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ADAPTIVE POTENTIAL PERFORMANCE OF REPRESENTATIVES OF THE TRIBE *Triticeae* L.

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The mechanisms of adaptation performance of the tribe *Triticeae* L. representatives were studied according to biochemical markers. It is shown that drought-tolerant tribe representatives are at the subcellular level characterized by presence of alleles of Dreb 1 genes of drought resistance, Glu-D1 of glutenin, Gli-1B1, Gli-6D2, Gli-6D3, Gli-6B2 of gliadin, and high protein content in grain (14.2–18.0%). Plants with low drought resistance exhibit heightened superoxide dismutase, peroxidase and catalase activity in leaves.

It is established that the criteria of frost and winter hardiness of plants are: accumulation of high total sugar content in the tillering node (26–38 mg/g) as cryoprotectants and energy sources, and economical consumption of them during the autumn-winter period. Exogenously, high levels of plant organism's adaptability to various stress conditions in winter are expressed as high photoperiodic sensitivity manifesting as weak differentiation of growth points in the fall and late spring vegetation restoration. Adaptive changes at the subcellular level are consistent with drought resistance indices (high leaf index, glossy cover, lingering green color of the leaf, presence of awns, significant growth in dry weight in dry conditions).

Key words: *Triticum aestivum* L., *Secale cereale* L., *Triticum trispecies* Shulind, biochemical markers.

Among the major Ukrainian food and industrial crops there are *Triticum aestivum* L. (common wheat), *Secale cereale* L. (winter rye), *Triticum trispecies* Shulind (winter triticale) of the tribe *Triticeae*. Increasing the genetic potential of the new varieties' productivity reduced the scope of their adaptation to certain conditions, tapering heterogeneity [1, 2]. Therefore creating varieties of winter crops that are able to overcome the negative correlation between yield and adaptive potential is a key issue today. Various kinds of stressors cause structural and metabolic changes in plants [3]. Knowledge of the mechanisms that underlie their reactions to prolonged abiotic stress factors, and condition the crop stability is important in understanding the fundamentals of adaptation, developing approaches for obtaining resistant varieties and forms of plants, especially in present global warming and arid climate, long spring and summer and autumn drought, adverse winter conditions, significant fluctuations in winter temperatures, thaws alternating with ice crust formations and damping-out, etc. [3–6]. Topical questions are adaptation of cultural species to current environmental conditions to which the plants are able to produce protective mechanisms signalizing not only the stress, but also before and after stress periods [7–9].

The aim was to investigate the mechanisms of adaptation performance of the representatives of tribe *Triticeae* L. according to biochemical markers.

Materials and Methods

The objects of research were new varieties and lines of tribe *Triticeae,* namely common wheat *Triticum aestivum* L. (Yuvivata 60 Zoriana Nosivska, Nosshpa 100, Daushka, KC 1, KC 5, KC 7, KC 14, KC 16, KC 17, KC 21, L -41, L-59, L-34-95; winter rye *Secale cereale* L. (Borotba) and winter triticale *Triticum trispecies* Shulind (Chaian, Vivate Nosivske, Pshenychne, Slavetne) of the Forest-Steppe and Polissia-Forest-Steppe biotypes (Nosivska selection and research station of Remeslo Myronivka Institute of Wheat of NAAS of Ukraine). The study was conducted in 2008–2015 in Forest-Steppe ecotope conditions (central part of Ukrainian northern Right-Bank Forest-Steppe zone with periodically erratic humidification) at the research field NSRC of Bila Tserkva NAU. Climate and weather conditions ecotope are temperate continental. The average air temperature is 6.9 °C with significant monthly fluctuations, and average annual rainfall which is unevenly distributed during the vegetation period is 538 mm: in summer the precipitation is much more intense than in spring and fall. Probability of the years with rainfall less than 350 mm is about 35%.

Regionally conventional technology for cultivating grain and winter crops was used in the study. The soil is deep common chernozem with medium humus concentration, humic clay-loam soil with humus content of 3.5%; easy hydrolyzed nitrogen (by Kornfield) — 140 mg/kg; mobile phosphorus and exchangeable potassium (by Chirikov) are respectively 120 and 90 mg/kg in soil. The soil is characterized by average nitrifiable ability of 2 3.5 mg/100 g of totally dry soil, and the average gross balance of P_2O_5 and K_2O compounds. Sowing was carried out in the optimal for this zone dates: September 15^{th}–25^{th}, by string method of seeding norm of 5.0 million of similar seeds per ha.

Years of research have varied by hydrothermal regime: 2011–2013 and 2015 were marked by decreased rainfall and increased temperatures above average long-term norms during tillering, stem elongation, anthesis, and ear formation compared with the favorable enough wet spring periods of 2008–2010 and 2014, which allowed us to comprehensively evaluate the adaptability of the studied genotypes tribe to climate of Forest-Steppe ecotope, and their ability to realize their biological performance potential.

According to the coefficient of significance of precipitation variation, the vegetation periods of 2009, 2010, 2011, 2012, 2013 and 2014 were arid (coefficient of variation significance < 1); by the coefficient of variation significance of the temperature regime these years were close to the average long-term exponent (±0.2–0.8). However coefficient of variation significance for hydrothermal index (HTI) during the research approached the value of this index in conditions close to extreme.

The most extreme months of atypical weather conditions were in May 2010 (−4.71), July 2010 (−2.45), May 2011 (−4.71), May 2012 (−4.75) and July 2012 (−2.48). Thus, in all the years of research May was the period of active plant growth and development, characterized by the most extreme weather conditions which significantly delayed intensity of dry vegetative mass accumulation. Generalized analysis of meteorological conditions suggests that deviation of a number of parameters, including temperature, an amount of precipitation from the average per years did not approach the critical values, except for some months of vegetation throughout the years.

The identification of low-molecular weight gliadin proteins was performed using polyacrylamide gel electrophoresis [10] in collaboration with the Plant Production Institute nd. a. V. Ya. Yuryev of NAAS of Ukraine using the catalog and nomenclature of Payne [11]. Identification of genes of drought resistance was conducted in collaboration with the Institute of Cell Biology and Genetic Engineering of NAS of Ukraine using uniplex and multiplex PCR. The study used gene primers Dreb 1: P21F/P21R, R25F/PR, P22F/PR, R18F/R18R, R20F/P20R according to Wei et al. [12], gene primers Glu-D1: UMN25F/UMN25R by Liu et al. [13]. Statistical data processing carried out according to Dospyehov [14].

Enzymatic activity was determined in flag leaf of plants in the most critical period of their growth (flowering and ear formation). Catalase activity (EC 1.11.1.6) was established gasometrically using 5 ml 3% H_2O_2 as substrate with incubation time 1 min, incubation temperature — 25 °C; polyphenol oxidase (EC 1.14.18.1) and peroxidase (EC 1.11.1.7) activity were determined by photocalorimetry using 1% solution of pyrogallol, based on the ability of enzymes to oxidise the latter to purpurgalin (Nakano modification), superoxide dismutase (SOD, EC 1.15.1.1) — using the enzyme's ability to inhibit photochemical reduction of Nitrotetrazolium blue to Hydrazine tetrazolium [15–17]. The total content of sugars in the tillering nodes was determined according to Pochynok (1978) [16, 17].

Leaf area was calculated according to Lavrynenko and Nychyporovych, parameters of root system and the above-ground plant part at the early stages of ontogeny were determined by Danylchuk, winter hardiness was evaluated according to the fall and spring surveys of plants in each iteration.

Results and Discussion

Since most of the features and properties of the organism are genetically determined, initial stage of our research was to study the representatives of the tribe *Triticeae* at the subcellular level, including the identification and expression of drought resistance Dreb 1 genes, Glu-D1 glutenins, and spectra of Gli gliadins. Plant varieties are carriers of unique gene associations created in the process of selection and collected in one genome ensuring their adaptation to the environment [7, 12].

Analysis of electrophoretic spectra of Glu-D1 gene amplification products made it possible to identify products of high glutenin subunits, in particular Glu-D1 5 + 10 allele, which was presented by two components of 397 and 281 p.n., and Glu-D1 2 + 12 allele, presented by amplicons of 415 and 299 p. n., respectively (Fig. 1). Tishchenko et al. [18] found that varieties containing “2 + 12” subunit can generate high-quality grain in the conditions of soil and atmospheric drought due to higher adaptability compared with varieties with the “5 + 10” subunit. Simultaneously, the authors note the connection between the subunits and strong and average winter hardiness, which is confirmed by our research on the manifestation of high adaptability to adverse abiotic factors (drought, unfavorable winter conditions, low temperatures, etc.). Of particular value are Yuvivata 60 and KC 21, identified to carry amplicons of both types which indicates their heterogeneity.

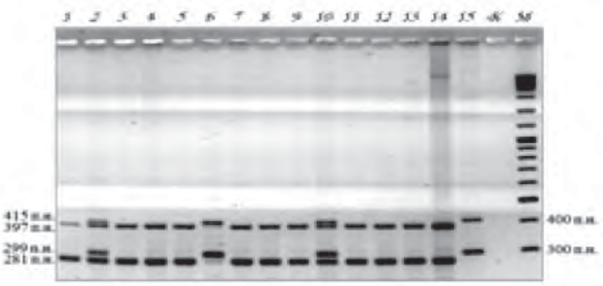

Fig. 1. **Electrophoregram of Glu-D1 gene amplification products, line *Triticum aestivum*:** *1* — КС 1; *2* — Yuvivata 60; *3* — КС 5; *4* — L 41; *5* — КС 14; *6* — КС 17; *7* — КС 16; *8* — L 59; *9* — Zoriana Nosivska; *10* — КС 21; *11* — Daushka; *12* — КС 7; *13* – L 34-95; *14* — Dvorianka; *15* — Trizo; *16* — Kuialnyk; *17* — Smuhlianka; *18* — *Aegilops cylindrica*; — *K* – negative control (without DNA); M — molecular weight marker GeneRuler™ DNA Ladder Mix

Adaptability mechanisms are also determined by many other biochemical markers, particularly informative low molecular weight, highly polymorphous gliadin proteins [19]. The composition of wheat gliadin is studied better than that of rye and triticale. Its six major controlling gene loci are *Gli A1, Gli B1, Gli D1, Gli A2, Gli B2, Gli D2*, which are located in short arms of chromosomes 1 and 6 of homeologous groups [20]. Some authors [21, 22] found an association of frost resistance alleles 1 D4, 1 D5, 1 D7, 1 D10 loci *Gli*-1 D and 6 A4 loci *Gli*-6A. Electrophoresis of *T. aestivum* and *T. trispecies* by the gliadin protein spectra (30–50 kDa) allowed us to identify allelic variants that determine high winter hardiness: *Gli*-1 D5 (Gli-1 B 5), Gli-1 A 4, Gli-6 A 3, Gli-6 A 4 (Fig. 2).

According to Popereli [20] and Tishchenko [22], wheats containing alleles *Gli*-6 D 2 or *Gli*-D 3 and *Gli*-6 B 2 are highly adaptive and productive biotypes with excellent quality grain. It can be seen at Fig. 2 that the sorts and lines №№ 2–6, 8, 10–13 have components of gliadin Gli-6 A 3 allele spectrum, which is responsible for tolerance of winter conditions. Along with spectra of gliadin alleles of winter conditions tolerance in Zoriana Nosivska, Noshpa 100, КС 5, КС 7, КС 16, КС 21, Chaian, products of expression of Gli-1 B 1 allele, a marker of high performance and adaptability to drought were identified. The most valuable group of biotypes constitutes of wheat strains KC 7, KC 21 and KC 22 that contain not only the two aforementioned components of gliadin spectrum but also expression products of *Gli*-1 D4 allele, a marker of frost-resistanse which, however, is somewhat suppressed by the *Gli*-1 D 1 allele of spring wheat strains, confirming the phenological observations data.

Drought resistance in plants corresponds to the *dehydration responsive element binding factors 1* (*Dreb 1*), that are located in the chromosomes *3B, 3D* and *3A*. According to the results of electrophoretic analysis of spectra of amplification products [23], in all investigated samples of wheat were the expected amplicons of 717, 789, 596, 1113, 1193 p.n. Exceptions are Daushka, KC 1, and KC 17 strains, which turned out to be heterogeneous, in particular lacking amplicons 1113 p. n. (in the chromosome *3D*) and 1193 p. n. (in *3A*).

One of the first adaptive responses of plant organisms to extreme stressors is the protective activation of increasing redox

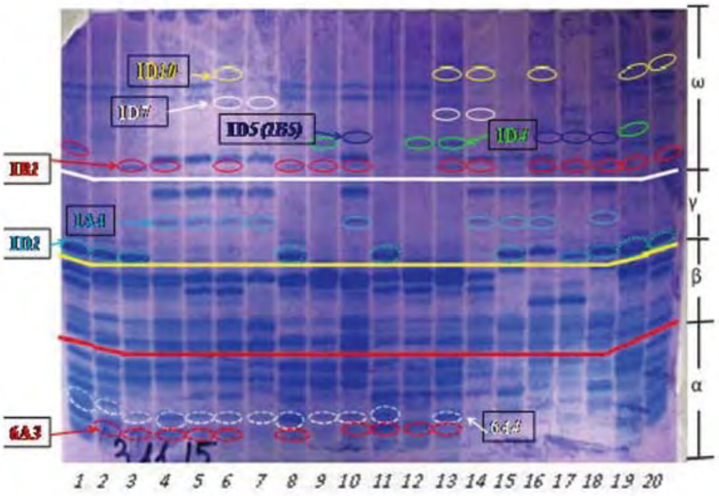

Fig. 2. **Electrophoretic spectra of spare gliadin controlled by Gli genes in *T. aestivum* and *T. trispecies*:** *1, 11, 20* — Bezosta 1 (control); *2* — Daushka; *3* — Prydesnianska napivkarlykova; *4* — Zoriana Nosivska; *5* — КС 14; *6, 14* — Noshpa 100; *7* — Yuvivata 60; *8* — КС 16; *9* — КС 7; *10* — КС 5; *12* — КС 17; *13* — КС 22; *15, 18* — Pshenychne; *16* — Chaian; *17* — Slavetne; *19* — КС 21

processes, resulting in accumulation of adverse products of free radical oxidation of biomembrane lipids. It causes increased synthesis of antioxidant enzymes [9, 24, 25]. The difference in redox reactions, including antioxidant enzymes, in the plants with varying degrees of drought resistance is important. Enzymes involved in plant response to the stress are superoxide dismutase, catalase, polyphenol oxidase, peroxidase, etc. [1, 15, 29]. New representatives of the tribe *Triticeae* differ by level of prooxidant-antioxidant balance, including oxidoreductase enzymatic activity (Table 1).

The protective mechanisms of less drought-resistant plants exhibit higher catalase and peroxidase activity compared to highly drought-resistant wheat forms. Some authors [24, 25] found that inhibition of catalase increases the activity of hydrogen peroxide, which, according to them, induces the activation of protein kinases and phosphorylation proteins, expression of «protective» genes and protein synthesis. Superoxide dismutase is the primary element of the protection of cells and tissues from oxidative degradation which converts the harmful to cells superoxide radical anion to the less active product, H_2O_2 [15].

Water deficit stress (2009, 2011–2013) allowed us to find that in some plants, SOD activity in leaves was higher by 18–22% to 13.7–15.2 c.u. than in other plants (Table 1). Sorts with high SOD activity (КС 1, КС 17, Daushka) are less drought-resistant. However, according to Mamenko [25], SOD does not completely protect cells from oxidative stress, as the formed H_2O_2 inhibits the enzyme. So the abovementioned activity is largely influenced by other components, particularly those that utilize H_2O_2 (catalase, peroxidase) and enzymes of glutathione ascorbate cycle [9]. Synergist of SOD in cell is catalase (CAT). We found a high correlation coefficient ($r = 0.78$, $P < 0.05$) between the abovementioned activity in leaves of average drought-resistant and drought-resistant biotypes of tribe *Triticeae*. High levels of peroxidase and catalase activity denote the intense need of protective reactions in leaf tissue of less drought-resistant representatives of the tribe *Triticeae* because of insufficient adaptive metabolic processes. As for the polyphenol oxidase activity, no significant difference between the studied varieties was found. The regularities of oxidoreductase activity were observed for these biotypes of tribe *Triticeae* both in the moisty, favorable for plant growth and development conditions of 2014, and in the rainfall deficit of 2013 (HTI < 1).

Consequently, changes which are caused by increased catalase, peroxidase and superoxide dismutase activity in flag leaf of varieties and lines of tribe *Triticeae*, can be considered a criterion of less drought-resistant plants (Daushka, КС 1, КС 17) adaptation to prolonged drought conditions. The data are consistent with data on changes in intracellular plant caused by moisture deficit, important for adapting to the abiotic and biotic stressors.

The study of morphological parameters of *Triticeae* plants made it possible to detect

Table 1. **Evaluation of xeromorphic representatives of tribe *Triticeae* by enzymatic redox activity (during flowering and ear formation), mean in 2013–2014**

№	**Sort, line of tribe Triticeae**	**Enzymatic activity ($M \pm m$)**			
		peroxidase	**polyphenol oxidase**	**catalase, mg O_2/ min/g sample**	**superoxide dismutase, mg hydrazine tetrazolium/g sample**
		mg purpurgaline/g sample			
1	Noshpa 100	2.0 ± 0.14	1.6 ± 0.29	1.9 ± 0.40	7.8 ± 0.21
2	Zoriana Nosivska	1.9 ± 0.29	1.4 ± 0.20	2.0 ± 0.35	8.3 ± 0.23
3	Yuvivata 60	1.7 ± 0.21	1.8 ± 0.23	2.3 ± 0.28	8.6 ± 0.38
4	КС 1	2.6 ± 0.26	1.7 ± 0.21	2.8 ± 0.25	13.7 ± 0.42
5	КС 17	2.8 ± 0.33	2.0 ± 0.25	3.0 ± 0.20	15.2 ± 0.25
6	КС 21	1.9 ± 0.23	1.6 ± 0.22	2.0 ± 0.30	8.0 ± 0.48
7	Daushka	2.5 ± 0.25	1.6 ± 0.27	2.8 ± 0.27	14.4 ± 0.33
8	Borotba	1.4 ± 0.40	1.8 ± 0.32	2.1 ± 0.20	6.9 ± 0.41
9	Chaian	1.3 ± 0.21	1.4 ± 0.28	2.2 ± 0.24	7.4 ± 0.26
10	Vivate Nosivske	1.3 ± 0.36	1.4 ± 0.23	1.9 ± 0.30	8.3 ± 0.45

certain xeromorphic characteristics (Table 2), and their subsequent cultivation allowed us to evaluate them according to other criteria and identify correlations. The precipitation in the central Forest-Steppe of Ukraine is characterized by autumn moisture deficit in the soil that often makes the prospective harvest unatteinable, so the study of drought in the germination phase is not only theoretical but also practical. Germination and growth of seeds in osmotic solutions of sucrose simulates the deficit of moisture and allows to establish the overall level of physiological and biochemical processes in the germinated seeds under stress, which determines the resistance of adult plants. The research results of drought resistance in new genotypes of *Triticeae* plants on the juvenile stage of development by germination of caryopsides in sucrose solutions with different osmotic pressure indicate a high level of polymorphism in initial samples. It was established that in average 84% of seeds germinated in the solution of osmotic pressure of 14 atm, 75% at 16 atm osmotic pressure, 52% at 18 atm, 26% at 20 atm, 12% at 22 atm, and 5% of seeds germinated at 24 atm osmotic pressure. The high drought tolerance in this phase at 14–18 atm osmotic pressure of sucrose solutions was found for Chaian, Fighting, Vivate Nosivske, Zoriana Nosivska, Yuvivata 60, KC 21, and KC 5 strains. The lowest ability to grow in sucrose solutions was exhibited by Daushka, KC 1, KC 17. All other strains formed the group of “medium resistance” [23].

Given the fact that drought-resistant forms usually have low crop yield, it is important for them to have stable performance under different hydrothermal conditions. These criteria during 2008–2014 were met by Zoriana Nosivska and Noshpa 100, which are characterized by well-filled grain, vitreousness of 60–70%, and grain unit of 760–815 g/l, which are important features of productivity and drought resistance.

The studied plants that accumulated dry matter most intensely from the beginning of stem elongation to ear formation plants were characterized by intense stem growth and the growth of leaf surface of cultures. Pre-ear formation plants accumulated in average 38.4–66.9% of maximum dry matter in the arid 2008, and 49.1–70.7% of maximum dry matter in relatively moist years. The high leaf index (> 14.2), glossy coating, long-term assimilation ability of the flag leaf during milky-wax and wax ripeness, the presence of awns shoud be added to the morpho-physiological drought resistance criteria.

Mechanisms of frost and winter hardiness are high accumulation of total sugars in the tillering node serving as cryoprotectants and energy sources, and economical consumption of assimilates during autumn-winter-spring period. Comparative study of winter hardiness of new genotypes of *Triticeae* representatives by determining the total sugar content in the tillering nodes of winter genotypes after the autumn growing season and before the spring growing season (Table 2) made it possible

Table 2. **Evaluation of winter hardiness representatives of the tribe *Triticeae* by total sugar content in the tillering node (mean, 2012–2013, 2013–2014)**

№	Sort, line of tribe *Triticeae*	Content of total sugars in the tillering node,% per absolutely dry matter			Points of winter hardiness
		after termination of autumn vegetation	before spring vegetation	Δ, %	
1	Noshpa 100	29.6 ± 1.2	28.6 ± 0.9	1.0	9.0
2	Zoriana Nosivska	30.2 ± 1.3	27.1 ± 1.4	4.1	7.0
3	Yuvivata 60	29.9 ± 1.0	28.4 ± 1.1	0.8	9.0
4	КС 1	29.2 ± 1.6	26.0 ± 0.8	3.2	7.5
5	КС 17	29.6 ± 1.5	25.6 ± 1.0	4.0	8.0
6	КС 21	28.8 ± 1.1	24.9 ± 0.9	3.8	8.5
7	Daushka	30.2 ± 1.0	29.6 ± 0.9	0.8	9.0
8	Borotba	29.1 ± 1.8	28.1 ± 1.0	1.0	9.0
9	Chaian	28.6 ± 1.3	27.5 ± 1.2	1.1	9.0
10	Vivate Nosivske	28.9 ± 1.5	27.4 ± 1.1	1.5	8.5

to establish that winter-hardy varieties while wintering reduce total sugar content by only 6–8% but medium winter-hardy (КС 1, КС 5, Daushka) reduce it respectively by 16–18%, which is crucial for successful overwintering of plants because of the ability to accumulate high content of spare sugars as cryoprotective biopolymers including proteins, as well as reserve energy sources. Biotypes that are depleted during wintering by wasteful consumption of sugars and resume growth on first warming can freeze even if insignificant frosts return, particularly during the «February windows» and significant ($P < 0.05$) decrease in temperature after the beginning of vegetation (mid-late March). More winter-hardy varieties (Noshpa 100, Yuvivata 60) slowly «wake up» in negative temperatures intermittent with thaws and warmings, and they begin growing later in spring compared to the less adaptive sorts. During the winter contrasty period, level of sugars in their tillering nodes decreased only by 0.9–1.4%, respectively, while they maintained high total sugar reserve — 27.4–28.5%.

The air temperature over the period (in particular, in December 2009, 2011, 2014) dropped to −25–30 °C for 8–10 days, and soil temperature at the depth of the tillering node lowered to −20 °C, which helped to identify frost resistant sorts and lines of wheat, rye and winter triticale. We found that the criteria of winter hardiness are not only the ability to withstand low temperatures, down to −20 °C and less, but also the anthocyanin colored leaves, powerful fibrous root system, wax cover, narrow leaf, the sugar content in the tillering node, as confirmed by the strong positive correlation with the index of general winter hardiness ($r = 0.82 \pm 0.7$).

The overall assessment of hardiness *in situ* (Table 2) confirms the high winter hardiness of Noshpa 100, Yuvivata 60, Borotba, Chaian, and Vivate Nosivske. Significant relationship (correlation coefficients +0.72 – +0.76, $P < 0.05$) is revealed between indices of frost and winter hardiness, and total sugar content in tillering node.

Duration of vegetation period and the pace of the individual development are among the most important features that determine the level of adaptation of plants to vegetation conditions. The pace of development cultural cereals are dependent on the sensitivity of the photoperiod [26]. We found that a high level of adaptation to different stress conditions of winter is characteristic of plants with a weak point of differentiation of growth in autumn and late spring vegetation restoration (LSVR). These are plants with high photoperiod sensitivity and long period of vernalization.

Correlation between indicators of high drought and winter hardiness, and total protein in wheat, rye and triticale amounted to 0.64–0.75. The relationship of these adaptive properties with a total protein content in grain is explained by the multifunctional action of stress marker polymers. Adverse abiotic factors during the growing season helped to highlight the highly adapted and stable biotypes according to indices of dry matter accumulation.

Several authors showed [6, 9, 17, 26–30] that winter hardiness and productivity of plants is determined primarily by two physiological mechanisms of ontogeny: the need for the appropriate duration of vernalization and light regime. Differences between sorts and lines on photoperiodic sensitivity (PHPS) and duration of the period of vernalization (DPV) are already identifiable at the initial stages of development. Thus, the plants with high PHPS and DPV needs exhibit weak development of aboveground mass and intensity cone differentiation in autumn, in response to the high level of resistance to stress in winter. Instead, weak PHPS and short DPV plants accelerate development in the fall, and thus lose significant amounts of assimilates, and often subsequently experience lethal stress. Plants of this group are marked by rapid regrowth in spring spending a lot of productive winter moisture, which significantly affects the deficit during the atmospheric and soil drought in May leading to reduction of productive stems and plant productivity in general. Plants of Yuvivata 60 strain have high DPV and DPV and are characterized by delayed development in the beginning of fall and resuming their vegetation in spring, avoiding the stress.

As a result of years of research of biochemical markers and adaptive properties of new *Triticeae* genotypes, biochemical and genetical mechanisms for implementing adaptive potential of representatives of the tribe *Triticeae* L. were established. Specifically, molecular genetic markers of xeromorphism are microsatellite *Dreb* **1** gene sequences, *Glu-D1* glutenin genes, and spectra of *Gli-1B1*, *Gli-6D2*, *Gli-6D3*, *Gli-6B2* gliadins. Drought resistant plants have a better ability to mobilize their own adaptation mechanisms to adverse abiotic environmental conditions, as reflected in lower enzyme activity in flag leaves during flowering and ear formation, signifying a lower intensity of oxidative processes. Increased activities of superoxide dismutase, catalase and peroxidase indicate plants with lesser stress tolerance. The revealed criteria of frost and winter hardiness of plants are the accumulation of high total content of sugars in tillering node that serve as cryoprotectants and energy sources, and economical consumption of assimilates during the autumn-winter period. Winter resistant plants reduce their total sugar content only by 6-8% during wintering, and medium winter-hardy (KC 1, KC 16, Daushka) reduce it by 16–18%. An exogenous manifestation of high level of adaptation to winter are, for example, weak differentiation of growth points in the autumn, and late spring vegetation restoration characterizing them as highly photoperiodically sensitive.

Most newly created adaptive sorts and lines of common wheat contain *Glu-D1 5+10* and *2+12* alleles of glutenin genes and *Gli*-6 D2 or *Gli*-6 D3, Gli-6 B 2 alleles of gliadin genes, the expression of which is manifested in the significantly high protein (14.2 18.0%) in grain. It was found that the exhibited adaptive changes at the subcellular level are consistent with indicators such as high leaf index (<14.2), glossy cover, long-term green flag leaf, presence of awns, significantly greater accumulation of dry weight.

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РЕАЛІЗАЦІЯ АДАПТИВНОГО ПОТЕНЦІАЛУ ПРЕДСТАВНИКІВ ТРИБИ *Triticeae* L.

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Досліджено механізми реалізації адаптації представників триби *Triticeae* L. за біохімічними маркерами. Показано, що посухостійкі представники триби на субклітинному рівні характеризуються ідентифікацією алелів генів посухостійкості Dreb 1, глютенінів Glu-D1, гліадинів Gli-1B1, Gli-6D2, Gli-6D3, Gli-6B2 та високим вмістом протеїну в зерні (14,2–18,0%). Слабопосухостійким рослинам притаманний підвищений статус супероксиддисмутазної, пероксидазної та каталазної активності листя. Встановлено, що критеріями морозо- і зимостійкості рослин є: нагромадження високого загального вмісту цукрів у вузлі кущення (26 38 мг/г) як кріопротекторів і джерела енергії та економна витрата їх упродовж осінньо-зимового періоду. Екзогенним виявом високого рівня адаптивності рослинних організмів до різноманітних стресових умов зимового періоду є висока фотоперіодична чутливість, що виявляється у слабкій диференціації точки росту восени і пізньому відновленні весняної вегетації. Адаптаційні зміни на субклітинному рівні узгоджуються з показниками посухостійкості (високим індексом листкової пластинки, глянцевим покриттям, довготривалим зеленим забарвленням листка, наявністю остюків, значним приростом сухої маси за посушливих умов).

Ключові слова: *Triticum aestivum* L., *Secale cereale* L., *Triticum trispecies* Shulind, біохімічні маркери.

РЕАЛИЗАЦИЯ АДАПТИВНОГО ПОТЕНЦИАЛА ПРЕДСТАВИТЕЛЕЙ ТРИБЫ *Triticeae* L.

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Исследованы механизмы реализации адаптации представителей трибы *Triticeae* L. по биохимическим маркерам. Показано, что засухоустойчивые представители трибы на субклеточном уровне характеризуются идентификацией аллелей генов засухоустойчивости Dreb 1, глютенинов Glu-D1, глиадинов Glи-1B1, Glи-6D2, Glи-6D3, Glи-6B2 и высоким содержанием протеина в зерне (14,2–18,0%). Слабозасухоустойчивым растениям присущ повышенный статус супероксиддисмутазной, пероксидазной и каталазной активности листьев. Установлено, что критериями морозо- и зимостойкости растений являются: накопление высокого общего содержания сахаров в узле кущения (26–38 мг/г) как криопротекторов и источников энергии и экономный расход их на протяжении осенне-зимнего периода. Экзогенным проявлением высокого уровня адаптации растительных организмов к различным стрессовым условиям зимнего периода является высокая фотопериодическая чувствительность, выражающаяся в слабой дифференциации точки роста осенью и позднем восстановлении весенней вегетации. Адаптационные изменения на субклеточном уровне согласуются с показателями засухоустойчивости (высоким индексом листовой пластинки, глянцевым покрытием, длительной зеленой окраской листка, наличием остей, значительным приростом сухой массы при засушливых условиях).

Ключевые слова: *Triticum aestivum* L., *Secale cereale* L., *Triticum trispecies* Shulind, биохимические маркеры.