wheat takes an important place in it. The biochemical composition of grain is a crucial indicator of its nutritional value, determining both crop quality and suitability for various types of processing.

Purpose. The aim of the study was to investigate the effect of pre-sowing seed treatment with combinations of metabolically active substances on the biochemical composition of spring wheat grain.

Methods. The theoretical framework of the research is based on an analysis of specialized scientific literature and generalization of existing studies, while the experimental part was conducted in accordance with established methodological guidelines for field trials.

Results. Pre-sowing treatment of seeds with metabolically active substances enhanced the carotenoid content in the grain of spring wheat cultivar *Panianka*. The highest carotenoid accumulation levels were recorded in the variants with pre-sowing seed treatment using the EMPMg and EQ combinations – exceeding the control variant by 24.3 % and 24.0 %, respectively. The highest protein content was observed in the variant with pre-sowing seed treatment using the EMPMg combination, reaching 4.45 mg/g of fresh weight, which exceeded the control values by 24.3 %. Pre-sowing seed treatment of spring wheat with combinations of metabolically active substances contributed to the increase in starch content in the grain by 6.2–12.4 % compared to the control. The highest starch content in the grain of the Panianka variety was observed under pre-sowing seed treatment with the EMPMg combination.

Conclusions. Pre-sowing seed treatment with combinations of metabolically active compounds EMPMg, EQ, and EMP contributed to the increase in protein, carotenoid, and starch content in the grain of spring wheat variety Panianka. Among the tested variants, the EMPMg combination has proved to be the most effective in improving the biochemical composition of spring wheat grain. The high efficiency of the above-mentioned treatments can be explained by the synergistic action of the components within the studied combinations and their optimal dosage during pre-sowing seed treatment.

Key words: metabolically active compounds, pre-sowing treatment, wheat seeds, carotenoids, protein, starch.

Гавій В. М., Трибель А. Г. Біохімічний склад зерна пшениці ярої за передпосівної обробки насіння метаболічно активними речовинами

Зернові культури мають велике значення в агропромисловому комплексі України, а пшениця яра займає в ньому важливе місце. Біохімічний склад зерна пшениці є важливим показником його поживної цінності, що визначає якість врожаю та його придатність для різних видів переробки. **Мета.** Дослідження впливу передпосівної обробки насіння комбінаціями метаболічно активних речовин на біохімічний склад зерна пшениці ярої. **Методи дослідження.** Теоретичне обґрунтування цього дослідження базується на аналізі спеціалізованих джерел інформації, узагальненні наукових праць, тоді як практична частина була виконана відповідно до методичних рекомендацій по проведенню польових дослідів. **Результати.** Передпосівна обробка насіння метаболічно активними речовинами сприяє підвищенню вмісту каротиноїдів у зерні пшениці ярої сорту Панянка. Найвищі показники накопичення каротиноїдів зафіксовано у варіантах із передпосівною обробкою насіння комбінаціями ЕМПMg та EQ – перевищення контрольного варіанту становило 24,3 % і 24,0 % відповідно. Найвищий вміст білка спостерігався у варіанті з передпосівною обробкою насіння комбінацією ЕМПMg – 4,45 мг/г сирої маси, що перевищувало контрольні значення на 24,3 % відповідно. Передпосівна обробка насіння пшениці ярої комбінаціями метаболічно активних речовин сприяла підвищенню вмісту крохмалю в зерні на 6,2–12,4 % порівняно з контролем. Найвищий показник вмісту крохмалю у зерні пшениці сорту Панянка відзначено за передпосівної обробки насіння комбінацією ЕМПMg. **Висновки.** Передпосівна обробка насіння комбінаціями метаболічно активних сполук ЕМПMg, EQ та ЕМП сприяла підвищенню вмісту білка, каротиноїдів і крохмалю в зерні пшениці ярої сорту Панянка. Комбінація метаболічно активних сполук ЕМПMg в порівнянні з іншими варіантами досліджень виявилося найефективнішою при дослідженні біохімічного складу зерна пшениці ярої. Високу ефективність вище зазначених речовин можна пояснити ефективністю компонентів досліджуваних комбінацій, їхнім дозуванням за передпосівної обробки насіння.

Ключові слова: метаболічно активні сполуки, передпосівна обробка, насіння пшениці, каротиноїди, білок, крохмаль.

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