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PRE-SOWING SEED TREATMENT FOR ENHANCING FROST RESISTANCE OF WINTER WHEAT

The study investigated the effect of treating winter bread wheat seeds with biologically active preparations or exposing them to negative temperatures on the frost resistance level of wheat seedlings. Cattle placenta extracts obtained by cryogenic molecular fractionation and containing a complex of biologically active substances (BAS) were used as preparations. Pre-sowing cooling of seeds was carried out at temperatures of –20, –40, –80, and –196 °C. The results of two-year experiments on determining the frost resistance of winter wheat revealed a clear trend toward an increase in this index after pre-sowing treatment of seeds by priming with BAS from animal placenta. Such treatment had a positive effect on the least frost-resistant of the studied wheat samples, the Solomiia cultivar, which was the weakest in terms of the biometric indices of the original seed seedlings. The mechanism of action of BAS as biological catalysts that contribute to increasing plant stress resistance is discussed. The role of negative temperatures as prerequisites for stratification has been determined. The data presented in the article testify to the effectiveness of the studied methods of pre-sowing treatment of winter wheat seeds regarding its frost resistance.

Key words: *biopriming, winter bread wheat, animal placenta preparations, negative temperatures, pre-sowing seed treatment, frost resistance.*

Winter bread wheat is one of the most important agricultural crops for the food, processing, and fodder industries in Ukraine. Due to unfavorable weather conditions, particularly as a result of climate change observed in recent decades, the search for ways to increase the productivity of cultivated plants, and primarily wheat, remains relevant by improving both the sowing qualities of seeds and plant growing conditions.

Numerous studies on the effect of cold and frost on plants indicate damage to or inhibition of the functioning of the plant organism, which inevitably leads to yield loss [7, 24]. The exposure of winter wheat plants to temperatures from −14 to −20 °C for a period of 2—10 days leads to a decrease in the yield declared by the variety originator, in particular to a decrease in the number of productive spikelets [3, 24]. To counteract these factors, various methods are used: from the hardening of seedlings to the use of biologically active substances (BAS) [2, 3, 10, 12, 19, 23]. Hardened wheat seedlings have lower susceptibility to photoinhibition compared to unhardened ones [7]. The results of storing winter rye seeds at temperatures of 4 and −20 °C for 42 months showed some changes in the yield structure, in particular, an increase in the

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1000-kernel weight in more than a third of the samples [23]. Modern agricultural science and food production increasingly gravitate toward the application of environmentally safe technologies that involve the use of special conditions or natural substances capable of activating the protective functions of plants, inducing in them non-specific resistance reactions to environmental stress factors or various pathogens [2, 10, 19]. Pre-sowing seed treatment with nitrate fertilizers, indirectly through increasing plant frost resistance, contributes to an increase in wheat yield, even with late sowing dates [2]. Priming wheat seeds with solutions of organic acids, phytohormones (gibberellic, indolyl-3-acetic), vitamins, salts (KNO_3 or $MgSO_4$), as well as hydropriming, improve seed germination and seedling growth under conditions of low positive temperatures [10].

The attention of many scientists is dedicated to the study of low-temperature storage of seeds of various crops [9, 18], namely to the preservation of original qualities, in particular, germination [12, 23]. However, as a rule, these studies do not aim to improve the sowing, adaptive, and productive quality of seeds through the action of low negative and ultra-low temperatures.

In our previous work, the effect of pre-sowing exposure of winter wheat seeds (cultivars Solomiia, Verden, and Staleva) at temperatures from −20 to −196 °C under laboratory conditions was investigated. It was shown that seeds after cooling to temperatures of –20 and –80 °C demonstrated a more pronounced stimulating effect on seed germination indicators (T_{50}, MGT, GI) and biometric indices of seedlings (shoot length, root length, and dry weight) [12].

Various natural substances are used as organic fertilizer to improve soil properties and increase crop yields. Currently, a number of studies have been published on the effect of pre-sowing seed treatment with BAS, in particular those obtained from placental tissue, on early plant growth and development. Both synthetic and natural plant growth regulators are widely used for biopriming in Ukraine. One of the natural preparations available on the domestic market is Bioglobin — a water-salt extract of the placenta of farm animals obtained by special oxidative-hydrolytic modification of tissues. The preparation contains a full complex of essential and non-essential amino acids, polypeptides, hexuronic acids, amino sugars, and trace elements. The effect of Bioglobin on the yield of soybean, parsley, parsnip, echinacea, winter wheat, and spring barley has been studied [4, 5, 13, 14].

The Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine has developed a cryogenic molecular fractionation complex for processing biological materials of both plant and animal origin. Using molecular fractionation of placental tissues of farm animals, the preparations Aminoplacentin and Cryoplacentin were obtained. Aminoplacentin is an aqueous fraction containing amino acids, vitamins, trace elements, and carbohydrates. Cryoplacentin is a protein-peptide fraction obtained using cavitation technologies from the meal remaining after cold extraction. This fraction contains amino acids, peptides, nucleic acids, hexuronic acids, polysaccharides, and vitamins [16]. Given the positive effect of Bioglobin for pre-sowing seed treatment, the question arises regarding the possibility of using peptide preparations obtained from the placenta by the method of cryogenic molecular fractionation for similar purposes.

In recent decades, despite global climate changes, in particular an increase in the average annual temperature by 1.0—2.5 °C, the importance of maintaining high frost resistance of winter crops is extremely relevant. This problem is solved both by creating varieties with genetically determined resistance and by searching for BAS that contribute to the processes of plant hardening in the autumn period. Therefore, the aim of this work was to determine the effect of biopriming and cooling to low negative temperatures of seeds of three winter bread wheat varieties on the level of their frost resistance under the conditions of a pot experiment.

MATERIALS AND METHODS

The studies used winter bread wheat cultivars: Verden, Solomiia, and Staleva. The seeds were obtained from the collection of the Faculty of Agronomy and Plant Protection of the State Biotechnological University (Kharkiv). All studied cultivars belonged to domestic breeding but were created in different ecological and geographical zones of Ukraine. The Staleva cultivar was created under the conditions of the steppe zone (the "Bor" farm, Odesa region); it has an awned spike, a high level of drought and frost resistance, and lodging resistance. The Verden cultivar, created at the "Sady Ukrainy" agricultural firm in the Kharkiv region, belongs to the forest-steppe ecotype; it has an awnless spike, a high level of resistance to low temperatures and spike diseases, and good grain quality. The Solomiia cultivar, created at the Institute of Plant Physiology and Genetics of the NAS of Ukraine (Kyiv) under the conditions of Polissia, is high-yielding and has high grain quality, but in terms of frost resistance, it belongs to the group with below-average resistance. Dry wheat seeds of the 2021 reproduction with an initial moisture content of 12.0% were subjected to treatment.

In the first experiment of the 2023/2024 vegetation years (v.y.), the effect of pre-sowing cooling of dry seeds to −20 °C, hydropriming, and treatment with Cryoplacentin and Aminoplacentin on the frost resistance of three winter wheat cultivars was investigated.

For the experiment of the 2024/2025 v.y., seeds of the Solomiia cultivar, which demonstrated the highest efficiency in previous trials, were selected. In addition to hydropriming and the use of Cryoplacentin and Aminoplacentin, the sowing material was exposed to low temperatures −20, −40, −80, and −196 °C) and ozonation, which demonstrated high efficiency in the initial stages of its ontogenesis [12].

The seeds were frozen at −20 °C in 'Samsung RB33J3200SA/UA' freezers (Samsung, Republic of Korea), at −40 °C — 'UGUR UCF 10 CF' (Ugur, Turkey), at −80 °C — 'HAIER-DW-86w100J' (Haier, China), and at −196 °C — by immersion in liquid nitrogen, and were held for a week; thawing was carried out at a temperature of 18–20 °C. Aminoplacentin was used as a ready-to-use solu-tion, while Cryoplacentin was prepared according to the following procedure: 15 ml of distilled water was added to 1 g of dry matter; after stirring, the mixture was left for 24 hours and then passed through a nylon filter. Pre-sowing priming was performed as follows: wheat seeds weighing 30 g were sprayed with 2 ml of water (hydropriming) or solutions of Cryoplacentin

Table 1. **Climatic conditions of the eastern forest-steppe zone of Ukraine (2023/2024 v.y.)**

Index	Climatic conditions					
	2023					2024
	September	October	November	December	January	February
Precipitation, mm	27	97	119	77	60	45
Precipitation (average multi-year), mm	43.5	44	41	43.5	37	33
Average daily temperature, °C	17.5	10.1	4.4	−0.1	−4.1	0.7
Average daily temperature (multi-year), °C	14.5	8.2	1.6	−3.7	−4.5	−3.7
Maximum daily temperature, °C	26	27	19	10	6	10
Minimum daily temperature, °C	7	−2	−10	−8	−19	−5
Minimum soil surface temperature, °C	6	−4	−14	−10	−21	−6

Table 2. **Climatic conditions of the eastern forest-steppe zone of Ukraine (2024/2025 v.y.)**

Index	Climatic conditions					
	2023					2024
	September	October	November	December	January	February
Precipitation, mm	0	16	61	43	15	26
Precipitation (average multi-year), mm	40	44	41	40	37	33
Average daily temperature, °C	20.5	11.0	2.9	0.2	1.5	−5.7
Average daily temperature (multi-year), °C	15.1	8.2	1.6	−2.9	−4.5	−3.7
Maximum daily temperature, °C	32	27	12	7	10	5
Minimum daily temperature, °C	7	−1	−5	−10	−8	−17
Minimum soil surface temperature, °C	4	−2	−4	−13	−8	−24

or Aminoplacentin and shaken for an hour to ensure uniform moisture distribution over the caryopsis surface, dried, and left until the start of sowing. For ozonation, wheat seeds weighing 30 g were treated for 30 min with an ozone-air mixture with an ozone concentration of 1 mg/l.

The study of the frost resistance of winter wheat samples of the Verden, Solomiia, and Staleva cultivars prepared in this manner was carried out at the experimental base of the Plant Production Institute named after V.Y. Yuryev of the NAAS of Ukraine according to the methodology developed by the authors [17]. The essence of the method consists in establishing the critical freezing temperatures of winter wheat cultivars by freezing plants grown in vegetation boxes with a soil mixture at temperatures at which about half of all plants in the sample die.

In the second half of the optimal dates (September 25), the seeds of each studied cultivar and the reference cultivar were sown in boxes with 3-fold replication, 18 pieces each. The experimental boxes were placed on a specially prepared vegetation site. During autumn and winter, the plants remained under natural conditions, where their passage through the first and second phases of hardening took place (Fig. 1).

Weather conditions during the study are presented in Tables 1 and 2.

The plants were frozen on January 25 in ‘Danfoss Optyma’ low-temperature chambers (Danfoss, Netherlands) in parallel in two regimens (down to −15 and −17 °C), at temperatures previously determined on reference cultivar with known frost resistance. Before freezing the studied cultivars, the level of critical freezing temperatures of the plants under the conditions of a specific year was determined. For this purpose, a block of boxes with reference ones (classifiers) sown in them was frozen (Fig. 2).

The samples were frozen in low-temperature chambers, where the boxes were transferred from the vegetation site. Using computer control, the temperature was gradually decreased (by 1—2 °C per hour) from the actual outdoor temperature to the specified experimental level, at which the samples were held for 24 hours. The thermal regimen in the chamber was monitored using thermographs. After the freezing was completed, the temperature in the working space was increased by 2 °C every hour. When the indicator reached 0 °C, the plants were transported to a room with a regimen of 4—7 °C to complete thawing.

Fig. 1. Hardening under natural conditions, appearance of plants on the vegetation site

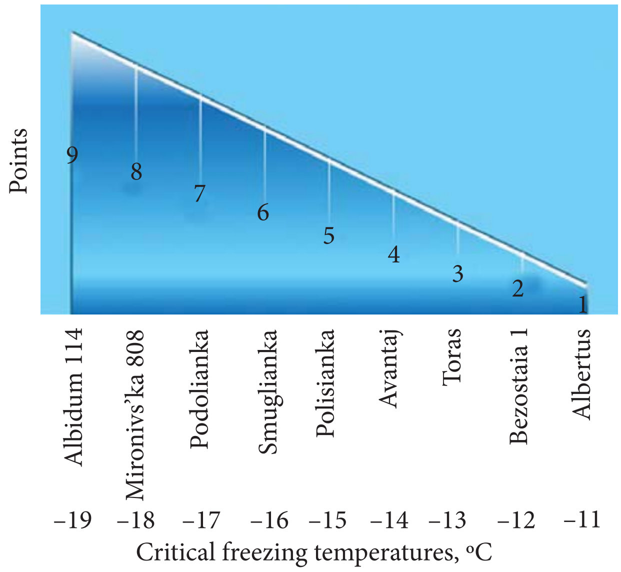

Fig. 2. Frost resistance of winter bread wheat reference cultivars

After thawing, the leaves on the plants were trimmed, leaving leaf blades 0.5 cm long, and placed in a greenhouse with a temperature of 18—24 °C and a 12-hour photoperiod. Due to the use of fluorescent and tungsten lamps, the light intensity was $4.9 \times \times 10^{19}$ photons/m^{2}s. If necessary, the plants were watered from time to time. Live plants were preliminarily counted after 10—12 days. Viability was determined on the 15th—16th day from the beginning of regrowth. Plants that were turgid, green, and had produced a leaf growth of at least 5 cm during the regrowth period since the previous count were classified as alive. In other cases, the plant was considered non-viable (dead). The obtained counting results were expressed as a percentage of live plants to the total number of plants. The temperature at which the percentage of live plants to their total number in a row was close to 50 was determined as the critical temperature for plant freezing.

Winter bread wheat varieties with a similar level of critical temperatures were combined into groups, comparing them with the critical temperatures of reference varieties (Fig. 2) and the identified level of frost resistance; as a result, each variety was assigned a corresponding resistance group.

Statistical processing of the research results was carried out using the 'Past Statistic v/3/01' software (University of Oslo, Norway). The mean value and standard deviation (M ± σ) were determined. The significance of the difference between the indices was evaluated using Tukey's test. The difference between the samples was considered significant at $p \le 0.05$.

RESULTS AND DISCUSSION

As a result of the conducted two-year experiments on determining the frost resistance of the aforementioned winter wheat varieties, the data were obtained that corresponded to the general concept of the positive effect of BAS and moderate stress on improving the adaptive capacities of plants.

Based on the results of determining the effect of biologically active preparations and cooling to −20 °C on the frost resistance level of winter bread wheat varieties, it was established that the action of none of the studied factors caused a negative effect on the formation of resistance (Table 3).

Despite the fact that the Solomiia cultivar is the least frost-resistant and, according to our previous data, was inferior to other cultivars in terms of seedling growth vigor from the original seed [12], the most pronounced positive effect was observed precisely on it. The genetic level of frost resistance of this cultivar in the control is average and amounts to 5.5 points (at a critical freezing temperature of −15.5 °C). While hydropriming and holding the seeds at −20 °C increased the wheat resistance index to an above-average level (6.0 points; critical freezing temperature of −16.0 °C), biopriming proved to be more effective, as it ensured high frost resistance at the level of 7.0 points and a decrease in the critical freezing temperature to −17.0 °C.

The Verden and Staleva cultivars demonstrated high frost resistance; however, the use of Cryoplacentin and Aminoplacentin for seed treatment allowed increasing this index by another 0.5 points. This pattern is confirmed by the data on the survival rate of wheat plants of all three studied cultivars after cooling to −15 and −17 °C (Table 3).

Taking into account the fact that in the experiment of the 2023/2024 v.y., among the three

Table 3. **Frost resistance of winter bread wheat samples after thermo- or biopriming according to the results of testing in freezers in the 2023/2024 v.y.**

Cultivar	Pre-sowing treatment	Live plants after freezing at t °C, %		Critical temperature for plant freezing, °C	Frost resistance assessment, #	Frost resistance
		−15.0	−17.0			
Podolianka	Reference cultivar	90.3 ± 0.6	50.3 ± 1.5	−17.0	7.0	High
Verden	Control	92.0 ± 0.0	50.3 ± 1.5	−17.0	7.0	High
	Hydropriming	91.7 ± 2.1	50.3 ± 0.6	−17.0	7.0	High
	Aminoplacentin	96.3 ± 1.5 *	55.0 ± 1.0 *	−17.5	7.5 *	High
	Cryoplacentin	94.0 ± 1.0 *	52.0 ± 1.0	−17.0	7.4	High
	−20 °C	92.0 ± 2.6	51.7 ± 1.5	−17.0	7.1	High
Solomiia	Control	72.0 ± 1.0	30.0 ± 2.6	−15.5	5.5 *	Average
	Hydropriming	74.7 ± 2.1	38.7 ± 1.2 *	−16.0	6.0*	Above-average
	Aminoplacentin	90.3 ± 0.6 *	50.3 ± 1.2 *	−17.0	7.0	High
	Cryoplacentin	90.0 ± 2.6 *	48.3 ± 0.6 *	−17.0	7.0	High
	−20 °C	78.0 ± 1.0 *	39.7 ± 1.5 *	−16.5	6.5 *	Above-average
Staleva	Control	90.3 ± 2.1	50.0 ± 0.0	−17.0	7.0	High
	Hydropriming	92.0 ± 0.0	50.0 ± 1.0	−17.0	7.0	High
	Aminoplacentin	97.0 ± 1.7 *	58.3 ± 0.6 *	−17.5	7.5 *	High
	Cryoplacentin	94.7 ± 0.6 *	54.7 ± 1.5 *	−17.5	7.5 *	High
	−20 °C	92.3 ± 1.5	52.0 ± 1.0*	−17.0	7.1	High

* The difference is significant relative to the control; determination according to Fig. 2.

studied wheat cultivars, the Solomiia reacted more actively to pre-sowing treatment with various factors and demonstrated an improvement in its sowing qualities, it was therefore selected for further research.

In the 2024/2025 v.y., hydropriming, biopriming, thermopriming, and ozonation were used to treat samples of the Solomiia wheat cultivar.

It was established that holding the seeds before sowing at low temperatures of −20, −40, and −196 °C and hydropriming practically did not change the frost resistance level of the cultivar, which corresponded to the control values (5.5 points; critical freezing temperature of −15.0 °C, resistance group — average). A slight increase in frost resistance was obtained after freezing the seeds to −80 °C (5.8 points; critical freezing temperature of −15.3 °C, resistance group — average-above-average). Ozone treatment of seeds slightly reduced the resistance level, which might have been caused by insufficiently effective ozonation conditions, since a decreased seed germination was noted in this variant. The greatest effect on increasing frost resistance was established in the variants with seed treatment with Aminoplacentin (5.9 points; critical freezing temperature of −15.5 °C, resistance group — above-average) and Cryoplacentin (6.2 points; critical freezing temperature of −16.7 °C, resistance group — above-average or high).

Thus, the two-year research on the frost resistance of winter bread wheat revealed a clear tendency toward an increase in this index due to pre-sowing seed treatment with both low temperatures and biologically active preparations obtained by the method of cryogenic molecular fractionation. Such treatment had an especially positive effect on the least frost-resistant among the studied wheat cultivars — Solomiia. The highest efficiency was found when treating seeds with Aminoplacentin and Cryoplacentin.

Under the conditions of this experiment, the winter wheat sowing material treated with various factors was initially subjected to natural hardening. For the two studied vegetation years, the natural environmental conditions differed (see Table 1, Table 2) and therefore influenced the measured parameters of frost resistance. Due to the elevated temperature regimen during the weather conditions of autumn 2024 and early winter 2025, the winter crops repeatedly ceased and resumed weak vegetation, which led to plant exhaustion. Thus, the level of plant hardening was lower, and the critical freezing temperatures were 0.5 °C higher, particularly in the reference cultivar, than in 2023. Despite this fact, the tendencies of the effect of the studied pre-sowing seed treatment factors on wheat frost resistance were clearly preserved. Therefore, certain assumptions can be made regarding the mechanisms of action of the studied factors on seeds.

Both studied preparations — Cryoplacentin and Aminoplacentin — contributed to increasing the survival rate and frost resistance of the three studied winter wheat cultivars. The BAS of extracts obtained by the method of cryogenic molecular fractionation, in particular amino acids, can act as regulators of germination and early plant growth [13, 14, 19]. The most studied example is proline,

Table 4. **Frost resistance of winter bread wheat samples treated with biologically active preparations or cooling according to the results of testing in freezers in the 2024/2025 v.y.**

Cultivar	Pre-sowing treatment	Live plants after freezing at −16 °C, %	Critical temperature for plant freezing, °C	Frost resistance assessment, #	Frost resistance
Podolianka	Reference cultivar	53.0 ± 0.0	−16.5	7.0	High
Solomiia	Control	38.0 ± 1.0	−15.0	5.5	Average
	−20 °C	37.3 ± 0.6	−15.0	5.5	Average
	−40 °C	37.0 ± 0.0	−15.0	5.5	Average
	−80 °C	40.7 ± 0.6 *	−15.3	5.8	Average-above-average
	−196 °C	36.7 ± 1.5	−15.0	5.4	Average
	Ozonation	34.7 ± 2.1 *	−14.8	5.2	Average
	Hydropriming	37.7 ± 0.6	−15.0	5.5	Average
	Aminoplacentin	42.3 ± 0.6 *	−15.5	5.9	Above-average
	Cryoplacentin	44.3 ± 0.6 *	−16.2	6.7	Above-average-high

* The difference is significant relative to the control; determination according to Fig. 2.

which acts as an effective priming agent. It improves plant growth under normal conditions and various types of abiotic stress (salinity, heavy metals, toxicants, frosts), and also functions as an osmoprotectant, antioxidant, and stabilizer of proteins and membranes. Other amino acids (tryptophan, arginine, aspartic acid, lysine, phenylalanine, tyrosine, *etc*.) are also capable of stimulating germination, reducing oxidative damage, and promoting the development of the root and shoot systems under stressful conditions.

Obtaining a more significant effect from the use of Cryoplacentin is explained by its higher saturation with protein and nucleic fractions compared to Aminoplacentin.

The introduction of the ozonation method in the vegetation experiment was conditioned by the positive results of its previous application [12]. The lack of a significant effect on the Solomiia wheat cultivar is probably explained by non-optimal exposure conditions with the ozone-air mixture, which emphasizes the expediency of further refinement of the technology for presowing seed treatment.

Regarding the low-temperature treatment of wheat sowing material, it should be noted that after classical stratification [1, 3, 6, 15], seeds are cooled to low positive temperatures, whereas in our study, pre-sowing cooling was carried out to low negative temperatures. The obtained data indicate a positive effect of such a modification on seed germination [12], as well as on the subsequent acclimation of plants under freezing conditions.

The stimulating effect of low-temperature presowing seed treatment differs from activation by classical stratification. The latter is characterized by a complex of chemical, hormonal, and physiological processes in germinating seeds. In particular, under the action of corresponding genes, the synthesis of gibberellic and indoleacetic acids is activated against the background of abscisic acid suppression. This leads to an increase in enzyme activity and higher concentrations of sugars and proteins, which collectively ensures accelerated germination [1, 11, 15, 20—22].

Cooling dormant seeds to low negative temperatures differs from classical stratification in terms of the activation processes within the caryopsis. Research results on the stratification of dormant wheat grains indicate that the release of seeds from this state is promoted by jasmonic acid [8, 21], the biosynthesis of which is induced by cold in wheat grain embryos, as evidenced by the upregulation of its synthesis gene expression; meanwhile, abscisic acid synthesis is indirectly inhibited through the suppression of its gene expression [21]. The effect of low-temperature stratification is observed during seed germination, when its positive impact becomes manifest.

In the future, to increase the level of wheat frost resistance after pre-sowing seed treatment with biologically active preparations, a more thorough study of its conditions is required, as well as expanding the experiment to other agricultural crops. The lack of the effect of pre-sowing cooling of wheat seeds to low negative temperatures of −40 and −196 °C on the frost resistance level of seedlings in this study does not provide grounds for excluding this type of treatment but implies a more meticulous approach to searching for more effective pre-sowing treatment conditions.

CONCLUSIONS

Presowing treatment of seeds from three winter bread wheat cultivars (Verden, Staleva, and Solomiia) by cooling to a temperature of –20 °C or by hydropriming had no negative impact on the frost resistance level of the wheat seedlings.

Exposure of Solomiia cultivar seeds to low negative temperatures of –40 °C and –196 °C did not alter the frost resistance level of the cultivar. A slight increase in this parameter was observed after freezing the seeds to –80 °C.

The application of Cryoplacentin and Aminoplacentin for presowing treatment contributes to enhancing the frost resistance of all studied wheat cultivars. The cultivar Solomiia, which exhibited the lowest biometric parameters among the seedlings, responded particularly actively to the treatment, showing an improvement in sowing qualities.

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ПЕРЕДПОСІВНА ПІДГОТОВКА НАСІННЯ ДЛЯ ПІДВИЩЕННЯ МОРОЗОСТІЙКОСТІ ОЗИМОЇ ПШЕНИЦІ

У роботі досліджували вплив обробки насіння пшениці озимої м'якої біологічно активними препаратами або витримкою за негативних температур на рівень морозостійкості проростків пшениці. В якості препаратів застосовували екстракти плаценти великої рогатої худоби, отримані методом кріогенного молекулярного фракціонування, які містять комплекс біологічно активних речовин (БАР). Передпосівне охолодження насіння здійснювали за температур –20, –40, –80 і –196 °С. Результати дворічних дослідів з визначення морозостійкості пшениці озимої виявили чітку тенденцію до підвищення даного показника після передпосівної обробки насіння праймуванням БАР із плаценти тварин. Така обробка позитивно вплинула на найменш морозостійкий з досліджених зразків пшениці сорт Соломія, який був найслабкішим за рівнем біометричних показників проростків вихідного насіння. Обговорено механізм дії БАР як біологічних каталізаторів, що сприяють підвищенню стресостійкості рослин. Визначено роль негативних температур як передумов до стратифікації. Наведені в статті дані свідчать про ефективність досліджених методів передпосівної обробки насіння пшениці озимої щодо її морозостійкості.

Ключові слова: біопраймінг, пшениця озима м'яка, препарати плаценти тварин, негативні температури, передпосівна обробка насіння, морозостійкість.