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COMMON WHEAT: ECOLOGICAL PLASTICITY BY BIOLOGICAL AND TECHNOLOGICAL MARKERS

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The priority in studying new lines and varieties of common winter wheat was their ecological plasticity by biological and technological markers. It was revealed that for stability and plasticity on the basis of seed production the varieties and lines are divided into stable, narrow and wide-adaptive ones, the latter of which are characterized by a wide range of ecological valence (with high and medium variability and homeostasis, with variance of stability which is close to zero, and with environmental factor plasticity which is greater than one). We studied new cultivars and lines of hexaploid common winter wheat from Bila Tserkva National Agrarian University and Nosovka Breeding and Research Station of V.M. Remeslo Mironovka Institute of Wheat by seed production, technological indicators of grain, flour and bread quality. The new perspective highly productive and ecologically plastic varieties and lines of common wheat are: Yuvivata 60, Zoriana Nosivska, Nosshpa 100, L 3-95, KS 14, KS 22-04. According to representative criteria, the most promising genotypes, which are the main products in Forest-Steppe of Ukraine and high-quality raw materials for bakeries and bioethanol were identified. It was found that technological characteristics of grain, flour and bread of new cultivars and lines of common wheat meet the modern requirements for production of dietetic food and bioenergy products, that is important and relevant in the context of food security in Ukraine.
***Key words**: common wheat winter, ecological plasticity, seed productivity, biological and technological markers.*

ПШЕНИЦА МЯГКАЯ ОЗИМАЯ: ЭКОЛОГИЧЕСКАЯ ПЛАСТИЧНОСТЬ БИОЛОГИЧЕСКИХ И ТЕХНОЛОГИЧЕСКИХ МАРКЕРОВ

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Использование биологических и технологических маркерных признаков для оценки экологической пластичности явилось приоритетом в изучении новых линий и сортов пшеницы мягкой озимой. Доказано, что по стабильности и пластичности на основе признаков семенной продуктивности сорта и линии подразделяются на стабильные, узко- и широко-адаптивные, последние из которых характеризуются широким диапазоном экологической валентности (имеют

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высокую и среднюю вариабельность и гомеостатичность, близкую к нулю варианс стабильности, больше единицы коэффициент экологической пластичности). По параметрам семенной продуктивности и технологическим показателям качества зерна, муки и хлеба идентифицированы наиболее перспективные биотипы пшеницы, основная продукция которых в условиях Лесостепи Украины является качественным сырьем для изготовления хлебопродуктов и биоэтанола.Перспективными высоко продуктивными и экологически пластичными сортами и линиями пшеницы мягкой являются Ювивата 60, Зоряна Носовская, Носшпа 100, Л 3-95, КС 14, КС 22-04. Установлено, что технологические показатели зерна, муки и хлеба новых сортов и линий пшеницы озимой соответствуют современным требованиям производства диетически-пищевых и биоэнергетических продуктов, что является актуальным и приоритетным в контексте продовольственной безопасности Украины.

Ключевые слова: *пшеница мягкая озимая, экологическая пластичность, семенная продуктивность, биологические и технологические маркеры.*

ПШЕНИЦЯ М'ЯКА ОЗИМА: ЕКОЛОГІЧНА ПЛАСТИЧНІСТЬ ЗА БІОЛОГІЧНИМИ ТА ТЕХНОЛОГІЧНМИ МАРКЕРАМИ

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Пріоритетом у вивченні нових ліній та сортів пшениці м'якої озимої була їх екологічна пластичність за біологічними та технологічними маркерними ознаками. Досліджено, що за стабільністю й пластичністю насіннєвої продуктивності сорти та лінії поділяти на стабільні, вузько- та широко-адаптивні, останні з яких характеризуються найширшим діапазоном екологічної валентності (мають високу й середню варіабельність та гомеостатичність, варіанса стабільності в них близька нулю, а коефіцієнт екологічної пластичності більший одиниці). За параметрами насіннєвої продуктивності та технологічними показниками якості зерна, борошна й хліба ідентифіковано найбільш перспективні біотипи пшениці, основна продукція яких в умовах Лісостепу України є якісною сировиною для виготовлення хлібопродуктів і біоетанолу. Перспективними високо продуктивними та екологічно-пластичними сортами та лініями пшениці м'якої є: Ювівата 60, Зоряна Носівська, Носшпа 100, Л 3-95, КС 14, КС 22-04. З'ясовано, що технологічні показники зерна, борошна та хліба нових сортів і ліній пшениці озимої відповідають сучасним вимогам виробництва дієтично-харчових і біоенергетичних продуктів, що є актуальним та пріоритетним у контексті продовольчої безпеки України.

Ключові слова: *пшениця м'яка озима, екологічна пластичність, насіннєва продуктивність, біологічні і технологічні маркери.*

INTRODUCTION

A variety as a genotype or combination of very close genotypes exists in a particular environment and moreover, interacts with the environment, when it confronted with abiotic and biotic factors which were complicated with intensity and time of manifestation (Parent et al., 2016; Moskalets, Moskalets, 2015; Bita, Gerats, 2013). An interaction system «genotype-environment» and «environment-genotype» (biotope genotype) is set, which defines the expression of morphological, biological and qualitative parameters of quantitative characters (Li et al., 2015). For the modern period not only high productivity of varieties, lines and hybrids, but their high ecological adaptability to abiotic and biotic stresses are important (Salari et al., 2015). In this connection, in the less favorable environmental conditions the role of plant genotypes with high environmental stability and plasticity increases substantially while reducing cost anthropic investments (Nezhadahmadi et al., 2013), and as the result it decreases the impact on the dynamic equilibrium. Undoubtedly, it is very difficult to combine high potential productivity and ecological plasticity in the variety (Iwaki et al., 2011), but, as experience of the best breeders in the world shows, this task is urgent (Pena, 1994). It is therefore very important to have varieties with stable implementation of their capabilities (Moskalets, Rybalchenko, 2015). In practical terms, the important features of wheat are seed production and the character of plant response to environmental conditions (Andresen, Gronau, 2007). Manifestation of genotype reaction to environmental factor fluctuation is determined by such specific marker characteristics as indicators of plasticity and stability of the variety.

It should also be noted that the common wheat is differently demanding of growing conditions and is the most capable among other crops in the area of weak implementation of biological potentials. Currently, there is a number of winter and spring wheat varieties with high productivity, high grain quality, and stable expression of economic characters (Tavares et al., 2015; Zhang et al., 2004). Not all varieties have got valuable economic characteristics that meet the requirements for baking and alcohol-distilling using. Thus expansion of gene pool of wheat with such properties is important for national nutritional safety.

The aim of the work was to screen new lines and varieties of hexaploid winter common wheat by ecological and technologic features.

MATERIAL AND METHODS

The objects of this research were new varieties and lines of common wheat (*Triticum aestivum* L.): Yuvivata 60, Zoriana Nosivska, Zirka Nosivska, Nosshpa 100, Daushka, Ariivka, Prydesnianska napivkarlykova, L 4639/96, KS 1, KS 5, KS 7, KS 14, KS 16, KS 17, KS 21, KS 22-02, L 41/95, L 59/95, L 3-95 (Shusteruk et al., 2008, 2013; Moskalets et al., 2009, 2013, 2014, 2015a, 2015b). The study was conducted during the 2008-2016 in forest-steppe (central part of northern right-bank forest-steppe of zone with periodically unstable wetting) – Research field NSRC of Bila Tserkva National Agrarian University. Climate and weather conditions of the ecotope are characterized by moderate continentality. The average air temperature is 6.9°C with significant fluctuations by months. The average annual rainfall is 538 mm, which during the growing season distributed unevenly. In summer period rainfall was much more than in the spring and fall. Probability of years with rainfall less than 350 mm is about 35%. In the experiment a conventional technology for winter grain crops of the region was used. Soil is black humus earth general, deep, medium humic and clay-loam soil, with humus content – 3.5% low-duty hydrolizable nitrogen (by Kornfild) – 140 mobile phosphorus and exchangeable potassium (by Chirikov) –120 and 90 mg/kg of soil, respectively. The soil is characterized by average nitrifiable ability 2–3.5 mg/100 g totally dry soil and average the gross providing compounds P_2O_5 and K_2O. Sowing was carried out in the optimal dates for zone: 15–25 September using string method of seeding with norm of 5.0 million seeds/ha. Years of research have varied by hydrothermal regime: periods of 2011–2013, 2015, 2016 were marked with deficits of rainfall and increased temperatures above average long-term norms during tillering – the tube formation and anthesis – ear formation compared with favorable wet spring period (2008–2010, 2014), which gave opportunity to comprehensively evaluate the adaptability of the studied wheat genotypes to climate forest-steppe and the ability to realize their biological potential.

For coefficient of variation materiality on precipitation of vegetation periods in 2009, 2010, 2011, 2012, 2013 and 2014 were arid (coefficient of variation materiality <1); the coefficient of variation materiality of the temperature regime was close to the average long-term exponent (±0.2–0.8). However, coefficient of variation materiality for hydrothermal coefficient (index) (HTI) during the research approached the value of the index in conditions close to extreme. The most extreme periods 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), that is, in all the years of research May – the period of active plant growth and development was 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 long-term the middle away from the critical values, except for some months of growth for years.

Ecological plasticity of varieties and lines determined by regression coefficient S. Eberhart and V. Russell (1966); their resistance to adverse environmental factors – in terms homeostatic (Hom) (Hanhyldyn, 1979); stress tolerance, index of stability – by I. Langer et al. (1979); coefficient of variation – by G. Lakyn (1990). The response of plant population to growing conditions was evaluated by calculation in terms of productivity and grain quality to the definition of the arithmetic mean, standard deviation, minimum and maximum magnitude and variation. Evaluation of triticale grain and flour as well as wheat bread by the cereal, protein-proteinase complexes, was done in collaboration with V.Ya. Yuriev Plant Production Institute of National Academy of Agrarian Sciences of Ukraine in the grain quality laboratory. Mathematical and statistical analysis was carried out according to B.O. Dospekhov (Dospekhov, 1985) using *Ecxel* 2007 and *Statistica* 6.0.

RESULTS AND DISCUSSION

As determined by long-term studies, some of the wheat varieties and lines such as Yuvivata 60 Zoriana Nosivska, Zirka Nosivska, Nosshpa 100, L 41/95, L 59/95, L 3-95 can in forest-steppe conditions produce high stable yield of high quality grain when grown using scientifically based technologies. Integral indicator, which determines the prospects of plant populations in their competition for ecological niches and mechanisms for coordinating of other components of an ecosystem are the seed production and evaluation of adaptive potential of plants by stability and plasticity, which they were ranged for: narrow and wide-adaptive (Fig. 1).

Stable forming of seed productivity under adverse weather and changing climate conditions (which are characterized by low values of the coefficient of variation, $CV < 10$ % and stress tolerance index, $У_2$–$У_1$; homeostatic $H_{om}>50$; variance stability, $S^2di \geq 1$; ecological plasticity coefficient, $bi \approx 1$) (Moskalets, 2015; Moskalets, Rybalchenko, 2016). Wide-adaptive – ecologically plastic biotypes that are characterized by high variability and average and homeostatyc, variance stability ~ 0, and the coefficient of ecological plasticity larger units. Under adverse environmental conditions such biotypes are able to form highly stable seed production (5,5–6,3 t/ha).

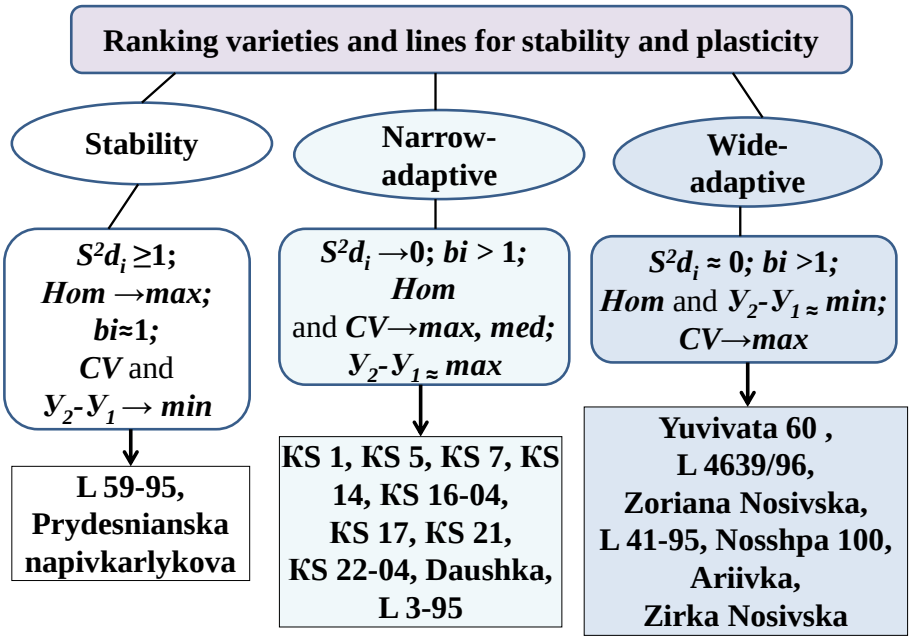

Fig. 1. Ranking varieties and lines of common wheat by stability and plasticity of seed productivity. Coefficients descriptions presented below.

Despite the fact that type of *T. aestivum* is self-pollinating, is worth noting Ariivka, KS 1, Yuvivata 60, L 4639/96, in which the ecological plasticity is related to many linearity, which is the basis of multi variability of synontogenesis that is the high variability of phenetical markers and totality biotypes of different vital state. The narrow adaptive group consists of those which characterized the narrow implementation of adaptive capacity is generally favorable to the optimal range weather and climate, but under adverse factors of influence they sharply lose performance that in them and so is unstable dynamics ($V \geq 20\%$, $H_{om} = 10–20$). The opposite dependence for many years' perennials communities of Carpathians found G.G. Zhilyaev (Zhylyaev, 2005), in which ability to reproduce is a constant and determined largely vitality of individuals and partly as age and was depend on environmental conditions.

The above mentioned lines and varieties have high bakery performance, for example, the grain nature makes up 744–800 g/L and vitrescence is 35–78% (flour quality indicators) (Table 1). Analysis of technological indicators of grain revealed that the new biotypes lead to the development of grain consisting of 13.4–15.8% protein, 26.8–36.4% gluten (Table 2). In particular, the flour of all studied new biotypes of winter wheat is first-class due to > 26% gluten content. The minimum indicator values of protein complex were in the Daushka.

Table 1. Marker features of common wheat grain

Variety or line	Grain performance indicators		
	weight of 1000 grains, g	bulk density, g/L	vitrescence, %
Yuvivata 60 (st.)	50 ± 2.4	786 ± 1.6	50 ± .7
KS 14	54 ± 2.2*	757 ± 2.4*	40 ± .9*
Nosshpa 100	50 ± 1.5	790 ± 2.0*	42 ± .8*
Prydesnianska napivkarlykova	51 ± 2.0	744 ± 4.1*	44 ± 1.0*
Zoriana Nosivska	57 ± 2.3*	800 ± 2.3*	50 ± 1.1
Daushka	48 ± 2.5	754 ± 3.1*	35 ± .9*
L 3-95	52 ± 1.9	798 ± 2.5*	46 ± 1.1*
KS 22-04	50 ± 1.3	762 ± 3.6*	47 ± .7*

*hereafter $P < 0.05$ versus control (Yuvivata 60).

Quality of baking industry depends on the dough elasticity. It is determined that the aforementioned biotypes (namely, Prydesnianska Napivkarlykova, KS 22-04, Ariivka, Yuvivata 60, L 4639/96, and KS 17) are characterized by dough elasticity of 71–100 mm, which eventually positively reflects on the total baking assessment of 7.5–9.0 points (Table 3, Fig. 2). Experimentally it was shown that the content of 'raw' protein for all studied grain genotypes varies insignificantly (except for sort Daushka where this indicator is only 1.0% although this is within the error relative to Yuvivata 60).

The quality of gluten as a combination of physical properties: elasticity, flexibility and extensibility is one the important characteristics of wheat grain quality. The resistance to compression deformation of gluten of these wheat varieties and lines (55–120 conventional units.) is much higher than that of the common wheat Yuvivata (–102 cond. u.). Although the grain of all studied genotypes by the resistance to compression deformation of gluten belongs to the I, II, and III quality group. The grain is characterized as 'good', 'satisfactorily weak', 'unsatisfactorily weak' one. It can be improved with oxidizing supplements which change gluten (Guzmán et al., 2011).

Figure 2. Ear and bread of sort and lines of common wheat: *A* – Daushka; *B* – Nosshpa 100; *C* – L 3-95; *D* – Yuvivata 60; *I* – Zoriana Nosivska; *F* – Prydesnianska napivkarlykova; *G* – KS – 14; *H* – KS-22-04.

Table 2. Special (technological) indicators of grain quality of winter common wheat by protein-proteinase complex

Variety, line	Raw protein content, %	Raw gluten content, %	Dough extensibility, mm	Dough elasticity, mm	Resistance to compression deformation (H^{MDG} def, c.u.)	Flour strength, u.a.
Yuvivata 60	14.2 ± .50	29.6 + .50	82 ± 2.50	53 ± 2.70	102 ± 2.02	272 ± 3.40
KS 14	14.0 ± .10	36.5 ± .70*	82 ± 1.30	69 ± 1.80*	74 ± 0.87*	260 ± 5.61*
Nosshpa 100	14.6 ± .20	23.5 ± .20	103 ± 4.60*	45 ± 2.20*	95 ± 1.5*	177 ± 2.09*
Prydesnianska Napivkarlykova	14.5 ± .30	28.5 ± .10*	84 ± 1.70	75 ± 2.30*	70 ± .66*	216 ± 4.02*
Zoriana Nosivska	15.0 ± .10*	23.5 ± .90*	78 ± 2.20	100 ± 3.50*	120 ± 2.12*	281 ± 3.15*
Daushka	13.2 ± .20*	36.5 ± 1.10*	69 ± 1.10*	58 ± .60*	75 ± 1.34*	214 ± 5.77*
L 3-95	15.8 ± .30*	28.0 ± .50*	62 ± .70*	57 ±2.40*	55 ± 3.05*	137 ± 6.03*
KS 22-04	14.1 ± .40	23.0 ± .80*	93 ± 1.40*	71 ± 1.90*	65 ± 2.11*	229 ±1.39*

Note: hereafter * – $P < 0.05$ versus control (Yuvivata 60).

It should be noted that weak gluten has high extensibility, minimum elasticity, and flows quickly.

Table 3. Average indicators of quality of winter common wheat bread

Variety, line	Volumetric bread output of 100 g of dough, cm^3	Total baking rating, points
Yuvivata 60	590.5 ± 6.5	8.7 ± .6
KS 14	540.9 ± 2.3*	5.7 ± .5*
Nosshpa 100	560.3 ± 3.5*	6.5 ± .4*
Prydesnianska Napivkarlykova	630.6 ± 6.2*	9.2 ± .1
Zoriana Nosivska	560.5 ± 5.9*	7.5 ± .7
Daushka	510.2 ± 4.4*	5.4 ± .9*
L 3-95	570.7 ± 7.2*	7.5 ± .1*
KS 22-04	600.5 ± 2.5*	8.9 ±.1

Note: hereafter * $P < 0.05$ versus control (Yuvivata 60).

Analysis of quality indicators of products made it possible to identify the best bakery common wheat: Prydesnianska Napivkarlykova, Zoriana Nosivska, Yuvivata 60, L 3-95. Bread, made from grain of wheat Daushka, Nosshpa 100 was of worse quality. This is due to low content of raw gluten and increased amylase activity. In addition, low gluten content in grain of that wheat causes poor bread porosity. The bread with the highest total baking rating, points (7.5–9.0 points) was made from wheat flour of Prydesnianska Napivkarlykova, Zoriana Nosivska, KS 22-04 characterizing it as the most promising for baking. L 3-95, KS 22-04, and KS 14 common wheat lines, characterized by high levels of protein-proteinase complex, perform well in bakery products and are also noteworthy.

CONCLUSIONS

Studying new lines and varieties of common wheat by ecological plasticity in particular biological and technological markers revealed that the stability and plasticity of performance seed divided into stable, narrow and wide-adaptive, the latter of which are characterized by the widest range of ecological valence (with high and medium variability and homeostatic, with variance of stability which is close to zero, and with environmental factor plasticity which is greater than one). The new perspective highly productive and ecologically-plastic cultivars and lines of winter hexaploid common wheat by seed production, technological indicators of grain, flour and bread quality are: Yuvivata 60, Zoriana Nosivska, Nosshpa 100, L 3-95, KS 14, KS 22-04 and other. According to representative criteria, the most promising genotypes, which are the main products in forest-steppe of Ukraine and high-quality raw materials for bakeries and bioethanol, were identified. It was found that technological characteristics of grain, flour and bread of new cultivars and lines of common wheat meet the modern requirements for production of dietetic food and bioenergy products that is important and relevant in the context of food security of Ukraine.

It is found that high-performance protein-proteinase and carbohydrate-amylase complexes, and qualitative assessment of bakery products as well as of new varieties and lines of common wheat meet modern requirements for effective production of important dietary food products, which is important and a priority in the context of food security of Ukraine.

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