Use of mathematical analyzes to determine the homogeneity of Bulgarian cultivars of common winter wheat (*Triticum aestivum* L.) I part

Evgeniy Dimitrov, Bogdan Bonchev*, Zlatina Uhr
Agricultural academy, Institute of plant genetic resources-Sadovo, Bulgaria
*E-mail: *bogybontchev@yahoo.com*

Citation
Dimitrov, E., Bonchev, B., & Uhr, Zl. (2022). Use of mathematical analyzes to determine the homogeneity of Bulgarian cultivars of common winter wheat (*Triticum aestivum* L.) I part. *Bulgarian Journal of Crop Science, 59*(5), 3-10

Abstract

The study period covers the vegetation season 2016/2017 to 2017/2018. To determine homogeneity of the cultivars, a complex of mathematical treatments was used homogeneity test of the traits of cultivars and one factor dispersion analysis for each of traits. The progenies must be homogeneous. Cultivar Nikibo (grain weight of spike), Ginra (length of spike) and Gaya 1 for number of tillers/m^2 showed trend of low homogeneity with significance less than 0.05 for two years. All studied progenies of the cultivars of common winter wheat did not show significant differences in the application of dispersion analysis. The described trend of low homogeneity for some traits (tiller number per m^2 for cultivar Gaya 1, length of spike of cultivar Ginra and weight grains per spike for cultivar Nikibo) is not enough evidence to claim that cultivars are not homogeneous in its progenies, because is not proven difference between them.

Tzarevetz is the cultivar that shows homogeneity of the all traits for whole period of study. The Cultivar Farmer is the second cultivar that is homogeneous for length of spike, plant height, and number of kernels per spike, weight of grains per spike, weight thousand grains, and kernel density for the period of study.

Key words: wheat; cultivars; homogeneity; progenies

INTRODUCTION

The cultivar is sufficiently homogeneous (except for a small number of deviations) if the plants of which it is composed are similar or genetically identical in terms of the traits taken as a whole (Article 5, paragraph 4). A population standard of 10% may be applied to establish homogeneity, provided that atypical plants and a level of probability of at least 90% are sought (Article 28, paragraph 4), (Council of Ministers of RB; 2010). Homogeneity of the cultivar can be observed mathematically by its traits. The external homogeneity of the cultivar may obscure its genetic heterogeneity. Excessive assessment of traits inherent in a given species does not express genotypic variability in many other traits such as response to day length, temperature, drought, radiation, self-pollination, and others (Dimova et al., 2010; Dimova, 2015). The incompetent or "cruel" discarding of progenies during different years and different regions leads to a significant equalization of the heterogeneous cultivars. It can change the ratio of biotypes within the cultivar itself, even to the disappearance of some of them (Shevtsova, 2008; Zobova, 2009). More are supporters about using the mass selection in cultivar maintenance (Mihova et al., 2010). The traits that can serve as morphological markers must meet the following characteristics: the progenies must be homogeneous; to vary low within the progenies and to have a low coefficient of variation; the strength of the genotype factor to be high (Lidanski, 2011).

MATERIAL AND METHODS

The experiment was carried out in the experimental field of the Institute of Plant Genetic Resources "K. Malkov" in the town of Sadovo, located in the South-Central region of Bulgaria in the period 2016/2017-2017/2018.). The soil is type Pellic vertisol (FAO), medium deep (A+B horizon=60-80 cm) slightly clay, with a high content of physical clay and silt fraction (Dimitrov, 2018).

The field trail was sown with elite pro-genies of common winter wheat cultivars Gaya 1, Nikibo, Ginra, Sadovo 1, Tzarevetz and Farmer.

Sowing was done according to a scheme for comparative testing of earlier generations in the first year (G1) in the maintenance of cereals (Ministry of Agriculture and Foods Industry, 1977).

Biometric measuring performed by the guidance of Dimova & Marinkov (1999) from plants collected of quarter square meter (50x50 cm), collected spikes were threshed manually separately. Mixing spikes is not admitted. Plant height without awn (cm), number of productive tillers per m², number of grains per spike, length of spike without awn (cm), weight of grain of spike (g), weight thousand kernel (g), kernel density were reported.

The following analyzes were performed: A test for homogeneity of the progenies of the cultivar was performed with the software product SPSS 19 (SPSS Inc.) and one factor dispersion analysis for each traits and year of study. The analysis ware made of cultivars between its progenies. The aim of the study is to determine homogeneity of the studied cultivars of common winter wheat.

RESULTS AND DISCUSIONS

In terms of climate, the region is characterized by a transitional-continental climate, with long and cool spring, dry and hot summer, prolonged and relatively dry and warm autumn, snowless, cold winter. The area is flat with an altitude of 158 m. The precipitation regime has a continental character with a summer maximum (June) and a winter minimum (February). It is characteristic that in August and September there is a clear drought in the region, when the second precipitation minimum is observed. The study period covers the vegetation years 2016/2017 and 2017/2018.

The deviation of the average monthly temperatures is positive in January and from March to July, being the largest in January (+3.3°C). In January 2017, a negative average monthly temperature (-4.4°C) was observed, which coincided with the climatic norm, as well as high June (23.7°C) and July temperatures (25.2°C), (Figure 1).

In March 2017 (9.8°C), April (16.2°C) and May (19.9°C) in 2018, higher average monthly temperatures were observed. Higher temperatures reinforce the effect of drought in April 2018. The high May average monthly temperature of 2018 is unfavorable

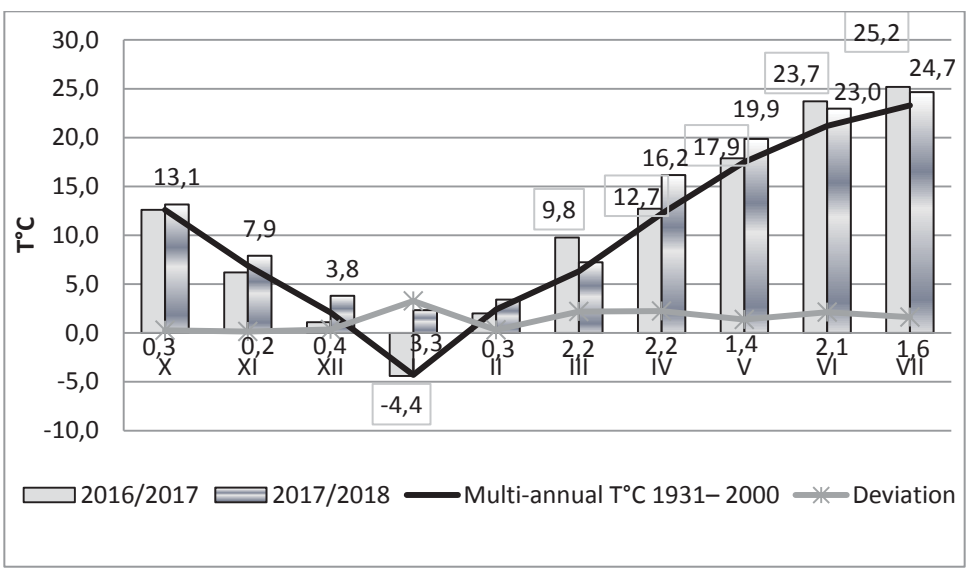

Figure 1. Average temperature T °C of months during two vegetation years 2016/2017-2017/2018

during the heading- an thesis period. The high July temperature during grain filling in 2017 may also speed up grain filling and terminate the process at an earlier stage.

The first year of the study 2016/2017 is characterized by periods of drought October-December, February-April, June, which are partially offset by precipitation around the norm in March and May 2017. During the vegetation year 2017/2018 there is a drought in January 2018, both during the growing season in April. Precipitation maximum (103.0 mm) in 2016/2017 is observed in January 2017. Precipitation maximum in 2017 with accumulation of precipitation (238 mm) is observed in the period October-December 2017. A second precipitation maximum is observed in February (101.5 mm) and precipitation maximum with accumulation of precipitation during the period May-July (223.9 mm) of 2018. The highest precipitation is in June (140 mm), which is significantly above the norm (Figure 2). The study period is characterized by contrasting conditions, with drought in April. During the first year there are periods of drought, the second year is rainy, but with uneven distribution of precipitation.

With the help of Levine's test it is established to what extent the data from the characteristics of the studied cultivars are homogeneous by years. The pro-genies of the cultivars Nikibo, Tzarevetz, Ginra and Sadovo 1 are homogeneous in 2016/2017 vegetation year by number of productive tillers per m² with a significance greater than 0.05. The studied progenies of Gaya 1 variety are not homogeneous in number of productive tillers per m² with a significance of less than 0.05 (table 1).

In terms of plant height, the cultivars Gaya 1, Tzarevetz and Ginra have homogeneous progenies, in the cultivars Sadovo 1 and Nikibo the homogeneity has a significance of less than 0.05, therefore they are not homogeneous. By length of the spike, the progenies of the Nikibo and Ginra cultivars are not homogeneous with a significance of less than 0.05. The progenies of the cultivar Gaya 1, Tzarevetz, Sadovo 1 and Farmer are homogeneous in 2017 by spike length. The number of kernels per spike has homogeneous data in all tested cultivars with a significance greater than 0.05. The progenies of the cultivars Gaya 1, Tzarevetz, Ginra, Sadovo 1 and Farmer are homogeneous in weight of grains of spike; the studied progenies of cultivar Nikibo are not homogeneous. The progenies of Gaya 1 cultivar are not homogeneous in weight per thousand grains. The progenies of Sadovo 1 cultivar are not homogeneous in kernel density at significance less than 0.05 (Table 1).

The results of the dispersion analysis for the cultivars traits of the vegetation year 2016/2017 show that no significant differences are observed between the studied progenies of the cultivars (table 2). Therefore, although the data show no homogeneity in some of the traits of the cultivar Gaya 1 (number of productive tillers/m², weight per thousand grains), Nikibo (plant height and spike length

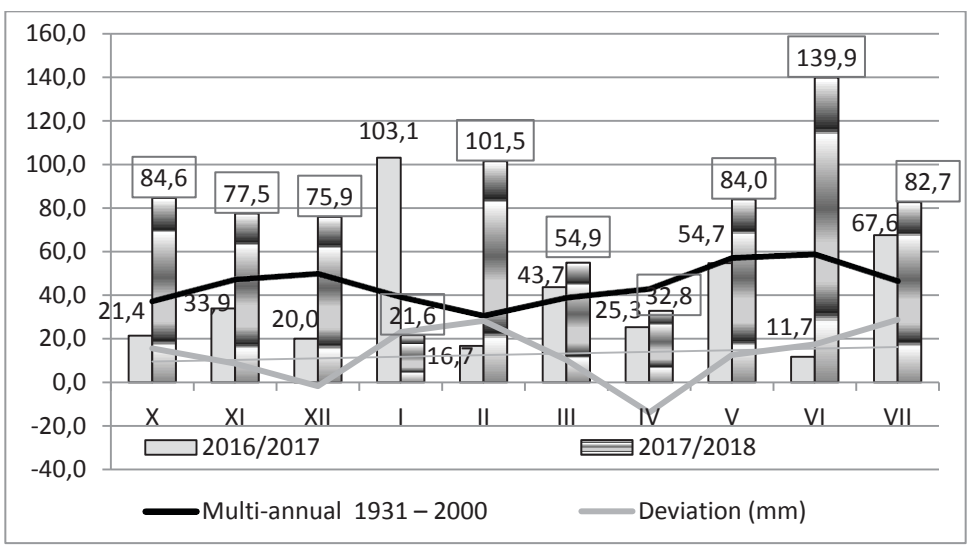

Figure 2. Sum of rainfall (mm) of months during two vegetation years 2016/2017-2017/2018.

Table 1. Test of homogeneity of the generations in vegetation 2016/2017 year

Traits 2017 year	Cultivar	Levine's statistic	FG 1	FG 2	Sig.
Number of productive tillers/ m²	Gaya 1	9.649	1	8	**0.015**
	Nikibo	0.052	1	8	0.826
	Tzarevetz	1.138	1	8	0.317
	Ginra	1.86	1	8	0.210
	Sadovo 1	0	1	8	0.986
	Farmer	0.939	1	8	0.361
Plant height (cm)	Gaya 1	0.332	1	8	0.581
	Nikibo	8.367	1	8	**0.020**
	Tzarevetz	0.267	1	8	0.620
	Ginra	4.823	1	8	0.059
	Sadovo 1	7.901	1	8	**0.023**
	Farmer	2.9	1	8	0.127
Spike length (cm)	Gaya 1	0.245	1	8	0.634
	Nikibo	10.26	1	8	**0.013**
	Tzarevetz	0.234	1	8	0.641
	Ginra	16.181	1	8	**0.004**
	Sadovo 1	0.002	1	8	0.968
	Farmer	0.292	1	8	0.604
Number of kernel per spike	Gaya 1	0.009	1	8	0.929
	Nikibo	1.113	1	8	0.322
	Tzarevetz	0.016	1	8	0.904
	Ginra	0.689	1	8	0.431
	Sadovo 1	0.164	1	8	0.696
	Farmer	1.068	1	8	0.332
Weight of grains per spike (g)	Gaya 1	0.986	1	8	0.350
	Nikibo	16.9	1	8	**0.003**
	Tzarevetz	3.768	1	8	0.088
	Ginra	0.124	1	8	0.734
	Sadovo 1	0.616	1	8	0.452
	Farmer	0.063	1	8	0.809
Thousand weight grain (g)	Gaya 1	12.724	1	8	**0.007**
	Nikibo	0.596	1	8	0.462
	Tzarevetz	0.237	1	8	0.640
	Ginra	0.021	1	8	0.888
	Sadovo 1	0.771	1	8	0.406
	Farmer	1.844	1	8	0.212
Kernel density	Gaya 1	0.669	1	8	0.437
	Nikibo	0.004	1	8	0.949
	Tzarevetz	1.873	1	8	0.208
	Ginra	0.021	1	8	0.888
	Sadovo 1	6.088	1	8	**0.039**
	Farmer	0.028	1	8	0.871

and grain weight of spike), Ginra (length of spike) and Sadovo 1 (kernel density) no proven differences were observed between the progenies. They are also called agronomic traits (Khan et al., 2021). The degree of variability of the traits belong to spike are strongly influenced by the number of productive tillers and this makes it impossible to conclude that it is inconceivable to perform discarding progenies in comparative testing of earlier generations in the first year (G1) according to the number of kernels

per spike and thousand grain weight (Lovnyaeva, 2007).

It's found that there were no difficult to separate intermixture (mechanic) from other cultivars of common winter wheat (*Triticum aestivum* L.). The cultivars Tzarevetz and Farmer are homogeneous in all traits, and there are no proven differences between their progenies during vegetation season 2016/2017 (Tables 1 and 2).

Table 2. Dispersion analysis of traits between generation's trough cultivars during vegetation 2016/2017

Traits 2017 year	Cultivars	Source of variation	SS	df	MS	F	Sig.
Number of productive tillers/ m²	Gaya 1	Between groups	360	1	360	0.368	0.561
	Nikibo		40	1	40	0.034	0.858
	Tzarevetz		40	1	40	0.031	0.866
	Ginra		250	1	250	0.251	0.630
	Sadovo1		6.4	1	6.4	0.015	0.907
	Farmer		0	1	0.000	0.000	1.000
Plant height (cm)	Gaya 1	Between groups	62.5	1	62.5	1.739	0.224
	Nikibo		12.1	1	12.1	1.294	0.288
	Tzarevetz		4.9	1	4.9	0.49	0.504
	Ginra		0.4	1	0.4	0.022	0.886
	Sadovo 1		78.4	1	78.4	1.889	0.207
	Farmer		62.5	1	62.5	2.104	0.185
Spike length (cm)	Gaya 1	Between groups	1.764	1	1.764	5.188	0.052
	Nikibo		0.256	1	0.256	1.02	0.342
	Tzarevetz		0.036	1	0.036	0.109	0.750
	Ginra		0.049	1	0.049	0.41	0.540
	Sadovo 1		0.625	1	0.625	2.216	0.175
	Farmer		0.081	1	0.081	0.236	0.640
Number of kernel per spike	Gaya 1	Between groups	0.9	1	0.9	0.023	0.883
	Nikibo		2.5	1	2.5	0.284	0.609
	Tzarevetz		0	1	0	0	1.000
	Ginra		3.6	1	3.6	0.595	0.463
	Sadovo 1		10	1	10	2.632	0.143
	Farmer		48.4	1	48.4	3.044	0.119
Weight of grain per spike (g)	Gaya 1	Between groups	0.015	1	0.015	0.077	0.789
	Nikibo		0.003	1	0.003	0.064	0.807
	Tzarevetz		0.074	1	0.074	0.492	0.503
	Ginra		0.072	1	0.072	0.657	0.441
	Sadovo 1		0.001	1	0.001	0.055	0.820
	Farmer		0.008	1	0.008	0.151	0.707
Thousand weight grain (g)	Gaya 1	Between groups	36.024	1	36.02	0.868	0.379
	Nikibo		4.134	1	4.134	0.436	0.528
	Tzarevetz		7.832	1	7.832	0.55	0.480
	Ginra		9.235	1	9.235	0.313	0.591
	Sadovo 1		15.228	1	15.23	4.389	0.069
	Farmer		8.482	1	8.482	1.348	0.279
Kernel density	Gaya 1	Between groups	0.123	1	0.123	3.305	0.107
	Nikibo		0.001	1	0.001	0.006	0.940
	Tzarevetz		0.006	1	0.006	0.148	0.711
	Ginra		0	1	0	0	1.000
	Sadovo 1		0.493	1	0.493	2.099	0.185
	Farmer		0.172	1	0.172	3.566	0.096

Table 3. Test of homogeny of the generations in vegetation 2017/2018 year

Traits 2018 year	Cultivars	Levine's statistic	FG 1	FG 2	Sig.
Number of productive tillers/ m²	Gaya 1	8.564	1	8	**0.019**
	Nikbo	2.783	1	8	0.134
	Tzarevetz	0.124	1	8	0.734
	Ginra	1.132	1	8	0.318
	Sadovo 1	9.203	1	8	**0.016**
	Farmer	8.482	1	8	**0.020**
Plant height (cm)	Gaya 1	4.07	1	8	0.078
	Nikbo	0.053	1	8	0.824
	Tzarevetz	1.646	1	8	0.235
	Ginra	3.445	1	8	0.101
	Sadovo 1	10.061	1	8	**0.013**
	Farmer	4.006	1	8	0.080
Spike length (cm)	Gaya 1	0.003	1	8	0.959
	Nikbo	0.014	1	8	0.910
	Tzarevetz	0.513	1	8	0.494
	Ginra	5.6	1	8	**0.045**
	Sadovo 1	5.388	1	8	0.049
	Farmer	0.546	1	8	0.481
Number of kernel per spike	Gaya 1	4.045	1	8	0.079
	Nikbo	4.358	1	8	0.070
	Tzarevetz	3.479	1	8	0.099
	Ginra	0.763	1	8	0.408
	Sadovo 1	1.992	1	8	0.196
	Farmer	0.008	1	8	0.931
Weight of grain per spike (g)	Gaya 1	4.226	1	8	0.074
	Nikbo	13.114	1	8	**0.007**
	Tzarevetz	0.633	1	8	0.449
	Ginra	0.005	1	8	0.947
	Sadovo 1	0.204	1	8	0.664
	Farmer	3.85	1	8	0.085
Thousand weight grain (g)	Gaya 1	2.705	1	8	0.139
	Nikbo	11.469	1	8	**0.010**
	Tzarevetz	0.21	1	8	0.659
	Ginra	0.111	1	8	0.748
	Sadovo 1	5.111	1	8	0.054
	Farmer	0.04	1	8	0.847
Kernel density	Gaya 1	0.122	1	8	0.736
	Nikbo	0.689	1	8	0.431
	Tzarevetz	0.272	1	8	0.616
	Ginra	1.162	1	8	0.312
	Sadovo 1	0.151	1	8	0.708
	Farmer	0.214	1	8	0.656

During the vegetation year 2017/2018 by number of productive tillers the progenies are not homogeneous of the cultivars Gaya 1, Sadovo 1 and Farmer with significance less than 0.05. The progenies of the cultivars Nikibo, Tzarevetz and Ginra are homogeneous of number of tillers per m^2 (Table 3). In terms of plant height, the progenies of cultivar Sadovo 1 is not homogeneous with significance less than 0.05. The cultivars Gaya 1, Nikibo, Ginra and Farmer are homogeneous of plant height. Along the

length of the spike, the progenies of Ginra cultivar are on the border of homogeneity with a significance (sig = 0.045), the cultivar Gaya 1, Nikibo, Sadovo 1 and Farmer are homogeneous of spike length. All tested progenies of the cultivars are homogeneous of number of kernels in the spike of vegetation season 2017/2018. By weight of grains of a spike and by thousand weight grains, the examined progenies of the Nikibo cultivar showed non-homogeneity at significance less than 0.05 during vegetation season

Table 4. Dispersion analysis of traits between generation's trough cultivars during vegetation 2017/2018

Traits 2018 year	Cultivar	Source of variation	SS	Df	MS	F	Sig.
Number of productive tillers/ m²	Gaya 1	Between groups	102.4	1	102.4	1.164	0.312
	Nikibo		504.1	1	504.1	0.94	0.361
	Tzarevetz		360	1	360	0.793	0.399
	Ginra		102.4	1	102.4	0.126	0.731
	Sadovo 1		102.4	1	102.4	1.198	0.306
	Farmer		57.6	1	57.6	0.057	0.817
Plant height (cm)	Gaya 1	Between groups	4.9	1	4.9	0.289	0.605
	Nikibo		4.9	1	4.9	0.616	0.455
	Tzarevetz		0.1	1	0.1	0.007	0.936
	Ginra		6.4	1	6.4	0.367	0.562
	Sadovo 1		28.9	1	28.9	3.658	0.092
	Farmer		1.6	1	1.6	0.091	0.77
Spike length (cm)	Gaya 1	Between groups	0.484	1	0.484	2.855	0.130
	Nikibo		0.169	1	0.169	0.546	0.481
	Tzarevetz		0	1	0	0	1
	Ginra		0.049	1	0.049	0.35	0.570
	Sadovo 1		0.361	1	0.361	2.704	0.139
	Farmer		0.324	1	0.324	1.093	0.326
Number of kernel per spike	Gaya 1	Between groups	16.9	1	16.9	2.061	0.189
	Nikibo		90	1	90	3.593	0.095
	Tzarevetz		19.6	1	19.6	0.891	0.373
	Ginra		14.4	1	14.4	1.231	0.299
	Sadovo 1		12.1	1	12.1	0.927	0.364
	Farmer		19.6	1	19.6	0.493	0.502
Weight of grain per spike (g)	Gaya 1	Between groups	0.001	1	0.001	0.011	0.919
	Nikibo		0.24	1	0.24	1.135	0.318
	Tzarevetz		0.164	1	0.164	1.828	0.213
	Ginra		0.01	1	0.01	0.083	0.780
	Sadovo 1		0.064	1	0.064	1.778	0.219
	Farmer		0.018	1	0.018	0.265	0.620
Thousand weight grain (g)	Gaya 1	Between groups	11.3	1	11.3	0.453	0.520
	Nikibo		0.007	1	0.007	0	0.988
	Tzarevetz		8.354	1	8.354	0.968	0.354
	Ginra		5.476	1	5.476	0.147	0.711
	Sadovo 1		2.673	1	2.673	0.204	0.663
	Farmer		8.136	1	8.136	0.254	0.628
Kernel density	Gaya1	Between groups	0.018	1	0.018	0.159	0.700
	Nikibo		0.018	1	0.018	0.259	0.624
	Tzarevetz		0.012	1	0.012	0.164	0.696
	Ginra		0.034	1	0.034	0.704	0.426
	Sadovo 1		0.008	1	0.008	0.095	0.766
	Farmer		0.001	1	0.001	0.027	0.873

2017/2018. The progenies of the cultivar Gaya 1, Tzarevetz, Ginra and Farmer are homogeneous of traits weight grain spike and thousand weight grains. All progenies of the studied cultivars of common winter wheat are homogeneous in traits of spike density at significance greater than 0.05. Tzarevetz is the cultivar that shows homogeneity on all traits.

All studied progenies of the cultivars of common winter wheat did not show significant differences in the application of analysis of dispersion (Table 4).

CONCLUSIONS

Cultivar Nikibo (grain weight of spike), Ginra (length of spike) and Gaya 1 for number of tillers/ m^2 showed trend of low homogeneity with significance less than 0.05 for two years. All studied progenies of the cultivars of common winter wheat did not show significant differences in the application of dispersion analysis. The described trend of low homogeneity for some traits (tiller number per m^2 for cultivar Gaya 1, length of spike of cultivar Ginra and weight grains per spike for cultivar Nikibo) is not enough evidence to claim that cultivars are not homogeneous in its progenies, because is not proven difference between them.

Tzarevetz is the cultivar that shows homogeneity of the all traits for whole period of study. The Cultivar Farmer is the second cultivar that is homogeneous for length of spike, plant height, and number of kernels per spike, weight of grains per spike, weight thousand grains, and kernel density for the period of study.

ACKNOWLEDGEMENT

The study was presented at the 2022 International Scientific Conference entitled "140 Years of Agricultural Science in Sadovo and 45 Years Institute of Plant Genetic Resources", which was held in Plovdiv from September 28 to September 29, 2022.

REFERENCIES

Council of Ministers of the Republic of Bulgaria (2010). Regulation №77 / 31 May.2006 Setting out the procedure for acceptance for inclusion of new cultivars of agricultural plant spices, conservation cultivars, and cultivars developed for growing under particular conditions in the official list of the Republic of Bulgaria and the common catalog of the EU member states (head amended, SG № 60/2010, effective date 03.08.2010). https://iasas.government.bg/att/R%D0%B5gulation-77-31052006.pdf

Dimitrov, G. (2018). Establishment of genotypes of common winter wheat and peas suitable for organic farming, *Abstract of Dissertation*, Plovdiv, Bulgaria (Bg).

Dimova, D. & Mainkov, E. (1999). Experimental work with biometrics. *Academic print of AU*, 50, 93, 98 (Bg).

Dimova, D. (2015). Selection-genetic studies on the productivity of feed barley, *PhD Thesis*, Karnobat, 66 (Bg).

Dimova, D., Valcheva, D., &. Valchev, Dr. (2010). Productive possibilities of selection samples of winter fodder barley from var. pallidum and var. parallelum for the region of Southeastern Bulgaria. *Plant Sciences*, 5, 413-422 (Bg).

Khan, A., Ahmad, M., Ahmed, Mu., Gill, K., & Akram, Z. (2021)**.** Association analysis for agronomic traits in wheat under terminal heat stress. *Saudi Journal of Biological Sciences*, XXX (XXX) 1-11. https://www.researchgate.net/profile/Mukhtar-Ahmed-11/publication/354083745_Association_analysis_for_agronomic_traits_in_wheat_under_terminal_heat_stress/links/616da6a3b90c51266265b72b/Association-analysis-for-agronomic-traits-in-wheat-under-terminal-heat-stress.pdf

Lidanski, T. (2011). *Biostatistics: methods, schemes, analysis, Part I, Basic of biostatistics analysis.* Methods of biologicals traits, Sofia (Bg).

Lovnyaeva, A. (2007). Variability of cultivars of spring common wheat and its use in primary seed production, Dissertation, Voronezh, (Ru). https://www.dissercat.com/content/izmenchivost-sortov-yarovoi-myagkoi-pshenitsy-i-ee-ispolzovanie-v-pervichnom-semenovodstve

Mihova, G., Penchev, P., Petrova, T., Iliev, I., Ivanova, V., & Doneva, S. (2010). Economic characteristics of the regionalized barley cultivars under the conditions of Dobrudja. *Research on field crops*, 1, 17-30 (Bg).

Ministry of Agriculture and Foods Industry (1977). *Instruction for production of super-elite and elite seeds and planting material from field, vegetable and perennial crops*, *NPO* "Cultivar seeds and planting material", direction "Cultivar maintenance", Sofia (Bg).

Shevtsova, H. (2008). Agroecological determination of the spring barley of Eastern Siberia by hordeincoding loci. *State Agrarian University*, 146 p. (Ru).

SPSS inc., IBM Corporation, Statistical package for the social sciences (SPSS 19).

Zobova, N. (2009). Increasing the resistance of barley to stress biotic and abiotic factors in Siberia: genetic and biotechnological aspects, PhD thesis, Krasnoyarsk, 1-298 p. (Ru). https://www.dissercat.com/content/povyshenie-ustoichivosti-yachmenya-k-stressovym-bioticheskim-i-abioticheskim-faktoram-v-sibi