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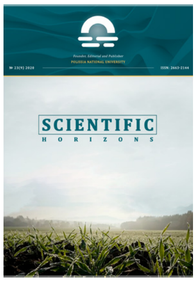

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Biocecological Features, Biochemical and Physicochemical Parameters of Grain of New Genotypes

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Abstract. The presented study allowed for better coverage of the features of new varieties of soft winter wheat and winter triticale, demonstrating the bioecological potential of their crops and the biochemical and physico-chemical parameters of grain, which is a relevant matter. This paper presents the results of selection work on winter triticale, highlights the parameters of productivity, the biochemical composition of grain of the new Myronosets variety. The purpose of this study was to create new genotypes of winter triticale and soft winter wheat and investigate them in terms of bioecological potential and biochemical, physico-chemical parameters of grain. The study involved biometric, physico-chemical, biochemical, and mathematical research methods. The Myronosets variety has a high grain yield (6.8-7.2 t/ha), a high protein content (⩾14.2%) and a composition of essential amino acids, which confirms its nutritional and consumer value. It is recommended to use flour from this variety to produce functional bakery products. For the first time, it was found that Myronosets triticale variety is superior (4919 mg/100 g DM) to Ariivka wheat variety (3977 mg/100 g DM) and Borotba rye variety (3241 mg/100 g DM) in total amino acid content. It was found that triticale grain is inferior to wheat grain in terms of tryptophan and isoleucine content. Rye is inferior to wheat grain in all essential amino acids except leucine, and to triticale – in all amino acids except tryptophan. The most represented amino acids in triticale grain were as follows: leucine (1442 mg/100 g), valine (733 mg/100 g), phenylalanine (720 mg/100 g) and isoleucine (510 mg/100 g), in rye – leucine (1343 mg/100 g), valine (481 mg/100 g) and phenylalanine (396 mg/100 g). Further broad targeted introduction of the new variety in agroecosystems will increase the volume of grain of valuable both animal feed and to produce functional bakery products

Keywords: essential amino acids, ecological and adaptive properties, bioecological potential, grain quality

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INTRODUCTION

Currently, the use of intergenerational synthetic hybrids is relevant, since the latter combine important complementary features of both parent species. Triticale is one of such selection developments, which is endowed with high yield and quality of wheat and stress resistance of rye. It is known that triticale (x *Triticosecale* Wittmack ex A. Camus) is the first successful synthetic amphiploid cereal crop, which originated in 1874 as a result of hybridisation of hexaploid wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) (Ayalew *et al.*, 2018; Liubych *et al.*, 2020). The production area under this grain crop has grown significantly in the world, as triticale compromises the beneficial agronomic properties of the parent forms (Moskalets *et al.*, 2016; Liubych *et al.*, 2020). In this regard, triticale grain production doubled – from six million tonnes in the 1990s to almost 13 million tonnes in 2020 on a planetary scale. Triticale is the leader in Poland in terms of cultivation worldwide. Thus, in Ukraine, the area under triticale is five times smaller than in Germany and three times smaller than in Belarus or China (FAOSTAT, 2019). Presently, triticale plants are used in many ways, mainly as a grain intended for feed production (Goral *et al.*, 2021). Furthermore, in spring, the land cultivated for triticale is used for pastures, as fresh livestock feed, or for hay and silage. Triticale is also cultivated for bioethanol (Randhawa *et al.*, 2015; Liubych *et al.*, 2020), as well as to produce food products such as functional bakery products (Liu *et al.*, 2017).

The first barren triticale was bred in 1875 in Scotland. Later, in 1888, Rimpau (Germany) crossed hexaploid wheat and rye to produce the first viable hybrid by spontaneous chromosome doubling (Würschum *et al.*, 2014; Liubych *et al.*, 2020). European countries were newcomers both to the creation of this essential species and to the cultivation of a new crop adapted to different environmental conditions. The first variety was created in Hungary in 1968 (Blum, 2014). Selective breeding of triticale in North America officially began in 1954 at the University of Manitoba in Canada, from where the industrial variety (Rosner) was bred in 1969 (Ayalew *et al.*, 2018).

Triticale fields occupy over 4 million hectares of land, with an average annual yield of nearly 18.4 million tonnes of grain in 2019 (FAOSTAT, 2019). According to the same data, Poland, Germany, Belarus, and France were and still are the leading triticale producing countries, accounting for 73% of global production. Germany and France showed the highest performance, followed by Poland and Belarus (Randhawa *et al.*, 2015; FAOSTAT, 2019).

Since triticale contains wheat (diploid, tetraploid, and hexaploid), rye, and various forms (primary, secondary, and substituted) of triticale as its genetic resource base, genetic variations can be continuously created (by crossbreeding) to enrich the genetic pool (Würschum *et al.*, 2014). However, the optimal use of triticale depends on the exact combination and use of germ plasma by applying various breeding and genetic tools to accumulate the desired genes in culture. Crop selection benefits from using both conventional and molecular selective breeding methods.

Global climate change requires a reassessment of the structure of acreage and species and varietal diversity of winter crops (Intergovernmental Panel…, 2014). This is because winter crops, including triticale, that are the leading link in ensuring sustainable production of food grains, since they are endowed with the highest yield potential with genetic resistance to limiting environmental factors of a particular region, pests, and pathogens, which is the main thing in adaptive agriculture (Sabagh *et al.*, 2021; Kim *et al.*, 2017). Targeted introduction of particular varieties is another way to regulate the grain productivity of triticale (Li *et al.*, 2013). Therefore, considering the specific features of soil and climatic conditions of a particular region upon introducing a particular variety allow fully coverage its bio-potential in terms of grain yield and quality.

The purpose of this study was to create a new genotype of winter triticale and to investigate it in terms of productivity, yield and quality of grain, resistance to lodging, shedding, brittleness of the ear, germination of grain in the ear, comprehensive resistance to pathogens and damage by the Hessian fly, frost, winter, and drought resistance.

MATERIALS AND METHODS

During 2008-2020, research was performed to create a new variety of winter triticale (Mironosets), which was investigated by genotypic and phenotypic characteristics in the conditions of Polissia (Nosivska Selection and Experimental Station of the National Academy of Agrarian Sciences of Ukraine) and Forest-Steppe (V.M. Remeslo Myronivskyi Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (MIW NAAS)). Triticale grain and flour was evaluated by biochemical and technical indicators at the V.Ya. Yuriev Institute of Crop Production of the National Academy of Agrarian Sciences of Ukraine in the grain quality laboratory. Morphological parameters of plants (leaves, bush, ear, grain) and stages of ontogeny were studied. Biometric plant parameters included: plant height, main ear length, number of spikelets in the main ear, number of grains in the main ear, grain weight from the main ear, thousand-kernel weight, and yield from an area of 10 m^2.

The dry weight of one grain and the water content of the grain were found by drying 100 g of grain at 80°C for 48 hours and re-weighing the sample at zero water content. Grain samples (30 g) were ground on LMT-2 equipped with a 1 mm mesh. Wholemeal flour samples (1 g) were dried in an oven at 80°C for 48 hours, then 5 mg of dry flour was weighed in tin capsules and the total N concentration was figured out according to Dumas burning using a DA 7440 infrared express analyser. The gluten content was found using the Inframatic 8600 device, and dietary fibre (cellulose) was found on the FIWE-3 analyser.

Amino acid composition was found by hydrolysis of flour samples using 6 n. HCL containing 0.1% phenol in an oven at 110°C for 24 h. Amino acids were found using mercaptopropionic acid, O-phthalaldehyde. Chromatographic separation was performed using an ODS2 Waters Spherisorb column. The analysis was performed using 20 mmol/L phosphate (potash) buffer (pH 6.48) as a solvent. A standard mixture of amino acids was prepared by mixing 8 different essential amino acids in 0.1 N HCL and included threonine (Thr), methionine (Met), phenylalanine (Phe), valine (Val), leucine (Leu), isoleucine (Ile), lysine (Lys), and tryptophan (Trp).

Data on grain yield, protein concentration, and gluten were presented as the average ± standard deviation of five biological repeats. Differences between treatments and varieties were separated by two-way analysis of variance performed in SPSS version 13.0. To compare the obtained data, the student's t-test was calculated using Delta 2D software at a significance level of $p \leq 0.05$.

RESULTS

Based on the results of selective breeding work performed during 2004-2017, several new genotypes were created. Special attention should be paid to some of the best varieties in terms of economic characteristics – soft winter wheat Ariivka and winter triticale Myronosets. Ariivka wheat variety was created using the method of intervarietal hybridisation by repeated individual selection from hybrid populations obtained from the crossing of ♀Donska semi-dwarf x ♂ Line K-6477/91. And the Myronosets variety is a method of intervarietal hybridization from crossing ♀ (♀Augusto x ♂Jaguar) x ♂K9844/93 (Fig. 1).

a *b* *c*

d *e* *f* *g* *h*

***Figure 1**. Winter triticale of Myronosets variety*

***Note:** a, b, c – crops, d, e – removal of stamens from triticale spikelets, f, g – ear, h – grain*

***Source:** photographed by the authors*

It is known that the growing season duration (GSD) and the phenological phases of plant development are genetically determined parameters (Alipour *et al.*, 2021), which vary in insolation, precipitation, and temperature conditions, which inherently determines plant productivity (Heimler *et al.*, 2010; Dennett *et al.*, 2013; Kim *et al.*, 2017). Therefore, the resistance of triticale Myronosets plants was evaluated in the main phases of plant development, depending on the place of cultivation. A sharp reduction in the duration of the passage of plant development phases affected the structure of the crop, which affected the overall productivity of crops. In this regard, a study of the adaptability of plant varieties for their further cultivation in particular places was conducted.

It was found that for plants of the above-mentioned triticale variety, there is a slow development of the ground part in autumn and spring, compared with plants of the rye varieties under study. This was noted in the tillering phase during 2017 and 2018. Therewith, the average weight of the plant's roots was 0.24 g, and the ground part was 1.9 g (in the Forest-Steppe). But in the stem elongation phase, the difference between both triticale and rye and wheat plants levelled off and further significant differences (R⩽0.05) is not observed between the dry matter accumulation indicators of the ground part and roots (Table 1).

***Table 1**. Features of dry matter accumulation by grain plants (2017-2018), n=27*

Organogenesis, stage	Weight, 10 plants, g DM	Variety, culture					
		Myronosets (triticale)		Ariivka (wheat)		Borotba (rye)	
		Forest-Steppe	Polissia	Forest-Steppe	Polissia	Forest-Steppe	Polissia
II	Roots	2.3±0.18*	2.5±0.11*	1.7±0.14	2.0±0.09	3.0±0.30	3.2±0.10
	Ground part	1.8±0.10*	2.1±0.15*	1.8±0.19	1.9±0.24	3.3±0.21	3.4±0.14
III	Roots	3.2±0.28*	3.4±0.27	2.8±0.22	3.3±0.29	4.7±0.45	5.2±0.23
	Ground part	2.5±0.26*	3.4±0.30	3.1±0.45	3.0±0.10	4.8±1.04	5.4±0.33
V-VI	Roots	15.7±2.06	19.3±2.00	13.5±2.05	15.0±1.21	18.8±3.20	22.4±2.15
	Ground part	19.5±1.80	20.1±2.16	15.0±2.58	16.5±1.80	20.2±3.76	19.4±2.06

***Note:** * – P⩽0.05 relative to the control (standard); SDx –the standard mean deviation. The differences between the study variants differ statistically at ⩽0.05*
***Source:** compiled by the authors*

The result of successful ecological testing of plants lies in the specific features of their reproductive biology. Both in the conditions of Polissia and in the conditions of Forest-Steppe, plants of the Myronosets variety form the largest number of flowers in the inflorescence (96-121 pcs.), seeds in an ear (73-77 pcs.), compared to wheat (62-70 and 56-59 pcs.) and rye (76-83 and 58-65 pcs.) (Table 2), which indicates a high biological yield potential in triticale.

***Table 2**. Elements of grain plant productivity, Forest-Steppe (2017-2020), n=27*

Total number	Variety, culture					
	Myronosets (triticale)		Ariivka (wheat)		Borotba (rye)	
	Forest-Steppe	Polissia	Forest-Steppe	Polissia	Forest-Steppe	Polissia
Flowers in one inflorescence, pcs.	96±4.0	121±3.0	70±3.0	62±2.0	83±3.0	76±2.0
Spikelets in the main ear, pcs.	32±2.0	31±2.0	22±1.8	23±2.0	28±2.0	29±2.0
Seeds in the main ear, pcs.	77±2.0	73±2.0	56±2.0	59±2.0	65±2.0	58±2.0
Grain weight from the main ear, g	3.6±2.0	2.8±2.0	1.6±2.0	1.1±2.0	2.7±2.0	2.4±2.0
Seed productivity of one plant	12.8±2.0	9.1±2.0	11.2±2.0	7.6±2.0	6.2±2.0	7.7±2.0

***Note:** * – P⩽0.05 relative to the control (standard); SDx – the standard mean deviation. The differences between the study variants differ statistically at ⩽0.05*
***Source:** compiled by the authors*

According to the duration of androgametogenesis and pollen viability in Myronosets plants (unlike rye and wheat), seeds are formed and ripen from the centre to the periphery of the ear. This feature in triticale is important in the formation of highly viable seeds in this part of the ear, and therefore, drought-resistant plant populations can produce conditioned seeds even under limiting factors. Notably, in triticale Myronosets, regardless of the year of research and weather conditions, the grain yield was no less than 8.0 points.

Tests of the new variety have shown that in terms of the number of spikelets in the ear, the number of grains from the main ear, the Myronosets variety is at the level of the best varieties (Ladne, AD 256, Dorena, Slavetne, etc.). And reliable differences obtained in terms of ear density (28.5 spikelets per 10 cm of rachilla) indicate that it forms a denser ear, which is characterised by a better harvesting index. On average, for 2008-2019, the LCH/97 line provided a yield of 6.17 t/ha, which is 0.15 t/ha less than for the AD 256 variety. It was found out that the high grain productivity of the variety is formed due to an increased number of productive stems per 1 m^2 (523 pcs.), a well-seeded dense ear, etc. The amount of protein in triticale grain, its fractional composition, the presence of essential amino acids, the amount and quality of gluten is an important technological criterion for the nutritional value of protein and grain quality (Rombouts *et al.*, 2009; Xu *et al.*, 2020).

According to 4-year studies, some triticale genotypes, such as rarity (national standard), Myronosets, can produce high stable yields of high-quality grain in Polissia and Forest-Steppe conditions. The data in Table 1 shows that the above-mentioned genotypes have high baking indicators, e.g., the grain character is 690-720 g/l and 35-44% vitreous (flour quality indicators) (Table 3). Analysis of technological indicators of grain showed that the new variety forms grain, with 14.5% protein, 26.8% gluten. The flour from the new winter triticale variety under study is first-class due to its gluten content >14%.

***Table 3**. Indicators of grain properties of winter triticale varieties, average for 2017-2020 (n=4)*

Cultivar	Grain indicators					
	TKW, g	Grain unit, g/l	Protein content, %	Raw gluten content, %	Fat content, %	Starch content, %
Rarytet (control)	47.4±0.9	717.5±2.1	13.5±0.5	23.4±0.3	2.0±0.1	62.0±0.2
Myronosets	46.2±1.5	690±1.5*	14.5±0.2*	26.8±0.2*	2.0±0.0	63.1±0.3*
Woltario	45.0±1.0*	720±2.4	12.9±0.3	22.5±0.3*	2.1±0.0	61.8±0.4
Pawo	44.3±0.8*	704±1.8*	13.6±0.7	26.5±0.2*	1.9±0.0	63.4±0.7*
Ariivka (wheat)	50.3±1.2*	786±2.1*	14.6±0.4*	29.7±0.5*	2.2±0.0	59.5±0.8*
Borotba (rye)	42.0±1.1*	680±0.9*	10.8±0.9*	11.3±0.7*	2.0±0.0	70.3±0.6*

***Note:** * – grain unit; ** – P⩽0.05 relative to control (standard); SDx – standard mean deviation. The differences between the study variants differ statistically at p⩽0.05*
***Source:** compiled by the authors*

Analysis of the fractional composition of triticale grain proteins of the Myronosets variety showed the superiority of spare proteins gliadins and glutenins (49.3%) over water-soluble proteins – albumins and globulins (36.4%) (Table 4), which is reflected in the higher quality of gluten, dough, bread, and overall bakery score (8.7 points). Rye has lower average and low baking properties (bread volume – 305 ml, total baking score 3.8 pts) caused by a low content of water-insoluble proteins (37.3%). The role of the ratio of gliadins to gluten (Gli/Glu) was established in determining the quality of gluten triticale of the variety under study with high baking properties of the Rarytet variety, which has a Gli/Glu ratio of 0.9, and which together with wheat have higher quality indicators.

***Table 4**. Ratio of protein fractions and baking properties of triticale, wheat and rye, Forest-Steppe, average for 2019-2020 (n=4)*

Cultivar	Grain indicators						
	Content, %			Gli + Glu	Gli/Glu	Bread volume, ml	Overall baking score, pts
	albumin + globulin	gliadin (Gli)	glutenin (Glu)				
Rarytet (control)	36.4±0.3	24.5±0.3	26.7±0.5	51.2	0.9	512±7.5	9.0
Myronosets	34.9±0.2*	22.8±0.4	26.5±0.3	49.3	0.9	520±5.1*	8.7
Woltario	43.5±0.6	20.7±0.3	18.3±0.2	39.0	1.1	440±3.0*	6.5
Pawo	41.7±0.5	21.0±0.4	19.1±0.4	40.1	1.2	407±5.4*	6.2
Ariivka (wheat)	34.6±0.5*	26.2±0.7	29.4±0.1	55.6	0.9	608±12.8*	8.4
Borotba (rye)	50.5±0.2*	20.8±0.3	16.5±0.6	37.3	1.3	305±8.2*	3.8

***Note:** * – P⩽0.05 relative to the control (standard); SDx – the standard mean deviation. The differences between the study variants differ statistically at ⩽0.05*
***Source:** compiled by the authors*

It is known that the combination of increased plant productivity with low growth and high baking properties in one variety while maintaining complex resistance to adverse environmental factors is important for strengthening its competitiveness (Martiniello, 2011; Liu *et al.*, 2017). In the Myronosets variety, this was achieved. According to the results of hybridological analysis, in crosses of Myronosets plants with tall-growing varieties in the first generation, heterosis is observed towards reducing the stem of hybrids compared to the parent forms based on "stem height". However, there is a different type of inheritance among hybrid combinations involving the newly created variety (depression, partial negative inheritance, intermediate inheritance, and partial positive dominance). Phenotypic changes in traits in F1 hybrids indicate that genetically, indicators for the "stem height" trait are dominated not only by the additive type of gene interaction, but also by negative dominance and super-dominance.

The quality of triticale grain depends not only on the gluten content and quality, but also on the carbohydrate-amylase complex of the grain (Alijošius *et al.*, 2016). The study of the features of starch content in grain and the carbohydrate-amylase complex allowed figuring out that the starch content in grain of these varieties and crops is quite high and amounts to 64.0-68.8% (Table 1). Starch is the main component of grain, so its content, condition, and properties always affect the rheological properties of the dough, and therefore the quality of the final products. Notably, triticale grain contains a considerable total amount of sugars and has a lower starch gelatinisation temperature, as well as highly active α-amylase (Guzmán *et al.*, 2011; Goral *et al.*, 2021).

Protein-amino acid composition is one of the most complex properties of grain composition. Amino acid composition determines the biological value of food and food products (according to the total amount of non-essential amino acids) as their biochemical criterion (Jaśkiewicz & Szczepanek, 2018). The analysed soft wheat genotypes differ significantly ($P \leqslant 0.05$) in terms of ash, moisture, protein, and starch content. Significant differences between the analysed genotypes were found in the lipid content ($P \leqslant 0.05$). All wheat genotypes were characterised by high protein content and optimal starch and lipid levels. Figure 2 shows a qualitative analysis of essential amino acids in some grain genotypes.

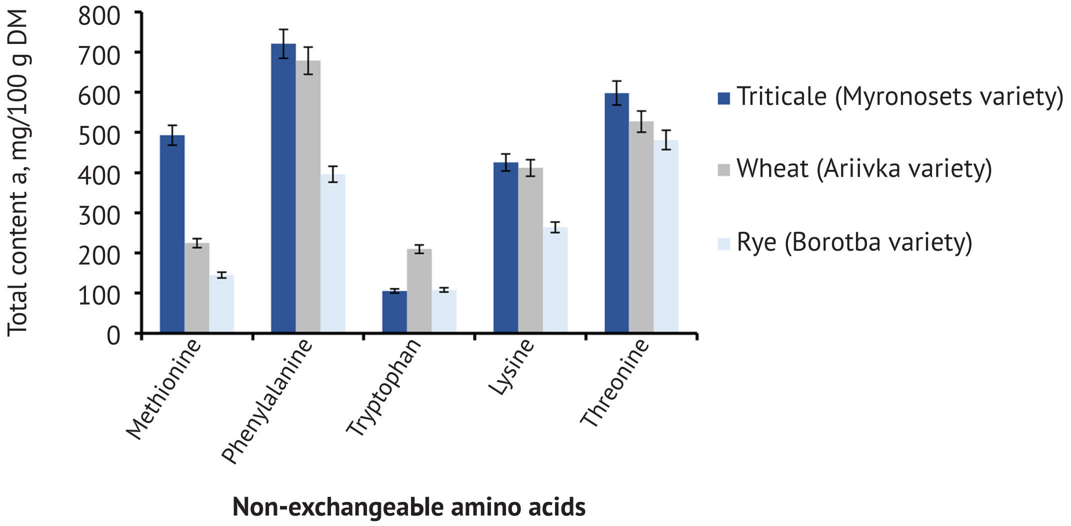

***Figure 1**. Content of essential amino acids in triticale, wheat, and rye grains*
***Source:** compiled by the authors*

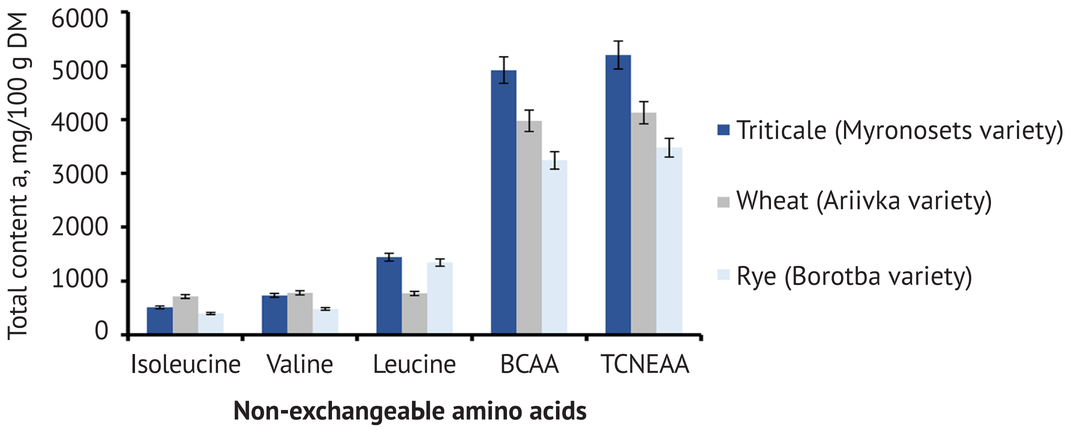

***Figure 2**. Content of essential amino acids in triticale, wheat, rye grains, BCAA, TCNAA index*
***Note:** (BCAA – aminoacids with branched side chains; TCNAA – total content of non-replaceable amino acids)*
***Source:** compiled by the authors*

Figures 2 and 3 show that different genotypes of cereals showed different content of essential amino acids. It was found that the content of such amino acids as leucine (1442 mg/100 g), valine (733 mg/100 g), phenylalanine (720 mg/100 g) and isoleucine (510 mg/100 g) is most pronounced in triticale grain. While in rye grain, the content of which was lower than in triticale and amounted to 1343 mg/100 g for leucine, 481 mg/100 g for valine, and 396 mg/100 g for isoleucine. The triticale of Myronosets variety is superior (4919 mg/100 g DM) to Ariivka wheat variety (3977 mg/100 g DM) and Borotba rye variety (3241 mg/100 g DM) in total amino acid content. However, it is somewhat inferior to wheat grain in terms of tryptophan and isoleucine content. In general, the triticale grain of the Myronosets variety is characterised by a high content of protein and amino acids, which indicates its high nutritional value.

Regarding the pathogens of leaf diseases, the most widespread on grain crops, the following were found: *Blumeria graminis (DS)f.sp. tritici Speer, Puccinia recondite Rob ex Desm f.sp. Septoria tritici Rob. et Desm.* In the conditions of Polissia and Forest-Steppe, the ecological test of the triticale of Myronosets variety allowed estimating the resistance of plants during 2017-2020 and compared with other varieties (Table 5) in terms of the degree of damage by powdery mildew, septoria, brown rust, root rot, and ear fusarium.

***Table 5**. Resistance of triticale plants of different varieties to diseases, pts (2017-2020), n=4*

Disease	Year	Rarytet (control)		Myronosets		Woltario	
		Forest-Steppe	Polissia	Forest-Steppe	Polissia	Forest-Steppe	Polissia
Powdery mildew	2017	9	9	9	9	9	9
	2018	9	8	9	8	9	9
	2019	9	9	9	8	9	9
	2020	9	9	9	8	9	9
	mean	9.0	8.8	9.0	8.3	9.0	9.0
Brown rust	2017	8	7	9	8	9	9
	2018	8.8	8	9	7.5	9	9
	2019	8.5	8.5	9	8	8	9
	2020	7.5	8.0	9	9	8	9
	mean	8.0	8.0	9.0	8.5	8.5	9
Septoria	2017	7.0	8	9	8	9	9
	2018	8.0	8.8	9	9	9	8
	2019	8.0	8.5	9	8	9	7.5
	2020	8.5	7.5	9	9	9	8
	mean	8.0	8.0	9.0	8.5	9.0	8.0
Root rot	2017	8	8	9	8	9	8
	2018	8	8	9	8.0	9	7.5
	2019	8	8	9	8.5	9	7.0
	2020	8	8	9	7.5	9	8
	mean	8.0	8.0	9	8.0	9.0	8.0
Fusarium head blight	2017	8	8	9	8	9	8
	2018	8	8	9	7.5	9	7.5
	2019	8	8	9	8	9	7
	2020	8	8	9	9	9	7
	mean	8.0	8.0	9.0	8.5	9.0	7.5

***Source:** compiled by the authors*

As data from Table 5 shows, the Myronosets variety showed the greatest resistance during the study period to powdery mildew (8.9 points), septoria (8.2 points), its values did not significantly exceed the control-rarity variety. Thus, it is advisable to use the new triticale variety in the selection breeding process for immunity, namely as a source of complex resistance to pathogens.

DISCUSSION

Triticale is the first artificially created grain crop that can to a certain extent predominate in terms of economically valuable characteristics of wheat and rye (Blum, 2014; Jaśkiewicz *et al.*, 2019). Presently, triticale culture has extensive breeding, industrial, and consumer opportunities (Gao *et al.*, 2013; Liubych *et al.*, 2020; Goral *et al.*, 2021). The triticale of Myronosets variety can take its rightful place among grain crops since it has high grain quality indicators, productive potential, and stable yields on an annual basis.

Triticale has a very narrow genetic basis (Blum, 2014; Kim *et al.*, 2017), since most of its germplasm was obtained from only a few materials that were crossed with each other (Ayalew *et al.*, 2018). Crossbreeding of improved wheat and rye varieties allows getting the best genetic combination to take advantage of the genetic benefits from the selection breeding capabilities of both parent species (Moskalets *et al.*, 2016; Blount *et al.*, 2017).

Back in 1937, Blakeslee & Avery noted that crossing wheat as the parent plant and rye as a pollen donor most often resulted in sterile hybrids. However, when colchicine usage induced polyploidy, they concluded that the chemical doubled the number of chromosomes and produced fertile offspring (Blum, 2014). Based on this knowledge, in 1937, the scientist Pierre Civodron in France improved the technique of obtaining reproductive offspring by crossing wheat and rye. Applying new selection methods, he created many industrial species with good production qualities (Blum, 2014; Moskalets *et al.*, 2016; Parent *et al.*, 2017; Ogbonnaya *et al.*, 2017; Laze *et al.*, 2019; Pradhan *et al.*, 2020).

Triticale refers to carbohydrate, energy-concentrated nutrients (Wang *et al.*, 2020). Recently, apart from corn, it is one of the most important nutrients and energy sources in the nutrition of domestic and farm animals in Ukraine (Sikora *et al.*, 2019). Grains, as well as by-products obtained from triticale processing, are extremely suitable well-digested nutrients for domestic and farm animals, as they contain a large amount of starch and are relatively poor in raw fibre (Makowska *et al.*, 2020). The importance of triticale in direct human nutrition or indirectly as food is great (Zhu, 2018). However, global production of triticale and other cereals is not proportional to the increase in the global population (Glamoclia *et al.*, 2017).

This artificial species is of interest due to its nutritional value, which in many ways exceeds the value of wheat and rye (Tricker *et al.*, 2016; Sheteiwy *et al.*, 2018). The nutritional value of triticale grain is conditioned upon its high content of protein, essential amino acids, minerals, vitamins B, PP, E, and carotenoids. As noted, (Shishlova, 2016; Gao *et al.*, 2016; Jaśkiewicz & Szczepanek, 2018), triticale culture is not very discriminatory in terms of growing conditions and is the most capable among other crops in the zone of weak realisation of biological potentials (Alijošius *et al.*, 2016). Currently, there are several varieties of winter and spring triticale with high productivity, grain quality and stable expression of economic characteristics (Blum, 2014; Würschum *et al.*, 2014). Not all varieties have valuable economic characteristics that meet the requirements of baking and alcohol use (Blount *et al.*, 2017; Glamoclia *et al.*, 2018). Therewith, the expansion of the triticale gene pool with such properties is important for national food safety (Moskalets *et al.*, 2016).

Essential and non-essential amino acids play a significant role in the human diet (Wan *et al.*, 2017; Yasir *et al.*, 2019). Due to their branched-chain structure, the essential amino acids – valine, leucine, and isoleucine – are collectively referred to as branched-chain amino acids (BCAAs). These amino acids play a crucial role in skeletal muscle, not only as a major component of proteins, but also as an energy source, especially during exercise. BCAAs are also involved in the regulation of protein metabolism in skeletal muscle cells (Tsunekawa *et al.*, 2021).

Branched chain amino acids (BCAAs), such as leucine, isoleucine, and valine, are essential for healthy functioning of cells and organs (Almeida *et al.*, 2020). Many authors (Kihlberg & Ericson, 1964; Morey *et al.*, 1983; Dennett *et al.*, 2013; Tsunekawa *et al.*, 2021) proved that high dietary intake of BCAAs prevent the prevalence of overweight and obesity in adults. The BCAA index of triticale grain is 1.4 times higher than that of Ariivka wheat grain and 1.5 times higher than that of rye, which confirms its nutritional and consumer value, from the flour of which it is advisable to produce functional bakery products.

Most of the amino acids present in the analysed genotypes of triticale, rye, and wheat are leucine (636-1442 mg/100 g), phenylalanine (396-720 mg/100 g), valine (291-733 mg/100 g), lysine (264-425 mg/100 g), isoleucine (222-715 mg/100 g), and threonine (481-598 mg/100 g). Gluten protein consists of the monomers gliadin and polymer glutenin, which are recognised as the main reserve proteins of wheat, rich in asparagine, glutamine, arginine, and proline (Rombouts *et al.*, 2009; Brzozowski & Stasiewicz, 2017), but very low in such nutritionally important amino acids as lysine, tryptophan, and methionine (Byrne *et al.*, 2012; Glamoclia *et al.*, 2018). Humans and animals can synthesise nine essential amino acids from 20 amino acids. The remaining amino acids, which are considered essential amino acids, must come from food. These include cysteine (as well as tyrosine), a semi-essential amino acid, since it can only be synthesised from methionine and phenylalanine (Kihlberg & Ericson, 1964; Aho & Koivistoinen, 2009). The amino acid composition is important for determining the nutritional value of cereals for human and animal nutrition (Mosaddek *et al.*, 2013; Penuelas *et al.*, 2020).

Elevated levels of lysine depend on biosynthesis, in which the enzymes aspartokinase (AK) and dihydrodipicolinate synthase (DHPS) play an important role (Postles *et al.*, 2016). An increase in lysine synthesis can be achieved by expressing enzymes (AK, DHPS) that are insensitive to lysine feedback inhibition. This is achieved in grain seeds with a high lysine content (Kondratenko *et al.*, 2015; Xu *et al.*, 2020). Tryptophan acts a precursor of the neurotransmitter serotonin and the pineal hormone melatonin. The tryptophan content obtained in the analysed wheat genotypes was lower than the content reported by Gafurova *et al.* (2002) (1.8-2%), which is higher than that reported by other researchers (Kihlberg & Ericson, 1964; Aho & Koivistoinen, 2009) (0.92-1.0%), but similar to the content reported by Kondratenko *et al.* (2015) (on average 1.07%). According to some authors (Aho & Koivistoinen, 2009; Ackah *et al.*, 2021), cereals contain the amino acid methionine in minimal amounts. Phenylalanine is essential for the growth and development of young children, and therefore it is enough to consume it in lesser amounts (Singh *et al.*, 2012; Alijošius *et al.*, 2016).

CONCLUSIONS

A study of the possibilities for agricultural reform has resulted in the following conclusions. As an analysis of global agricultural experience showed, the effective functioning of the agricultural sector could not be achieved without appropriate regulation of tax mechanisms. In each country, the taxation system has its own specific features, which reflect the current state and trends in agricultural development. Primarily, the income tax system is applied, while land taxation has the function of levelling the conditions of agricultural activity.

Each country adapts its agricultural taxation system according to the current economic situation and specific historical background of the state. There are two main approaches to setting up a taxation system for agricultural producers: unified and specialised. In Azerbaijan, the tax legislation classifies the simplified tax as a state tax, although in terms of content and essence it can be considered a special tax regime. The government provides a large number of benefits for enterprises that are involved in the agricultural sector. Yet, the incentive mechanisms must be used rationally, as poor management will not only fail to achieve the long-term goals but will also deteriorate the overall situation in a particular area.

Based on a system-structural approach, a system of definite steps that would optimise the agricultural taxation system in Azerbaijan has been developed. These can be divided into two key areas: the design of a coherent and transparent system of taxation of agribusinesses and the establishment of a system to monitor the effectiveness of enterprises in utilising the various tax incentives.

The modernisation and efficiency of the tax system and the use of new approaches to taxation have always been and will be of great interest to entrepreneurs and ordinary citizens alike. Efforts towards the improvement of the tax system must be sustained at all times. This issue should always be on the national government's agenda. In summary, the findings of this investigation and the conclusions drawn from it can be used as an effective scientific basis for further studies on the prospects for amending the Tax Code in the agricultural sector. This study may prompt other researchers to approach the issue from a new perspective.

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Біоекологічні особливості, біохімічні та фізико-хімічні показники зерна нових генотипів

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Анотація. Представленні дослідження дозволили більше розкрити особливості нових сортів пшениці м'якої озимої та тритикале озимого, демонструючи біоекологічний потенціал їх посівів та біохімічні та фізико-хімічні показники зерна, що має актуальний характер. У статті надані результати з селекційної роботи тритикале озимого, висвітлено параметри продуктивності, біохімічний склад зерна нового сорту Мироносець. Метою досліджень було створити нові генотипи тритикале озимого і пшениці м'якої озимої та вивчити їх за біоекологічним потенціалом та біохімічними та фізико-хімічними показниками зерна. В роботі використані біометричні, фізико-хімічні, біохімічні та математичні методи досліджень. Сорт Мироносець має високу урожайність зерна (6,8-7,2 т/га), високий вміст білку (≥14.2%) і склад незамінних амінокислот, що підтверджує його харчову та споживчу цінність, з борошна якого доцільно виробляти функціональні хлібобулочні вироби. Вперше визначено, що сорт тритикале Мироносець за вістом загальних амінокислот переважає (4919 mg/100 g DM) пшеницею сорту Аріївка (3977 mg/100 g DM) і жито сорт Боротьбу (3241 mg/100 g DM). Встановлено, що зерно тритикале поступається зерну пшениці за вмістом триптофану і ізолейцину. Жито поступається зерну пшениці за усіма незамінимими амінокислотами окрім лейцину, а перед тритикале усіма амінокислотами, окрім триптофану. Найбільше представленими амінокислотами в зерні тритикале були: Лейцин (1442 мг/100 г), Валін (733 мг/100 г), Фенілаланін (720 мг/100 г) і Ізолейцин (510 мг/100 г), у жита – Лейцин (1343 мг/100 г), Валін (481 мг/100 г) і Фенілаланін (396 мг/100 г). Подальша широка адресна інтродукція нового сорту в агроекосистемах дозволить збільшити обсяги зерна цінного як корму для тварин, так і для виготовлення функціональних хлібобулочних виробів

Ключові слова: незамінні амінокислоти, еколого-адаптивні властивості, біоекологічний потенціал, якість зерна