UDK: 633.11:631.524.84

CONTRIBUTION OF GENOTYPIC FACTORS IN THE GRAIN YIELD DEPENDING ON THE ENVIRONMENTAL CONDITIONS

V. Gerasymenko
Odessa State Agrarian University

It is shown that the genetic growth of a grain yield (GY) is provided with two factors: a biological yield (BY) and a harvest index (HI). Depending on the ecological conditions their contribution can be both positive and negative. The genetic diversity BY is a result of the genotype-environment interaction. The interaction of genotypic factors with ecological conditions permits to consider genetic progress GY as two-step-by-step process, first of which is a creation of the corresponding ecological conditions which provide advantages to new genotypes, and second is a selection of these new genotypes.

Keywords: harvest, wheat, environmental conditions, genotype, genetic progress.

In the hierarchy of the genotypic factors, biological yield (BY) and the proportion or percentage of the output of the useful products from it (factor of the economic suitability in Nychyporovyc - K_{hos} [1] or the harvest index in Donald - HI [2]) are the final factors of economically useful products of the plant. The Nitchiporovich equation describes the relationship between economically useful part of products and genotype factors. For cereals, where economically useful part is the grain yield (GY), this equation is represented as:

$$GY = HI * BY \qquad (1)$$

The equation shows that the genetic progress of the grain yield ultimately determined by these two factors. Determination of their contribution in genetic crop growth depending on the environmental conditions and genotype are important for understanding the selection regularities.

Material and Methods. This work is a continuation of the previous article, in which we investigated the genetic shift of key factors in grain yield of the winter wheat: biological yield and harvest index, depending on the weather conditions in testing years [3]. In this regard, it became possible to use the same experimental material: cultivars of Southwestern region of Ukraine, state tested cultivars and one cultivar from the foreign breeding.- Gaines. Nine cultivars were involved in the study in 1979: Hostianum 237 (1929), Odeska 16 (1952), Bezosta 1 (1959), Odeska 51(1969), Erytrospermum 127 (1977), Odeksa 66 (1979), Odeska napivkarlykova (1980), Obrii (1983), Gaines (1961). 13 cultivars and two advanced breeding lines from the winter wheat breeding program the Plant Breeding and Genetic Institute-National Center of Seed and Cultivar Investigation the were part of the study in 1980-1981 years: Hostianum 237 (1929) , Odeska 3 (1939), Odeska 16 (1952), Bilotserkivska 198 (1955), Odeska 26 (1965), Odeska 51 (1969), Pryboi (1973), Maiak (1973), Odeska 66 (1979), Progres (1980), Salut

(1983) , Odeska 75 (1983), Iuzhnaia Zaria (1983), F1095/ 76 (1983), F1108/77 (1983). A year of realization of cultivars and a year of test for breeding lines are specified in brackets. The experiments were conducted on 5 м^2 plots. The total area in the middle of the plot was 1 m^2. We estimated the biological yield, grain yield, and plant height.

Each set of cultivars, that were created in the different periods of breeding, were grouped into three categories, which, for this purpose, will be called old (I), middle (II), and new (II) (Table 1). The first group includes the cultivars established in the period from 1929 to 1959, the second - from 1960 to 1979, and the third group - since 1980.

The algorithm of evaluation of the genotypic factors contribution in grain yield was obtained from the previously mentioned Nitchiporovich equation. Thus, genetic progress grain yield (ΔGY) is the difference between genotypes of the following period (GY_2) selection and the initial period (GY_1): $\Delta GY = GY_2 - GY_1$. Using the expression 1, GY_1 and GY_2 can be written as:

$GY_1 = HI_1 * BY_1$ (2), and $GY_2 = HI_2 * BY_2$, (3)

where: HI_1 and BY_1 are harvest index and biological yield of old cultivars from the initial period of breeding and HI_2 and BY_2 are harvest index and biological yield of new varieties in the next season. To determine the rates of the grain yield caused by biological harvest only assume that $HI_1 = HI_2$, then: $\Delta GY_{BY} = GY_2 - GY_1 = HI_2 * (BY_2 - BY_1)$. Similarly, accepting that $BY_2 = BY_1$ then find the gain caused by harvest index: $\Delta GY_{HI} = BY_2 * (HI_2 - HI_1)$. The correctness of the expressions 2 and 3 confirmed by equality: $\Delta GY = \Delta GY_{BY} + \Delta GY_{HI}$.

Results. In the previous work the intensity of the weather conditions in each year of study was defined by comparing the values of the biological yield, grain yield and plant height in the test set of cultivars. 1980 was the most unfavorable year. 1979 occupied a middle position, and 1981 was the most favorable one.

Although, the absolute values of features of the plant height and the harvest index in the set of cultivars vary depending on the weather conditions during the test-year, the differences between the groups are retained (Table 1). Cultivars of each following group of plants have a lower height and a higher harvest index. This corresponds to the general pattern of the selection. As a contrast to these traits, the value of the biological yield depends on the environmental conditions. For example, 1980 was the worst year in terms of its conditions. The significant differences in the biological yield were between all groups of cultivars. The maximum expression of this trait were in old cultivars - 15.0 t/ha, 13.7 t/ha in the average, and the lowest 12.7 t/ha in new semi-dwarf cultivars. Due to the average conditions in 1979, the biological differences between the old crop cultivars did not exceed the average LSD = 0.79 t/ha, therefore they were unreliable. However, both groups were significantly more productive for biomass compared to new cultivars. The groups of cultivars did not differ on this trait in the most favorable 1981 year. It is clear that the differences in the expression of the biological crop in different years were caused by genotypic specificity of the cultivars' reaction to the conditions in the year that determines the appropriate type of genotype-environment interaction.

The genotype-environment interaction also can be stated for a grain yield. Thus, in 1980 and 1981 each next in the time group of cultivars showed a higher grain yield: I <II <III. The genotype-environment interaction, in 1979 caused the change in the ranks of groups of cultivars and this sequence was impaired. The middle group of cultivars became the most productive: I <II> III.

Genetic increase of the grain yield is determined by the contribution of the genotypic factors: the biological yield and the harvest index, which in 1980, in the group of middle cultivars, was 0.54 t/ha, or 14.9 %. Increasing of the harvest index from 24.1 % in group of the old cultivars to 30.4 % in the group of middle ones led to the increase of the grain yield by 0.94 t/ha (26%), but the reduction in the biological yield from 15.0 t/ha to 13.7 t/ha, which caused a drop in the grain yield of 0.4 t/ha (-10.9 %) , which together resulted in its growth by only 0.54 t/ha. Increased harvest index in the group of new cultivars to 34.7% provided increase in grain yield 1.59 t/ha, but further reduction of biological yield to 12.7 t/ha reduced increase of the grain yield compared with the middle group of cultivars by twice, by 0, 80t/ha. The genotypic factors’ total contribution into the growth of the grain yield by the new cultivars was 0.79 t/ha.

Table 1

The contribution of genotype factors into the grain yield of the group of soft winter wheat depending on a year testing conditions

Years	Groups of cultivars		HP (cm)	BY (t/ha)	HI (%)	GY (t/ha)	ΔGY		Genotype factors contribution to the grain yield (ΔGY)			
									BY		HP	
							t/ha	%	t/ha	%	t/ha	%
1979	I,. old		119,6	15,6	18,7	2,92	0	0	0	0	0	0
	II,. middle		106,8	15,3	28,4	4,34	1,42	48,6	-0,09	-3,1	1,51	51,7
	III,. new		80,4	13,4	30,8	4,13	1,21	41,4	-0,68	-23,3	1,89	64,7
	Middle		102,3	14,8	26,0	3,80						
	$LSD_{(0,05)}$	I, II	2	0,79	1,6	0,96	0,96	-	-	-	-	-
		I, III	2,1	0,84	1,7	1,02	1,02	-	-	-	-	-
		II, III	1,8	0,7	1,4	0,85	0,85	-	-	-	-	-
1980	I,. Old		138,1	15	24,1	3,62	0	0	0	0	0	0
	II,. Middle		99,7	13,7	30,4	4,16	0,54	14,9	-0,4	-10,9	0,94	26
	III,. New		80,9	12,7	34,7	4,41	0,79	21,8	-0,8	-22,1	1,59	43,9
	Middle		106,2	13,8	29,7	4,06						
	$LSD_{(0,05)}$		3,4	0,8	1,5	0,33	0,33	-	-	-	-	-
1981)	I,. Old		147	20,6	21,0	4,33	0	0	0	0	0	0
	II,. Middle		116	20,5	29,2	5,99	1,66	38,3	0	0	1,66	38,3
	III,. New		87	20,6	32,9	6,78	2,45	56,6	0	0	2,45	56,6
	Middle		116,7	20,6	27,7	5,70						
	$LSD_{(0,05)}$		4,6	1,5	1,9	0,6	0,6	-	-	-	-	-

The feature of 1979 is the lower grain yield of the new group of cultivars compare to the middle group. At the same time, the harvest index showed the gain of the grain yield in the group of new cultivars by 1.89 t/ha (64.7%), while in the middle group of cultivars by only 1.51 t/ha (51.75%). However, the biological yield of middle cultivars (15.3 t/ha) remained on the level of the old group (15.6 t/ha). The difference between them is not significant, and, therefore, the negative contribution of the genotypic factor in grain yield is not significant: -0.09 t/ha. At the same time, reduced biological yield in the group of new cultivars has resulted in a reduction of the grain yield by -0.68 t/ha., that neutralized its gain in the harvest index. Ultimately, total grain yield and its growth in the group of the new cultivars was lower than in the group of middle ones. With the improvement of the environmental conditions in 1981, the genetic progress of the grain yield was secured only by the harvest index because the differences of the genotypes in the biological crop this year was not evident.

Type	Year	# of irrigation	GY	BY▼	HI▼	Genotype factors contribution to the grain yield ▼ (ΔGY)

The influence of the other type of the environmental conditions on the value of the genotypic factors' contribution on the grain yield we will show using the data Singh R.P. at all [4]. In their experiments, they compared the isogenic Rht lines of nearly ten cultivars of wheat (Triticum aestivum L.) and six cultivars of durum wheat (T. turgidum L.) with their tall analogues in three types of soil moisture for two years in northwestern Mexico. Variations in soil moisture were created carrying one, two and six irrigations during each growing season. In this paper, the authors aimed to show that in regions with unfavorable climate conditions and low levels of agriculture, which is a characteristic of poor countries, it is advantageous to cultivate tall cultivars, which in harsh conditions show the same grain yield as a dwarf cultivars but much larger crop straw, which in these countries occupies an important place in the diet of animals. Since the publication presents the data of the grain and straw harvest, we calculated the biological yield and its contribution to the harvest index in the grain yield (Table 2).

Table 2

The genotype factors contributions into the grain yield of soft and durum wheat depending on the irrigation and a year conditions. (Singh R.P. at all[4])

			D	T	Δ	D	T	Δ	D	T	Δ	HI	BY
T. aestivum	1996/97	1	2235	2228	7	7829	8477	-648	28,5	26,3	2,3	192	-185
		2	4309	3834	475†	13168	12672	496	32,7	30,3	2,5	313	162
		6	6590	5623	967†	16768	16066	702	39,3	35/0	4,3	691	276
	1997/98	1	4164	3599	565†	10447	9757	690	39,9	36,9	3	290	275
		2	5052	4594	458†	12249	12372	-123	41,2	37,1	4,1	509	-51
		6	6706	5207	1499†	15700	14481	1219	42,7	36.0	6,8	978	521
T. turgidum	1996/97	1	1821	1918	-97	6921	7575	-654	26,3	25,3	1	75	-172
		2	4352	3999	353$^{\#}$	13555	13421	134	32,1	29,8	2,3	310	43
		6	5962	5529	433$^{\#}$	16802	16905	-103	35,5	32,7	2,8	470	-37
	1997/98	1	3597	3570	27	8685	9821	-1136	41,4	36,4	5,1	497	-470
		2	4796	5210	-414$^{\#}$	11110	12363	-1253	43,2	42,1	1	127	-541
		6	7130	5672	1458†	15578	14952	626	45,8	37,9	7,8	1171	287

$^{\#}$, † – confirmed at P = 0.01 and P = 0.001, accordingly. ▼ – we calculated

As in our experiment, the gain in the crop yield is determined by both genetic factors. In this case, the contribution of the harvest index is always positive, but the contribution of the biological yield fluctuates between negative in unfavorable conditions and positive in favorable ones. The negative contribution to the biological yield in the unfavorable conditions is explained by the lack of low-growing genotype in the grain yield and the high-growing one. But in the favorable conditions first mentioned genotype has an advantage and a positive contribution to the grain yield. Therefore, we can state the presents of the genotype-environment interaction based on the ability of the biological yield in the system of tall-dwarf genotypes.

The uniqueness of Singh R.P with co-authors data is that they provide an opportunity to compare the tall and dwarf genotypes by their response to the environmental conditions in its biological crop. For this purpose we used one of the kinds of regression methods to assess the ecological plasticity – the regression of genotype-standard [5]. In this method the ecological plasticity of the genotype is estimated based on the regression coefficients: the y-intercept estimates the adaptability of the genotype and the regression coefficient estimates its response to the environmental conditions.

The estimation of the parameters of ecological plasticity separately in a sample of soft wheat genotypes (Triticum aestivum L.) and durum wheat (T. turgidum L.) showed that the parameters of the reaction of dwarf genotypes to environmental conditions were statistically significant. The Student Coefficient of the sample genotypes of soft wheat was 12.97* and 13.03$^{\#}$ in the sample of durum wheat genotypes (Table 3). In both cases, their values were greater than one, that is higher than these figures tall genotypes but the excess was not significant. The y-intercept of dwarf genotypes in both types of wheat is negative and statistically insignificant. Combining of the two samples did not improve the statistical significance of the parameters. This is due to the fact that the original samples differed among themselves, although not significantly, both in the value of the y-intercept and the regression coefficients. In the combined sample, this led to a "blurring" of the correlation field and, as a result, decreasing of the likelihood of the parameters. Thus, the value of the y-intercept in a set of lines of durum wheat is 1.36 times higher than in the set of lines of the soft wheat (2056.5 / 1507.2 = 1.36). Therefore, to eliminate the effect of the differences between samples regarding to the y-intercept the data was centered in each sample relative to the mean values of the traits in the combined sample.

The centering does not change the relative position of the data in the sample, consequently, the regression coefficient retains its original value, but much improves the statistical significance of the estimated parameters.

Thus, the y-intercept that was determined on the basis of the centered sample is -1759,0 and t-test - 2.48 *, which is likely at the level of significance P = 0.05. The negative value of the y-intercept of the dwarf genotypes suggests that their biological yield in all environmental conditions is less then the biological yield of tall lines caused by their reduced adaptability. The regression coefficient increased to $20.52^{\#}$. It is important that its value is statistically greater than the value of the regression line of tall genotypes - 1,0, (t = 2.54*). This means that the dwarf genotypes have a greater response in the biological yield to the environmental conditions compared to the tall lines.

Table 3

The parameters of ecological plasticity of the tall (T) and dwarf (D) genotypes of soft and durum wheat by biological yield

Various peer grouping	Parameters	Valuation results	Standard Error	T statistics
Biological Yield				
Triticum aestivum L.	$A_{(D)}$	-1507, 2	1118,8	-1,35
	$A_{(T)}$	0.0	-	-
	$B_{(D)}$	1,154	0,0890	$12,97^{\#}$
	$B_{(T)}$	1.000	-	-
	$B_{(D)}$ - 1	0,154	-	1,73
T. turgidum L.	$A_{(D)}$	-2056,5	1120,1	-1,84
	$A_{(T)}$	0.0	-	-
	$B_{(D)}$	1,133	0,0869	$13,03^{\#}$
	$B_{(T)}$	1.000	-	-
	$B_{(D)}$ - 1	0,133	-	1,53
Cumulative sample *Triticum aestivum* L. +	$A_{(D)}$	-1696,4	911,1	-1,86
	$A_{(T)}$	0.0	-	-

T. turgidum L.	$B_{(D)}$	1,136	0,0716	$15,88^{\#}$
	$B_{(T)}$	1.000	-	-
	$B_{(D)}$ - 1	0,136	-	1,99
Cumulative centered sample *Triticum aestivum* L. + *T. turgidum* L.	$A_{(D)}$	-1759,0	708,0	-2,48*
	$A_{(T)}$	0.0	-	-
	$B_{(D)}$	1,141	0,0556	$20,52^{\#}$
	$B_{(T)}$	1.000		-
	$B_{(D)}$ - 1	0,141	-	2,54*
Grain Yield				
Cumulative centered sample *Triticum aestivum* L. + *T. turgidum* L.	$A_{(D)}$	-660,6	478,0	-1,38
	$A_{(T)}$	0.0	-	-
	$B_{(D)}$	1,268	0,108	$11,73^{\#}$
	$B_{(T)}$		-	-
	$B_{(D)}$ - 1	0,268	0,110	2,44*

A – y-intercept in the regression equation , adaptability factor; B – the regression coefficient of the biological yield to the index of environment conditions, factor of the genotype reaction to environment conditions, * - statistically significant at P = 0.05.

Such combination of the parameters of the ecological plasticity leads to the advantage of tall over dwarf genotypes in the biological crop in relatively unfavorable environment (Fig. 1). However, due to the plants' higher reaction in better environmental conditions, they become equal with the tall genotypes' biological yield, and exceed it with the following improvement of the environmental conditions. The equality in the biological yield of dwarf and tall lines is achieved at the environmental conditions index value of 12435 kg/ha. Worsening of the environment conditions and the index decrease explains the worse biological yield of the dwarf genotypes compared to the biological yield of the tall genotypes, and their negative contribution to the grain yield. When the environment conditions improve and the index of the environmental conditions increases from the determined value the dwarf genotypes exceed the tall ones in the biological yield, and their contribution in the grain yield is positive.

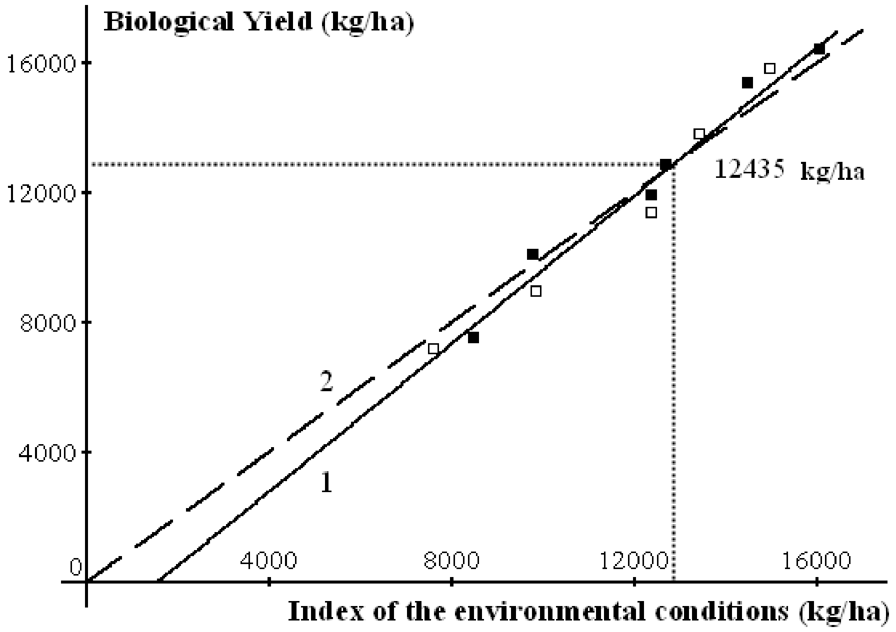

Fig. 1. Dependance of the biological yield of dwarf and tall genotypes from the environmental conditions index.

■ - The line of the soft wheat
□ - the durum wheat lines

The advantage of dwarf over tall genotypes in reaction of biological yield to the environmental conditions led to their advantage in grain yield reaction. Thus, the value of grain yield reaction to the environmental conditions for dwarf genotypes was 1.268 t/ha. In the tall genotypes this parameter exceeded by 0.268, which is as twice as much than the increase in the biological yield, which is 0.141.. Obviously, the additional increase in the grain yield is a reaction specified by the harvest index, but statistically it was not possible to prove.

There is an opinion that the genetic progress of the wheat grain yield could be explained by harvest index exclusively; and it is widely thought that the plant breeding is unable to shift the biological yield significantly. For the first time this conclusion was formulated by V. Medinets [6]. Later it was confirmed by several experiments in genetic progress of the wheat crop. However, the experimental data proved that the value of the genetic diversity of the biological yield is determined by the genotype-environment interaction.

The feature of the experiments evaluating the genetic progress of the grain yield is the artificially created and most favorable environment conditions for the experiments.

Effect of agronomic factors such as: irrigation, mineral nutrition, protection from pests and diseases, use of supporting grid of lodging in these experiments, was so strong that leveled the weather differences over the years. This is so narrowed the differences in the conditions of the experiments that we can talk about their essential absence. As a result, the environment, and the genotype-environment interaction were not studied by the researchers of the mechanisms of genetic progress of the wheat crop.

The results of our research confirmed the leading role of the environmental conditions in the genetic progress of the wheat yield. In retrospective view, the display of the factors of the genotype-environment interaction associated with the improved environmental conditions as a result of the intensified production technologies. In a primitive system of agriculture the population of local cultivars was most adaptable. Although, the mutation process evolved the genotypes with the higher harvest index. Although, the mutation process emerged the genotypes with the higher harvest index, they were not subject of the selection, and were behind in biological and grain yield compared to the landraces. But as soon as the cultivation conditions improved, the new genotypes obtained an advantage in the specified earlier factors and became the subjects of the selection. Kulshresta and Jan [7] stated the dependence of the plant breeding from the level of the cultivation technology. In their opinion, the first successful wheat breeding in Europe is related to improved cultivation, and absents of the results in the plant breading in India with its undeveloped farming.

Conclusion

1. Two factors led to the genetic increase in the grain yield: the biological yield and the harvest index. Their contribution could be positive or negative depending on the environmental conditions. The type of the biological yield contribution to the grain yield is determined by the genotype-environment interaction between the tall and dwarf genotypes.
2. The genetic variety of the biological yield appears as a result of the genotype-environment interaction, and determined by the differences of the tall-dwarf genotypes in the reaction of the biological yield to the environment.
3. The interaction of the genotype factors with the environmental conditions allows to consider the genetic progress of the grain yield as a two-step process. First step is a development of the appropriate environmental conditions, that led to the advantages for the new genotypes,; and the second step is a selection of the new genotypes.

References

1. Nycyporovyc A.A. Photosynthesis and the theory of high yields, XV Timiryazevskoye chteniye./ A.A. Nycyporovyc. – Moscow. USSR Academic Press, 1956. – 96 p.(In Russian)
2. Donald C.M. In search of yield / C.M. Donald // J. Aust. Inst. Agric. Sci. - 1962. Vol. 28. - P. 171-178.
3. Gerasymenko V.P. Main factors’ genetic alteration of the soft winter wheat yield. / V. Gerasymenko // Scientific-technical Bulletin of All-Union Breeding-Research Institut. – 1988. Vol. 68, №2. (In Russian)
4. Singh R.P. Grain yield and other traits of tall and dwarf isolines of modern bread and durum wheat / R.P. Singh, J. Huerta-Espino, S. Rajaram, J. Crossa // Euphytica. - 2001. Vol. 119. - P. 241-244.
5. Ostroverhov V. Comparative evaluation of ecological plasticity of agriculture cultivars. / V. Ostroverhov // Genetic of quantitative factors of agriculture plants. Editor D. Belyaev, Moscow Science, 1978: P. 128-141. (In Russian)
6. Medinets V.D. The importance of estimate of grain ratio in the total cultivar yield/ V.D. Medinets // Breeding and seed production. Bimestrial science and production journal. USSR Ag. Dept. – 1961. Vol. 26, №5. – P 21-24. (In Russian)
7. Kulshrestha V.P. Eighty years of wheat breeding in India: Past selection pressures and future prospects / V.P. Kulshrestha, H.K. Jain // Z Pflanzenzuchtg. - 1982. Vol. 89. - P. 19-30.

ВКЛАД ГЕНОТИПИЧЕСКИХ ФАКТОРОВ В УРОЖАЙ ЗЕРНА ПШЕНИЦЫ В ЗАВИСИМОСТИ ОТ УСЛОВИЙ

В.Ф. Герасименко

Одесский государственный аграрный университет

Показано, что генетический рост урожая зерна (GY) обеспечивается двумя факторами: биологическим урожаем (BY) и уборочным индексом (HI). В зависимости от условий среды их вклад может быть, как положительным, так и отрицательным. Генетическое многообразие BY проявляется в результате взаимодействия генотип-среда. Взаимодействие генотипических факторов с условиями среды разрешает рассматривать генетический прогресс GY как двух шаговый процесс, первым из которых есть создание соответствующих условий среды, которые обеспечивают преимущества новым генотипам, а на втором шаге отбор этих новых генотипов.

Ключевые слова: урожай, пшеница, условия среды, генотип, генетический прогресс

ВНЕСОК ГЕНОТИПОВИХ ЧИННИКІВ В УРОЖАЙ ЗЕРНА ПШЕНИЦІ В ЗАЛЕЖНОСТІ ВІД УМОВ СЕРЕДОВИЩА

В.П. Герасименко

Одеський державний аграрний університет

Показано, що генетичний ріст урожаю зерна (GY) забезпечується двома чинниками: біологічним урожаєм (BY) і збиральним індексом (HI). В залежності від умов середовища їх внесок може бути, як позитивним, так і негативним. Генетичне різноманіття BY проявляється в результаті взаємодії генотип-середовище. Взаємодія генотипових чинників з умовами середовища дозволяє розглядати генетичний прогрес GY як двокроковий процес, першим з яких є створення відповідних умов середовища, що забезпечує переваги новим генотипам, другим – добір цих нових генотипів.

Ключові слова: урожай, пшениця, умови середовища, генотип, генетичний прогрес