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Stability and Plasticity of Collection Samples of Durum Spring Wheat in the Forest-Steppe Conditions of Ukraine

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Abstract: When working with collection material, one of the main problems is the study of most of the samples in a cycle of three years and the annual partial renewal of the set under study. Therefore, only a part of the varieties can be directly compared with each other in terms of ecological stability, and the main grouping has to be carried out by comparing the behavior of samples with standard varieties under conditions of different years. Even well-studied varieties are not always suitable for such comparisons. When selecting the starting material for breeding, it is important not only to find forms with a high level of manifestation of quantitative traits, but also to minimize this level under unfavorable conditions for plant growth and development. The purpose of our research was to determine the stability and plasticity of collection samples of spring durum wheat of various ecological and geographical origins. Over the years of the research, the yield averaged 330.3 g/m^2 and varied from 434.3 g/m^2 (max) in 2015 to 188.5 g/m^2 (min) in 2018. This indicates that the genotype and contrast weather conditions of the years significantly affect the yield of collection samples of spring durum wheat. Stable and plastic collection samples of spring durum wheat were identified for yield: 193 THKNEE 8 (Mexico) (b_i = 1.02, S^2d_i = 0.11), ARN AAZ-1.040 YRC-4M (Mexico) (b_i = 1.35, S^2d_i = 0.12), SHAG 21 / CASCA (Mexico) (b_i = 1.07, S^2d_i = 0.23), Hordeiforme 13-07 (Ukraine) (b_i = 2.11, S^2d_i = 0.31). According to the results of our research, it was found that the highest grain weight per spike (1.90 g) was in the sample Voronezhskaya 11 (Russia), and the lowest value was in the sample Damsinskaya yantarnaya (Kazakhstan) (1.57 g). Among the plastic and stable collection samples by the grain weight per spike, the following samples were distinguished: DUN / MUSK 1 (b_i = 3.45; S^2d_i = 0.07), SHAG 9 / BBUTO / 7 (b_i = 1.61; S^2d_i = 0, 05), CASM 3 // SRN 3 ASAIH 15 (b_i = 1.47; S^2d_i = 0.00), GREEN / SOMO (b_i = 1.35; S^2d_i = 0.01) (Mexico), Lilek (Russia) (b_i = 0.92, S^2d_i = 0.03), MAGH 72 FUTO ALG 86 (Mexico) (b_i = 0.75, S^2d_i = 0.01), YAZI 13 (Mexico) (b_i = 0.12, S^2d_i = 0.07).

Keywords: Spring Durum Wheat, Collection Samples, Stability Variance, Plasticity, Yield, Grain Weight per Spike

1. Introduction

When selecting the starting material for breeding, it is important not only to find forms with a high level of manifestation of quantitative traits, but also to minimize this level under unfavorable conditions for plant growth and development [1].

The main task of breeding grain crops is to increase the adaptive potential of newly created varieties while maintaining the achieved yield level [2]. The adaptability of the variety is one of its most important properties; therefore, considerable attention is paid to this trait in breeding programs in most countries of the world [3, 4]. The experience of domestic and world breeding testifies to the fact that in the process of creating wheat varieties, the availability of starting material is of decisive importance, which combines productivity with adaptive traits [5, 6]. Thus, the issues of ecological adaptability and plasticity of individual genotypes occupy an important place in the development of selection [7, 8].

Determination of the optimal type of plants capable of stably realizing their potential and at the same time adequately responding to changes in growing conditions constantly attracts the attention of scientists [9−11].

The method for assessing the ecological plasticity and variance of its stability of varieties based on the analysis of variance and regression makes it possible to assess their reactions under different growing conditions [12, 13].

The study of breeding material in the years that are different in hydrothermal conditions provides information on the characteristics of the reaction of genotypes to changing environmental conditions [14−16]. The concepts of "stability" and "plasticity" are interpreted differently in the scientific literature, which complicates the assessment of these parameters and their use in selection [17−19].

The ecological plasticity of a selection trait of a sample is its average response to changes in environmental conditions. The stability variance of the selection trait of the sample is the deviation of empirical data in specific environmental conditions from the ecological plasticity of the selection trait, that is, from the average response to a change in growing conditions. As a factor "conditions" can be years of research, zone, fertilizer doses, plant density, sowing dates, etc. [20].

The regression coefficient (b_i) characterizes the average reaction of the selection trait of the sample to changes in environmental conditions and shows the plasticity of the selection trait, which makes it possible to predict the change in the trait studied in different years.

The stability variance (S^2d_i) indicates how reliably the selection trait of a sample corresponds to the plasticity estimated by the regression coefficient (b_i). The stability of the manifestation of the trait level is expressed at low coefficients of regression (plasticity) and low fluctuations in their stability variance.

The high sensitivity of individual varieties to unfavorable growing conditions often narrows the area and limits their overall distribution. Based on the testing of spring durum wheat varieties in different growing regions, it is possible to predict a genetically determined degree of yield stability (adaptability to growing conditions) [21].

Since the weather conditions become more and more changeable every year, the creation of new varieties with a high level of productivity, regardless of growing conditions, remains relevant up to now. The application of ecological plasticity and stability is widely used in such agricultural crops as winter bread wheat [22], spring bread and hard wheat [23, 24], winter and spring barley [25−28], soybean [29], winter triticale [30], oats [31, 32], corn [33], bean [34], etc. The stability of the breeding trait of sample is the deviation of empirical data in each environmental condition from the ecological plasticity of the breeding trait, that is, from average response to changing growing conditions.

The aim of the study was to determine the stability and plasticity of collection samples of spring durum wheat of various ecological and geographical origins.

2. Materials and Methods

The research was carried out during 2015–2018 at the Spring Wheat Breeding Laboratory of the V. M. Remeslo Myronivka Institute of Wheat of National Academy of Agrarian Sciences of Ukraine.

There were studied 104 collection samples of different ecological and geographical origin. The collection samples of spring durum wheat originate from 6 countries and belong to five varieties (var. *hordeiforme*, var. *leucurum*, var. *leucomelan*, var. *melanopus*, var. *valenciale*). Most of them were from Mexico 74 (71.2%), the others were from Ukraine 12 (11.5%), Kazakhstan 9 (8.7%), Russia 5 (4.8%), Canada 3 (2.9%) and France 1 (0.9%).

Sowing was carried out in optimal terms on the experimental fields of breeding crop rotation using the SKS-6-10 seeder in four replications. The accounting area of the plot is 1 m^2. The standard was the variety Spadshchyna which was sown every 25 samples. Stability and plasticity parameters were determined by the method of Eberhart, Russell [35]. Statistical indices were calculated according to Dospekhov [36].

3. Results

During period of the study (2015-2018), the weather conditions differed from the average annual indicators in terms of temperature, amount of precipitation and their distribution by months.

The hydrothermal coefficient (HTC) proposed by Selyaninov [37] is used for comprehensive characterization of the area's moisture content and its temperature regime. The period from sowing to germination was characterized by excessively humid conditions in 2015 (HTC = 4.40), optimal moisture conditions in 2017 (HTC = 1.27), dry conditions in 2016 (HTC = 0.90), very dry conditions in 2018 (HTC = 0.12). The period from germination to booting was characterized by optimal moisture conditions in 2015, 2016, 2017, and 2018 (HTC = 1.16; 1.10; 1.43; 1.07, respectively). The period from booting to heading was characterized by excessive moisture in 2016 and 2018 (HTC = 2.20 and 2.35, respectively) and optimal conditions in 2015 and 2017 (HTC = 1.10 and 1.05, respectively).

Therefore, this gave us the opportunity to evaluate collection samples of spring durum wheat in terms of adaptability and to identify the best genotypes.

Over the years of the research, the yield averaged 330.3 g/m^2 and varied from 434.3 g m^2 (max) in 2015 to 188.5 g/m^2 (min) in 2018. This indicates that the genotype and contrast weather conditions of the studied years significantly affect the yield of collection samples of spring durum wheat.

The best collection samples of spring durum wheat with high regression coefficient b_i and the most response to changes in environmental conditions in terms of yield are presented (Table 1): Hordeiforme 13-07 (b_i = 2.11), Kharkivska 27 (b_i = 1.97) (Ukraine), NDER2 RASCON 22-1Y (b_i = 1.61), Hordeiforme 13-08 (b_i = 1.51) (Ukraine), Lilek (Russia) (b_i = 1.47), YAZI 13 (Mexico) (b_i = 1.45), SHAG 8.2B-OYRC (b_i = 1.40), ARN AAZ-1.040 YRC-4M (b_i = 1.35), COTE / ASAISA // FILLO 3 (b_i = 1.30), Adomar 7 (b_i = 1.29).

Table 1. *Plasticity coefficients and stability variances by yield of collection samples of spring durum wheat (2015-2018).*

Variety	Origin	Yield, g/m^2				Mean, x_i	b_i	S^2d_i
		2015	2016	2017	2018			
Spadshchyna (standard)	Ukraine	494.3	411.0	291.0	181.0	344.3	1.15	0.11
Hordeiforme 13-08	Ukraine	634.3	464.0	445.0	157.0	425.1	1.51	1.19
Hordeiforme 13-07	Ukraine	698.6	556.0	308.0	135.0	424.4	2.11	0.31
Lilek	Russia	557.1	620.0	206.0	293.0	419.0	1.47	1.57
ARN AAZ-1.040 YRC-4M	Mexico	575.7	536.0	311.0	252.0	418.7	1.35	0.12
Kharkivska 27	Ukraine	654.3	577.0	240.0	180.0	412.8	1.97	0.45
COTE / ASAISA // FILLO 3	Mexico	457.3	598.1	378.6	194.0	407.0	1.30	0.76
Omskiy izumrud	Russia	410.0	559,0	363,0	268,0	400.0	0.86	0.67
Adomar 7	Mexico	605.7	458.0	270.0	258.0	397.9	1.29	0.71
MUSK DUKEN	Mexico	408.6	354.0	507.0	310.,0	394.9	0.10	1.06
143 KIRKI 9	Mexico	457.1	486.0	500.0	134.0	394.3	1.12	1.97
193 THKNEE 8	Mexico	517.1	445.0	359.0	231.0	388.0	1.02	0.11
Bezenchukskaya 105	Russia	430.0	561.0	278.0	280.0	387.3	0.98	0.79
Neodur	France	477.1	433.0	410.0	228.0	387.0	0.84	0.33
NDER2 RASCON 22-1Y	Mexico	671.4	393.0	295.0	165.0	381.1	1.61	1.61
SHAG 8.2B-OYRC	Mexico	592.8	444.0	264.0	211.0	378.0	1.40	0.55
SHAG 21 / CASCA	Mexico	441.4	521.0	320.0	224.0	376.6	1.07	0.23
YAZI 13	Mexico	446.3	587.6	298.4	164.0	374.1	1.45	0.68
211 TIANES	Mexico	512.8	377.0	351.0	250.0	372.7	0.81	0.40
SHAG 9 / BBUTO / 7	Mexico	455.7	424.0	398.0	213.0	372.7	0.84	0.34
Mean xj*	-	434.3	418.6	280.0	188.5	330.3	-	-
environmental index lj**	-	103.9	88.2	-50.3	-141.8	-	-	-
LSD_{05}	-	3.53	3.36	2.79	2.28	-	-	-

[*] xj is average for 104 collection samples; **lj is the difference between the average yield of all varieties for the year conditions to the total average yield for all experiments; LSD is the least significant difference

The regression coefficient close to 1.0 was a feature for the following samples: Bezenchukskaya 105 (b_i = 0.98), Omskiy izumrud (b_i = 0.86) (Russia), Neodur (France) (b_i = 0.84), SHAG 9 / BBUTO / 7 (b_i = 0.84), 211 TIANES (b_i = 0.81) (Mexico). Such samples showed the best results under stress (contrast) growing conditions.

Stabile and plastic collection samples of spring durum wheat were identified according to yield: 193 THKNEE 8 (Mexico) (b_i = 1.02, S^2d_i = 0.11), ARN AAZ-1.040 YRC-4M (Mexico) (b_i = 1.35, S^2d_i = 0.12), SHAG 21 / CASCA (Mexico) (b_i = 1.07, S^2d_i = 0.23), Hordeiforme 13-07 (Ukraine) (b_i = 2.11, S^2d_i = 0.31). These collection samples can be used in subsequent breeding programs for yielding capacity.

An important element of productivity of durum spring wheat is grain weight per spike which depends on a number of factors: spike length, grain number per spike, grain size, as well as on growing conditions.

According to the results of our research, it was found that the highest (1.90 g) grain weight per spike was noted in the sample Voronezhskaya 11 (Russia), and the least (1.57 g) it was in the sample Damsinskaya yantarnaya (Kazakhstan) (Table 2).

According to the stability of the trait grain weight per spike, high indicators of the regression coefficient (b_i) and the most response to changes in environmental conditions were revealed in the following collection samples: ETH-LRBRA-2-28 / ALTAR 84 // (Mexico) (b_i = 4.84), DUN / MUSK 1 (Mexico) (b_i = 3.45), Seymour (Kazakhstan) (b_i = 2.94), Tera (Ukraine) (b_i = 2.27), SHAG 9 / BBUTO / 7 (Mexico) (b_i = 1.61), Ertol (Kazakhstan) (b_i = 1.57), S 15 FOCHA 1.030M-1Y (Mexico) (bi = 1.49), Damsinskaya yantarnaya (Kazakhstan) (b_i = 1.49), CASM 3 // SRN 3 ASAIH 15 (Mexico) (b_i = 1.47), Voronezhskaya 11 (Russia) (b_i = 1.45), Kharkivska 27 (Ukraine) (b_i = 1.43), GREEN / SOMO (Mexico) (b_i = 1.35).

The collection samples were identified with regression coefficient being close to 1.0 under fluctuating weather conditions: Lilek (Russia), MAGH 72 FUTO ALG 86 (Mexico).

According to the stability variance (S^2d_i), the following samples were distinguished among the plastic and stable collection samples: DUN / MUSK 1 (b_i = 3.45; = 0.07), SHAG 9 / BBUTO / 7 (b_i = 1.61; S^2d_i = 0.05), CASM 3 // SRN 3 ASAIH 15 (b_i = 1.47; S^2d_i = 0.00), GREEN / SOMO (b_i = 1.35; S^2d_i = 0.01) (Mexico), Lilek (Russia) (b_i = 0.92, S^2d_i = 0.03), MAGH 72 FUTO ALG 86 (Mexico) (b_i = 0.75, S^2d_i = 0.01), YAZI 13 (Mexico) (b_i = 0.12, S^2d_i = 0.07).

Table 2. *Plasticity coefficients and stability variances of collection samples of spring durum wheat by grain weight per spike (2015-2018).*

Variety	Origin	Grain weight per spike, g				Mean, x_i	b_i	S^2d_i
		2015	2016	2017	2018			
Spadshchyna (standard)	Ukraine	1.50	2.17	0.98	1,97	1.65	1.13	0.70
Voronezhskaya 11	Russia	1.96	2.58	1.46	1.62	1.90	1.45	0.56
GREEN / SOMO	Mexico	2.19	1.81	1.68	1.86	189	1.35	0.01
193 THK NTF 8	Mexico	1.96	2.23	1.54	1.71	1.86	1.16	0.17
ETH-LRBRA-2-28 / ALTA 84 //	Mexico	2.99	1.72	1.28	1.42	1.85	4.84	0.17
S 15 FOCHA 1.030M-1Y	Mexico	2.30	1.39	1.73	1.92	1.84	1.49	0.27
Seymur	Kazakhstan	2.53	1.70	1.48	1.63	1.84	2.94	0.07
CASM 3 // SRN 3ASAIH 15	Mexico	2.07	1.80	1.54	1.70	1.78	1.47	0.00
YAZI 13	Mexico	1.84	1.55	1.76	1.95	1.77	0.12	0.07
143 KIRKI 9	Mexico	1.50	1.44	1.97	2.18	1.77	-1.51	0.17
LABUD SRN 2	Mexico	1.61	1.60	1.77	1.95	1.73	-0.55	0.04
SHAG 21 / CASCA	Mexico	1.73	1.58	1.71	1.89	1.72	-0.04	0.03
CN 16 // BER / SB 15 (3) POLEMA 4523	Mexico	1.50	1.33	1.93	2.13	1.72	-1.39	0.22
Tera	Ukraine	2.19	1.70	1.37	1.52	1.70	2.27	0.01
193 THKNEE 8	Mexico	1.61	1.46	1.74	1.92	1.68	-0.48	0.07
RU / MINIMUS	Mexico	1.61	1.52	1.70	1.89	1.68	-0.37	0.04
MAGH 72 FUTO ALG 86	Mexico	1.84	1.61	1.55	1.72	1.68	0.75	0.01
030M- Y-0M	Mexico	1.27	1.55	1.83	2.02	1.67	-1.72	0.08
SHAG 9 / BBUTO / 7	Mexico	2.07	1.48	1.48	1.63	1.67	1.61	0.05
Neodur	France	1.84	1.71	1.45	1.60	1.65	1.07	0.00
Ertol	Kazakhstan	1.84	1.98	1.29	1.43	1.63	1.57	0.14
DUN / MUSK 1	Mexico	2.42	1.54	1.19	1.32	1.62	3.45	0.07
SBH (5) BRCH / 134*5-6	Mexico	1.50	1.30	1.74	1.92	1.61	-0.83	0.14
MUSK DUKEN	Mexico	1.38	2.04	1.44	1.59	1.61	-0.18	0.26
Lilek	Russia	1,84	1,47	1,49	1,65	1,61	0,92	0,03
Kharkivska 27	Ukraine	1.73	2.00	1.23	1.36	1.58	1.43	0.21
Toma	Kazakhstan	1.44	2.15	1.29	1.43	1.58	0.46	0.43
Damsinskaya yantarnaya	Kazakhstan	1.84	1.70	1.31	1.45	1.57	1.49	0.02
Mean xj*		1.70	1.51	1.33	1.47	1.50		
environmental index lj**		0.20	0.01	-0.17	0.03			
LSD_{05}		0.14	0.16	0.11	0.31			

[*] xj is average for 104 collection samples; **lj is the difference between the average yield of all varieties for the year conditions to the total average yield for all experiments; LSD is the least significant difference

4. Conclusions

As a result of the studies, it was found that stability and plasticity depend on the genotype. Stable and plastic collection samples of spring durum wheat were identified based on yield: 193 THKNEE 8 (Mexico) (b_i = 1.02, S^2d_i = 0.11), ARN AAZ-1.040 YRC-4M (Mexico) (b_i = 1.35, S^2d_i = 0.12), SHAG 21 / CASCA (Mexico) (b_i = 1.07, S^2d_i = 0.23), Hordeiforme 13-07 (Ukraine) (b_i = 2.11, S^2d_i = 0.31). It was found that the high (1.90 g) grain weight per spike was in the sample Voronezhskaya 11 (Russia) and the lowest value (1.57 g) was in the sample Damsinskaya yantarnaya (Kazakhstan). Among the plastic and stable collection samples by the grain weight per spike were the following samples were identified: DUN / MUSK 1 (b_i = 3.45; S^2d_i = 0.07), SHAG 9 / BBUTO / 7 (b_i = 1.61; S^2d_i = 0.05), CASM 3 // SRN 3 ASAIH 15 (b_i = 1.47; S^2d_i = 0.00), GREEN / SOMO (b_i = 1.35; S^2d_i = 0.01) (Mexico), Lilek (Russia) (b_i = 0.92, S^2d_i = 0.03), MAGH 72 FUTO ALG 86 (Mexico) (b_i = 0.75, S^2d_i = 0.01), YAZI 13 (Mexico) (b_i = 0.12, S^2d_i = 0.07).

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