UDC 635.652/.654:575 DOI: 10.30835/2413-7510.2020.222257

ENVIRONMENTAL TRIALS OF A MODEL POPULATION OF PHASEOLUS VULGARIS L. IN CONTRAST CLIMATES

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The study purpose was to evaluate the potentials of bean genotypes in contrast climates, to identify the most informative environments for assessing the adaptability of genotypes, to select promising starting material for specific areas where this crop is supposed to be bred. To accomplish this purpose, environmental trials were conducted on a collection of bean (*Phaseolus vulgaris* L.) accessions in four sites located in different climatic zones of Ukraine: the eastern Forest-Steppe – Kharkiv region; southern Forest-Steppe – Poltava region; Woodlands – Chernivtsi region; southern Steppe – Odesa region. Genotypes and environments were evaluated using the GGE biplot method, which allowed us to graphically visualize the environmental trial data. To develop cultivars for different zones of Ukraine, we recommend selecting parents, taking into account the weather conditions: drought- and highly heat-tolerant genotypes (Holberg) for the south of Ukraine; intensive genotypes (Pervomaicka, Mistseva Bomba 5) for Woodlands; genotypes with stable yields and high drought tolerance (Holberg, Nadiia, UD0300104) for Forest-Steppe. The GGE biplot analysis distinguished the most informative environments allowing full assessments of the adaptability of genotypes – the Forest-Steppe of Ukraine (Kharkiv region and Poltava region). The genotypes with stable yields of seeds were identified: Holberg, Otrada, UD0300104, Bogema, UD0300152, N 201-15 and Synelnykivska 8. Of these accessions, Holberg, Otrada, UD0300104 and Synelnykivska 8 gave high yields, and Holberg and UD0300104 approached the “ideal” genotype. The southern subzone of the Steppe is the most informative for identification of drought- and heat-tolerant bean accessions; the Woodlands – for selection of genotypes with high potential yields.

Key words: *bean, genotype, environment, GGE biplot*

Introduction. Evaluation of the “genotype × environment” interaction is very important for selection of starting material used in breeding [1, 2]. It is well known that one of the parents in hybridization should be a genotype that is well-adapted to local climatic conditions [3]. Valuable features of a collection accession (genotype) will be negated by unfavorable environmental conditions, if they are not taken into account [4]. Most modern bean cultivars having sufficiently high potential yields are characterized by low homeostaticity and adaptability to unfavourable environmental factors [5]. Therefore, when developing new cultivars, one should use genotypes that are adapted to the conditions of a particular zone. In order to get an idea of the responses of bean accessions to an environment, we formed a model population, which included genotypes with various characteristics according to the multi-year data from the National Center for Plant Genetic Resources of Ukraine (NCPGRU) [6]. The effects of abiotic factors on the yields of bean accessions were studied [7], and, as a result, a trait collection of *Phaseolus vulgaris* L. was compiled [8]. This collection became the basis of the model population [9], in which each genotype is original and has an extensive range of adaptive features allowing it to adapt to the growing conditions.

The purpose of our study was evaluate the potentials of bean genotypes in contrast environments, to identify the most informative environments for assessing the adaptability of genotypes, to select promising starting material for specific areas where new cultivars will be bred.

Materials and methods. To accomplish this purpose, environmental trials were conducted in 2015–2017 on the collection of bean accessions at four institutions in Ukraine, which differ by climatic characteristics. The eastern Forest-Steppe: Kharkiv region, Plant Production Institute nd. a. V.Ya. Yuriev of NAAS (PPI); southern Forest-Steppe: Poltava region, Ustymivka Experimental Station (UES) of Plant Production Institute nd. a. V.Ya. Yuriev of NAAS; Woodlands: Chernivtsi region, Bukovina State Agricultural Experimental Station (BSAES) of the Institute of Agriculture of the Carpathian Region of NAAS; southern Steppe: Odesa region, Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation (PBGI-NCSCI).

To assess the response of a genotype to an environment, depending on the weather peculiarities during the bean vegetation period, the hydrothermal coefficient (HTC) was used. The HTC was calculated from the formula (1) :

$$HTC = \frac{\sum r}{0.1 \times \sum t}, \qquad (1)$$

where ∑r – is precipitation amount during the vegetation period, mm; ∑t − sum of temperatures above 10°C during the vegetation period, °C; 0.1 – coefficient.

The PBGI is situated in the steppe in the South ean daily air temperature is 15.6–22.6 C; the precipitation amount is 130 mm. In 2015, the vegetation period was characterized by above-average mean daily air temperature (20.4°C), and the precipitation amount was significantly below the multiyear average (83.8 mm). Thus, the HTC was 0.45, which is significantly lower than the optimum for the crop (1.00–1.10).

The UES and PPI are located in the Forest-Steppe of Ukraine; however, their multiyear average parameters during the bean vegetation period are different. The mean daily air temperature: UES – 15.5–20.5°C, PPI – 15.6–21.3°C. The precipitation amount: UES – 210 mm, PPI – 170 mm. Accordingly, in 2015, the weather conditions during the crop vegetation period were different: at UES the mean daily air temperature reached the upper limit of the multiyear average (20.5°C); the precipitation amount was above the multiyear average (226.7 mm); the HTC was 1.20, which is higher than the optimum. At the PPI, the mean daily air temperature was close to the average (19.6°C); the precipitation amount exceeded the multiyear average (211 mm); the HTC was not much higher than the optimum (1.17). It should be noted that precipitation was rain showers resulted in inopportune watering of plants.

BSAES is located in the Woodlands of Ukraine, where the multiyear average parameters during the bean vegetation period are as follows: the mean daily air temperature is 13.8–18.3°C; the precipitation amount is 274 mm. However, the mean daily temperatures during the crop vegetation period in 2015 exceeded the multiyear average by >1°C (19.5°C), and the precipitation was much below the average (224.3 mm); therefore, the HTC did not significantly exceed that at UES (1.24) (Table 1).

Table 1

The weather conditions in the sites of the environmental trials

Site	Mean daily temperature °C		Precipitation amount mm		Hydrothermal coefficient
	2015	multiyear average[1)] min–max	2015	multiyear average[1)]	
PBGI	20.4	15.6–22.6	83.8	130	0.45
PPI	19.6	15.6–21.3	211	170	1.17
UES	20.5	15.5–20.5	226.7	210	1.20
BSAES	19.5	13.8–18.3	224.3	274	1.25

[1)] – according to WRB, 2018 [10]

The model population consisting of 24 collection bean accessions with various responses to fluctuations in temperature and humidity in the environment, which were taken from the core

collection of the National Centre for Plant Genetic Resources of Ukraine (NCPGRU), served as the test material to investigate the "genotype × environment" interaction. The accessions were sown with manual planters within the timeframe that is optimal for bean. The collection accessions were assessed in accordance with the valid classifier [11] and methodical recommendations for studying collection accessions of grain legumes [12]. The experimental data were statistically processed by analysis of variance in Microsoft office Excel. The environmental assessment of the genotypes was performed by GGE biplot method [13, 14, 15].

Results and discussion. When studying the "genotype × environment" interactions, several researchers [16, 17, 18] noted a strong influence of the crop cultivation environment on the yield variability and emphasized that the "genotype" (G) and the "genotype × environment" (GE) effects should be analyzed. GGE biplot using in the researches allows to graphical visualise their results. It promotes to concretize analysis of this observing [13, 19]. A clear "genotype × environment" relationship was established by the GGE biplot method in studies on wheat [20], sorghum [21, 22, 23], soybean [24, 25] and bean [26, 27].

In 2015, the environmental trials of the model population of bean were conducted in four environments (PPI, UES, BSAES, PBGI) differing in the temperature-water regime during the period of growth and development of the crop.

On average, in the model population, the highest yields were obtained in the woodlands of Ukraine (BSAES) – 0.37 kg*m^{-2}. Moderate yields were registered in the forest-steppe of Ukraine: in the southern part (UES) – 0.28 kg*m^{-2} and in the eastern part (PPI) – 0.19 kg*m^{-2}. The lowest yields were in the southern steppe of Ukraine (PBGI) – 0.07 kg*m^{-2}. There were accessions giving high yields in each environment. At the PPI, UD030076 (0.38 kg*m^{-2}), Holberg (0.350 kg*m^{-2}) and UD030104 (0.33 kg*m^{-2}) gave the highest yields; at UES, such accessions were Dniprovska Bomba (0.48 kg*m^{-2}), Nadiia (0.48 kg*m^{-2}), Prelom (0.45 kg*m^{-2}) and Holberg (0.44 kg*m^{-2}); at BSAES – Mistseva Bomba 5 (0.58 kg*m^{-2}), Pervomaiska (0.58 kg*m^{-2}), Sperantsa (0.54 kg*m^{-2}) and Prelom (0.50 kg*m^{-2}); at the PBGI – Holberg (0.14 kg*m^{-2}) and Bukovinka (0.10 kg*m^{-2}) (Table 2).

Table 2

Seed yield of the bean accessions from the model population in different sites of the environmental trials, 2015

Genotype[1)]	Number of the National Catalogue of Ukraine	Name	Country of origin	Seed weight/m^2, kg				
				PPI	UDE	BSAES	PBGI	average
1	2	3	4	5	6	7	8	9
G1	UD0300025	Pervomaiska	Ukraine	0.16	0.16	0.58	0.06	0.24
G2	UD0300045	Prelom	Bulgaria	0.16	0.45	0.50	0.02	0.28
G3	UD0300076	–	Moldova	0.38	0.26	0.39	0.07	0.28
G4	UD0300104	–	Hungary	0.33	0.38	0.41	0.09	0.30
G5	UD0300152	–	Ukraine	0.07	0.12	0.24	0.07	0.12
G6	UD0300227	Holberg	USA	0.35	0.44	0.40	0.01	0.30
G7	UD0300238	Synelnykivska 8	Ukraine	0.22	0.30	0.28	0.07	0.22
G8	UD0300285	Belgorodskaia 1	Russia	0.16	0.16	0.32	0.02	0.16
G9	UD0300286	–	Ukraine	0.10	0.28	0.33	0.10	0.20
G10	UD0300388	Mistseva Bomba 5	Ukraine	0.05	0.25	0.58	0.01	0.22
G11	UD0300397	Sperantsa	Moldova	0.23	0.34	0.54	0.08	0.30
G12	UD0300413	Dniprovska Bomba	Ukraine	0.22	0.48	0.20	0.07	0.24
G13	UD0300463	–	Ukraine	0.16	0.19	0.30	0.01	0.16

1	2	3	4	5	6	7	8	9
G14	UD0300465	–	Ukraine	0.15	0.27	0.31	0.07	0.20
G15	UD0300775	Dokuchaev-ska	Ukraine	0.18	0.16	0.32	0.07	0.18
G16	UD0301092	Yuvileina 287	Ukraine	0.19	0.20	0.40	0.05	0.21
G17	UD0301094	Nadiia	Ukraine	0.19	0.48	0.41	0.09	0.29
G18	UD0303258	Perlyna	Ukraine	0.10	0.21	0.44	0.10	0.21
G19	UD0303351	Otrada	Ukraine	0.22	0.25	0.44	0.10	0.25
G20	UD0303441	Bukovinka	Ukraine	0.06	0.23	0.43	0.10	0.20
G21	UD0303568	Nespodivanka	Ukraine	0.26	0.27	0.35	0.06	0.24
G22	UD0303753	Veselka	Ukraine	0.16	0.28	0.28	0.09	0.20
G23	UD0303805	Bogema	Nitherlands	0.09	0.19	0.42	0.07	0.19
G24	UD0303971	Panna	Ukraine	0.14	0.29	0.32	0.08	0.21
			LSD_{005}	0.05	0.06	0.06	0.02	
		Average		0.18	0.28	0.38	0.06	

[1)] – genotype designation for visualization of the environmental trial data

The GGE biplot polygon (Figure 1) shows patterns of the "genotype × environment" relationship. The polygon is divided into sectors. The genotype that is the most adapted to the growing conditions of an environmental trial site is located at the top of the polygon in the same sector with the test marker [14]. We identified genotypes that are the most adapted to these environments: to the forest-steppe – Holberg (G6); to the woodlands – Mistseva Bomba 5 (G10) and Pervomaiska (G1); to the southern Steppe – Holberg (G6).

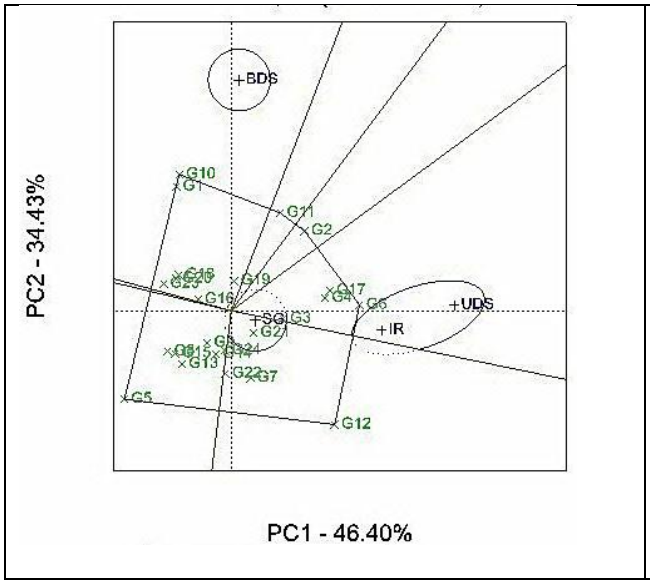

Figure 1. GGE biplot, "Which-Won-Where"

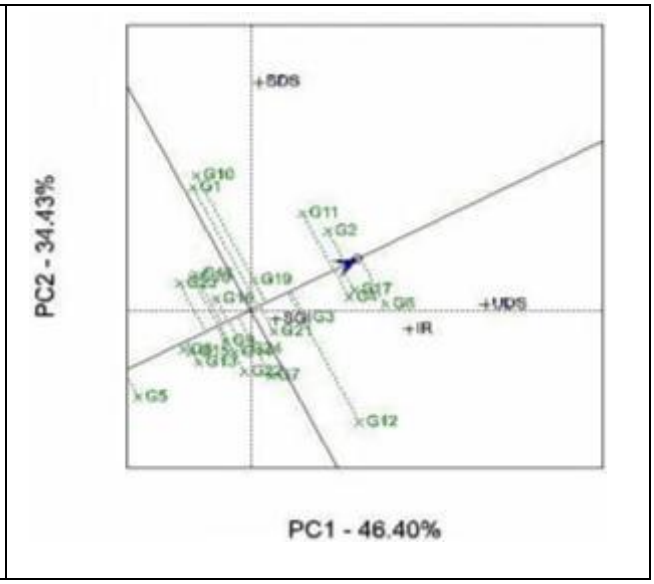

Figure 2. GGE biplot, "mean vs. stability"

In the environments where the limiting factor for the bean growth and development is water deficit during the crop vegetation period (PPI, UES and PBGI), drought-tolerant Holberg, giving a high yield of seeds, is advantageous.

Upon excess water (BES), genotypes with high potential yields, however with low stability of yields, which depend on the environment and respond positively to favourable for bean conditions of cultivation, are advantageous: Pervomaiska and Mistseva Bomba 5.

Thus, when selecting starting material for hybridization in the woodlands of Ukraine, one should give priority to genotypes with high potential yields, and in the forest-steppe and steppe of Ukraine – to highly drought-tolerant genotypes with stable yields of seeds.

To analyse the genotypes' responses to various environmental conditions, the GGE biplot "mean vs. stability" (Figure 2), which is based on their average yields and stability in the environment trial sites, was used. The line passing through the biplot origin and the average environment is called the average environment coordinate (AEC) axis or the yield line. The arrow shows the direction of yield growth. Another axis, perpendicular to the AEC axis, is the stability line dividing the genotypes into highly and poorly stable ones. Accessions with the shortest projection lengths on this axis are considered the most stable (Solonechnyi et al., 2014). Stable genotypes and genotypes with high potential yields were identified. Among them, there are valuable genotypes with high yields of seeds and high stability of yields – Nadiia (G17), Prelom (G2), UD0300104 (G4); genotypes with high potential yields – Dniprovska Bomba (G12), Mistseva Bomba 5 (G 10), and Pervomaiska (G1).

The "ideal" genotype is a stable genotype with a high average yield, which has a wide range of adaptive characteristics. To find genotypes combining high yields and stability, the GGE biplot comparing the genotypes with the "ideal" one was used (Figure 3).

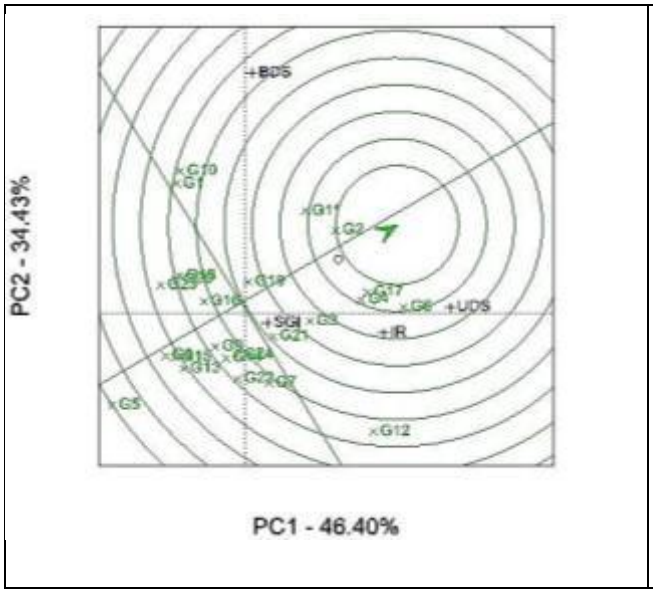

Figure 3. GGE biplot, comparison of the genotypes under investigation with the "ideal" genotype

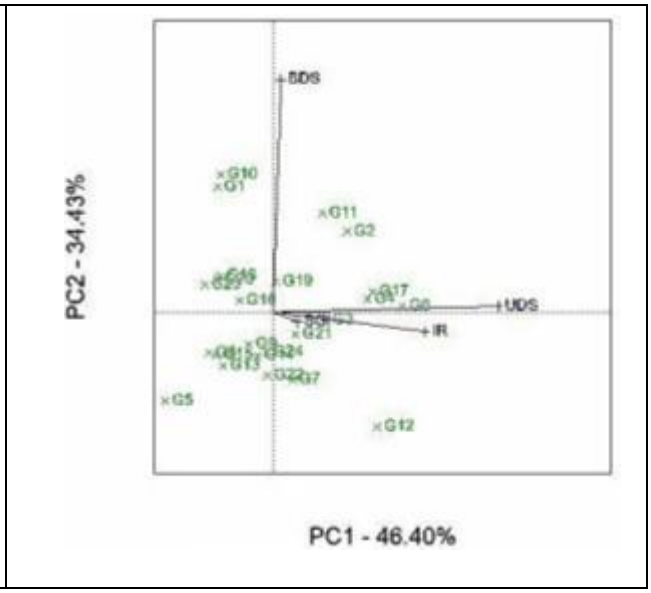

Figure 4. GGE biplot, discriminating and representative capacities of the environments

The center of the circles shows the position of the "ideal" genotype. The closer the genotype projection to the center of the circles is, the closer the genotype under investigation to the "ideal" one is (Solonechnyi et al., 2015; Solonechnyi, 2017; Solonechnyi et al., 2018). These are the following collection accessions: Holberg (G6) (with the average seed yield of 0.33 kg*m^{-2}), Prelom (G2) (0.28 kg*m^{-2}), Nadiia (G17) (0.29 kg*m^{-2}), UD0300104 (G4) (0.30 kg*m^{-2}), and Sperantsa (G11) (0.30 kg*m^{-2}). The distinguished genotypes are highly resistant to Fusarium (Fusarium Link.) infection, viruses (bean common mosaic virus, bean yellow mosaic virus, Nicotiana virus) and bacterial wilt (*Corynebacterium flaccumfaciens* (Halges) Dowson), tolerant to bacterial spots *Xanthomonas phaseoli* (E. Smith) Dowson, *Xanthomonas phaseoli* v. *fuskans* Burkholder, *Pseudomonas medicaginis* (Sackelt) v. *phaseolicola* (Burclh), *Pseudomonas vignae* Gardener et Kendrick). Holberg is the most valuable genotype, especially for the forest-steppe of Ukraine, since it is characterized by high drought tolerance. We recommend it as a reference accession for yield (Table 2).

Prelom is the most adapted to mechanized harvesting. Its plants are bushy with indeterminate growth and above-average resistance to lodging. Sperantsa has seeds of an above-average size (1000-seed weight is 0.30 kg). UD0300104 is the earliest ripening (the vegetation period is 73 days) (Table 3).

Table 3

Characteristics of the genotypes that are close to the "ideal" genotype according to the results of the trials in the eastern forest-steppe of Ukraine, 2015–2017

Genotype	Vegetation period, days	Plant type score[1)]	Lodging resistance score[2)]	1000-seed weight kg
Holberg	76	3	3	0.26
Prelom	80	1	6	0.21
Nadiia	76	3	5	0.23
UD030104	73	1	5	0.24
Sperantsa	79	3	3	0.30

[1)] – 1 – bushy, 3 – bushy with nutating top; [2)] – 3 – high, 5 – moderate, 6 – above-moderate

Fan et al. [28] used GGE biplot analysis to assess the discriminating and representative capacities of environments. Due to this method, the testing environments that are more informative for assessing the adaptability of the collection accessions were identified (Figure 4). The vector length is directly proportional to the standard deviation of the genotype yield in this environment. If the testing environment marker is close to the biplot center, i.e. has a short vector, all the genotypes have similar yields, so this environment is not informative for the differentiation of genotypes. A small angle between the environment vector indicates a strong correlation between the genotype yields in these environments [29, 30]. Thus, the GGE biplot categorized the testing sites of the environment trials into three groups.

Group I includes the PBGI site (southern Steppe of Ukraine) with a short vector, which indicates a low informativity of this environment about the genotypes under investigation. The accessions grown in this site gave similar yields (Table 2). This is a region with high summer temperatures and water deficit. Consequently, all the genotypes were suppressed by drought and heat, which made it impossible to determine the whole range of their adaptive features. However, we identified genotypes with high drought- and heat-tolerance: Holberg (G6) and Bukovinka (G20), which gave the highest yields in this environment.

Group II includes the site with a long vector and a large angle with the AEC axis – BSAES (Woodlands of Ukraine). This environment has the highest discriminating capacity, which does not allow evaluating genotypes in terms of the whole range of adaptive features, either. Excess water prevents from determining the level of drought tolerance – a trait that limits the bean cultivation in Ukraine. In this environment, the intensive genotypes were chosen: Pervomaiska, Mistseva Bomba 5, Sperantsa and Prelom, which gave seed yields of over 0.50 $kg*m^{-2}$ (Table 2).

Group III includes the environments that have long vectors and moderate yields (eastern and southern forest-steppe of Ukraine – PPI and UES, respectively) and are the most informative for assessing the adaptability of genotypes. These sites of the environment trials are located in the moderately moistened zone and allow evaluating genotypes for stability of seed yields.

Thus, the GGE biplot analysis of the environments singled out the most informative sites of the environment trials, where the study of the genotypes was continued in 2015–2017: PPI – eastern Forest-Steppe of Ukraine and UES – southern Forest-Steppe.

The weather during the bean vegetation period in 2015–2017 differed both between the sites of the environment trials (eastern Forest-Steppe – PPI and southern Forest-Steppe – UES) and between the study years (Figure 5).

2015 was the most favourable year (HTC: PPI – 1.17, UES – 1.20). The 2016 hydrothermal balance at UES was close to optimal (HTC = 0.97), whereas the PPI site was waterlogged (HTC = 1.88), which caused severe damage of bean plants by Fusarium and bacterial infections. In 2017, there was a water deficit for the crop growth and development (HTC: PPI – 0.28, UES – 0.73), especially at the PPI. This accordingly affected the average yield throughout the genotypes: in 2015 PPI – 0.20 $kg*m^{-2}$, UES – 0.26 $kg*m^{-2}$; in 2016 PPI – 0.17 $kg*m^{-2}$, UES – 0.22 $kg*m^{-2}$; in 2017 PPI – 0.14 $kg*m^{-2}$, UES – 0.18 $kg*m^{-2}$.

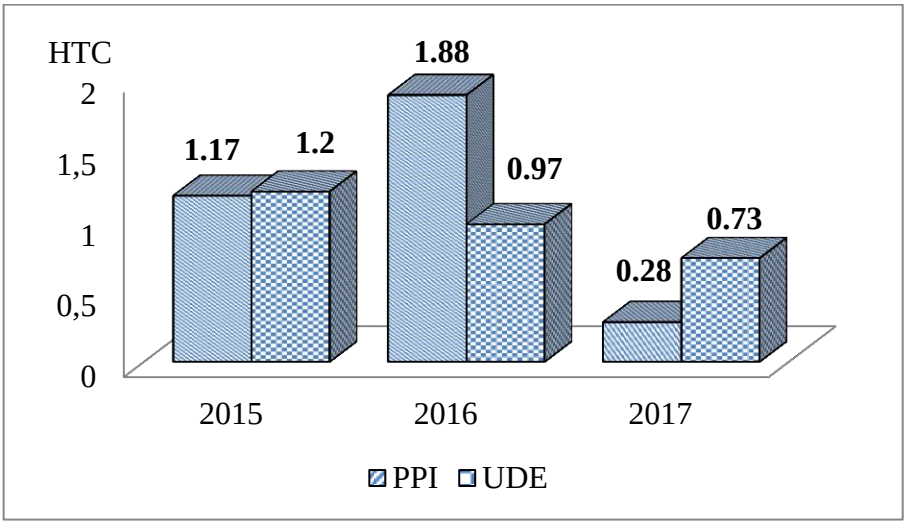

Figure 5. The weather in the eastern (PPI) and southern (UES) Forest-Steppe of Ukraine

Thus, the informative environments have different characteristics: the weather in the eastern Forest-Steppe of Ukraine is rougher for the bean growth and development than that in the southern Forest-Steppe. The temperature/moisture ratio in the eastern Forest-Steppe varied greatly (HTC = 0.28–1.88), whereas in the southern Forest-Steppe the hydrothermal balance was more stable (HTC = 0.73–1.20).

As a result of the three-year study, we identified the most productive genotypes: for the eastern Forest-Steppe of Ukraine (PPI) – UD0300076 (G3) (0.36 kg*m^{-2}), Holberg (G6) (0.31 kg*m^{-2}) and UD0300104 (G4) (0.36 kg*m^{-2}); for the southern Forest-Steppe (UES) – Holberg (G6) (0.36 kg*m^{-2}, Dniprovska Bomba (G12) (0.34 kg*m^{-2}), UD0300104 (G4) (0.31 kg*m^{-2}) and Nespodivanka (G21) (0.31 kg*m^{-2}) (Table 4).

Table 4

Bean seed yield in the eastern (PPI) and southern (UES) forest-steppe of Ukraine

Genotype	Name	Bean seed yield kg*m^{-2}							
		PPI				UES			
		2015	2016	2017	average	2015	2016	2017	average
G1	Pervomaiska	0.16	0.04	0.02	0.07	0.16	0.18	0.14	0.16
G2	Prelom	0.16	0.22	0.07	0.15	0.45	0.18	0.12	0.25
G3	UD0300076	0.38	0.48	0.21	0.36	0.26	0.13	0.13	0.17
G4	UD0300104	0.33	0.27	0.23	0.28	0.38	0.35	0.21	0.31
G5	UD0300152	0.07	0.07	0.07	0.07	0.12	0.10	0.08	0.10
G6	Holberg	0.35	0.28	0.31	0.31	0.44	0.32	0.33	0.36
G7	Synelnykivska 8	2.22	0.20	0.16	0.19	0.30	0.20	0.14	0.21
G8	Belgorodskaia 1	0.16	0.13	0.19	0.16	0.16	0.16	0.12	0.15
G11	Sperantsa	0.23	0.21	0.17	0.20	0.10	0.06	0.27	0.14
G12	Dniprovska Bomba	0.22	0.22	0.17	0.20	0.48	0.29	0.26	0.34
G15	Dokuchaevska	0.18	0.04	0.02	0.08	0.16	0.29	0.24	0.23
G16	Yuvileina 287	0.19	0.15	0.20	0.18	0.20	0.10	0.14	0.15
G17	Nadiia	0.19	0.16	0.15	0.17	0.40	0.25	0.16	0.27
G19	Otrada	0.22	0.20	0.15	0.19	0.25	0.26	0.19	0.23
G21	Nespodivanka	0.26	0.23	0.12	0.20	0.27	0.39	0.26	0.31
G22	Veselka	0.16	0.12	0.10	0.13	0.28	0.21	0.22	0.24
G23	Bogema	0.09	0.05	0.09	0.08	0.19	0.13	0.09	0.14
G24	Panna	0.14	0.21	0.15	0.17	0.29	0.40	0.21	0.30
G25	N 201-15	0.19	0.04	0.01	0.08	0.06	0.21	0.08	0.12
	Average	0.20	0.17	0.14		0.26	0.22	0.18	
	LSD_{005}	0.05	0.06	0.04		0.07	0.06	0.04	

The GGE biplot analysis showed that the most stable seed yields were obtained from Holberg (G6), Otrada (G19), UD0300104 (G4), Bogema (G23), UD0300152 (G5), N 201-15 (G25) and Synelnykivska 8 (G7) (Figure 6). Holberg and UD0300104 were close to the “ideal” genotype (Figure 7).

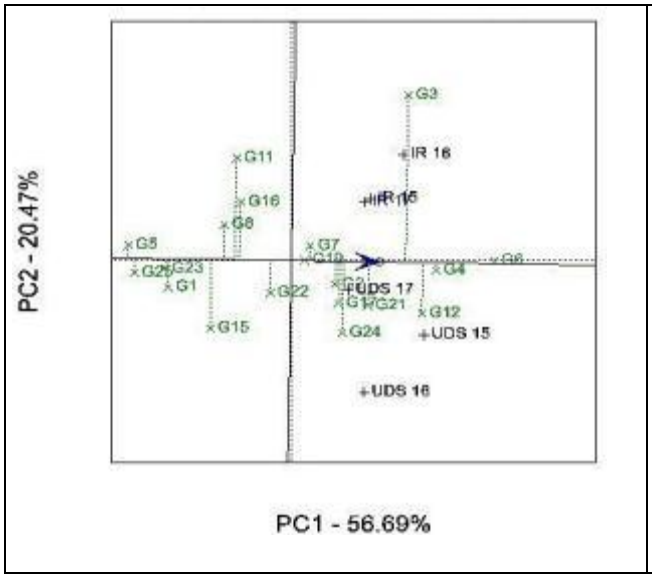

Figure 6. GGE biplot, “mean vs. stability”

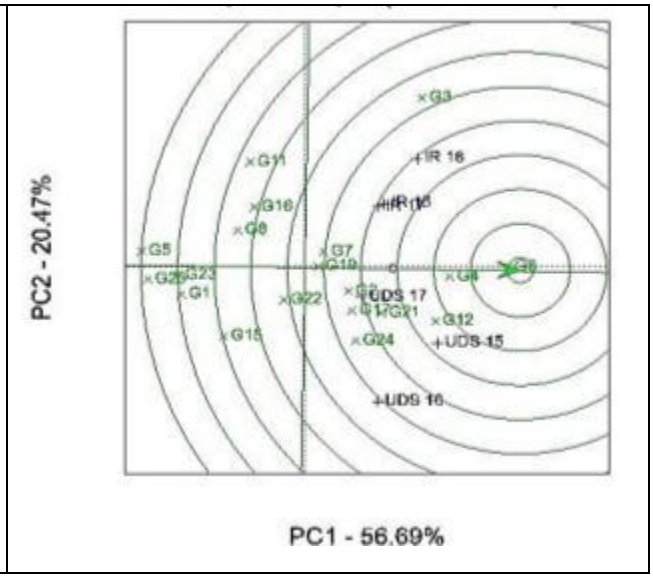

Figure 7. GGE biplot, genotypes close to the “ideal” genotype

Conclusions. The environment trials of the bean genotypes at the sites differing in the climatic conditions ensured comparison of their informativity. It was established that the southern Steppe (PBGI) and Woodlands of Ukraine (BSAES) did not allow a full assessment of the adaptive potentials of the genotypes due to the extreme for bean weather during its vegetation period: at the PBGI site, it is high temperatures and water deficit in summer; at the BES site – excess water. However, these environments are necessary for evaluating drought- and heat-tolerance (PBGI) as well as for identification of genotypes with high potential yields (BSAES). The weather conditions in the eastern (PPI) and southern (UES) Forest-Steppe of Ukraine, which make it possible to assess genotypes in terms of stability of their seed yields, are the most informative for assessing the adaptability of the genotypes.

When developing cultivars for different zones of Ukraine, one should select parents, taking into account their responses to the weather: for the South of Ukraine (PBGI) – drought-tolerant genotypes with high heat tolerance (Holberg); for the Woodlands (BSAES) – intensive genotypes (Mistseva Bomba 5, Pervomaiska); for the Forest-Steppe (PPI and UES) – stable genotypes with high drought tolerance (Holberg, Nadiia, UD0300104).

The study of the bean genotypes in the Forest-Steppe of Ukraine (PPI and UES) revealed that the following genotypes gave the most stable yields of seeds: Holberg, Otrada, UD0300104, Bogema, UD0300152, N 201-15 and Synelnykivska 8; of them Holberg, Otrada, UD0300104 and Synelnykivska 8 are noticeable for high yields. Holberg and UD0300104 were close to the “ideal” genotype.

Acknowledgments. We are deeply grateful to the teams that participated in the environment trials in compliance with all methodological requirements: the Department of Legume Breeding, Genetics and Seed Production of the Plant Breeding and Genetics Institute - National Center of Seed and Cultivar Investigation and personally to Candidate of Agricultural Sciences Oleh Volodymyrovych Bushulian and Candidate of Biological Sciences Halyna Dmytrivna Lavrova; to the Laboratory of Grain Legumes, Groat Crops and Corn of Ustymivka Experimental Station of Plant Production of Yuriev Plant Production Institute and personally to Candidate of Agricultural Sciences Serhei Ivanovych Sylenko; to the Laboratory of Grain Legumes of the Bukovina State Agricultural Experimental Station of the Institute of Agriculture of the Carpathian

Region and personally to Candidate of Agricultural Sciences, Honored Worker of Agriculture Mariia Hryhorivna Holokhorynska.

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ЕКОЛОГІЧНЕ ВИПРОБУВАННЯ ГЕНОТИПІВ КВАСОЛІ В КОНТРАСТНОМУ СЕРЕДОВИЩІ

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Мета досліджень – визначити можливості окремо взятого генотипу та запропонувати селекціонерам вихідний матеріал, який адаптовано до регіону, де буде створено майбутній сорт.

Матеріали і методи. Для досягнення поставленої мети було проведено екологічне вивчення колекційних зразків квасолі (*Phaseolus* L.) в чотирьох пунктах, які відрізняються один від одного за кліматичними характеристиками: Інститут рослинництва ім. В.Я. Юр'єва НААН – м. Харків, східний Лісостеп; Устимівська дослідна станція рослинництва Інституту рослинництва ім. В.Я. Юр'єва НААН – Полтавська область, південний Лісостеп; Буковинська державна сільськогосподарська дослідна станція Інституту сільського господарства Карпатського регіону НААН – м. Чернівці, Полісся; Селекційно-генетичний інститут – Національний центр насіннєзнавства та сортовивчення – м. Одеса, південний Степ.

Обговорення результатів. Оцінку генотипів та середовища досліджень проводили методом GGE biplot, який дозволяє візуально представити результати екологічного випробування. Установлено, що кліматичні умови південного Степу та Полісся України не дозволяють в повній мірі оцінити адаптивний потенціал генотипу через екстремальні для квасолі погодні умови в період її вегетації: Селекційно-генетичний інститут – Націона-

льний центр насіннєзнавства та сортовивчення – високі літні температури та недостатнє вологозабезпечення рослин, Буковинська державна сільськогосподарська дослідна станція Інституту сільського господарства Карпатського регіону НААН – надлишок вологи. Але ці середовища необхідні для визначення стійкості до посухи і спеки (Селекційно-генетичний інститут – Національний центр насіннєзнавства та сортовивчення) та визначення генотипів з високою потенційною урожайністю (Буковинська державна сільськогосподарська дослідна станція Інституту сільського господарства Карпатського регіону НААН). Найбільш інформативні для оцінки адаптаційних властивостей генотипів є погодні умови східного (Інститут рослинництва ім. В.Я. Юр'єва НААН) та південного (Устимівська дослідна станція рослинництва Інституту рослинництва ім. В.Я. Юр'єва НААН) Лісостепу України, які дозволяють оцінити генотип за стабільністю урожаю насіння.

Висновки. В результаті проведеного GGE biplot-аналізу, рекомендуємо при створення сортів для різних кліматичних зон України добирати батьківські форми, виходячи з погодних умов: південь України – посухостійкі генотипи з високою стійкістю до спеки (Holberg), Полісся – генотипи інтенсивного типу (Первомайська, Місцева бомба 5), Лісостеп – стабільні генотипи з високою посухостійкістю (Holberg, Надія, UD030104). Виявлені стабільні генотипи: Holberg, Отрада, UD0300104, Bogema, UD0300152, N 201-15 і Сінельниківська 8. З них поєднували стабільність та високу урожайність насіння: Holberg, Отрада, UD0300104 і Сінельниківська 8. Наближалися до «ідеального» генотипу Holberg і UD0300104.

Ключові слова: *квасоля, генотип, середовище, GGE biplot*

ЭКОЛОГИЧЕСКОЕ ИСПЫТАНИЕ ГЕНОТИПОВ ФАСОЛИ В КОНТРАСТНЫХ СРЕДАХ

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Цель исследований – выявить возможности отдельно взятого генотипа и предложить селекционерам исходный материал, адаптированный к региону, где будет создаваться будущий сорт.

Материалы и методы. Для достижения поставленной цели, было проведено экологическое испытание коллекционных образцов фасоли (*Phaseolus* L.) в четырех пунктах, которые отличаются по климатическим характеристикам: Институт растениеводства им. В.Я. Юрьева НААН – г. Харьков, восточная Лесостепь; Устимовская опытная станция растениеводства Института растениеводства им. В.Я. Юрьева НААН – Полтавская область, южная Лесостепь; Буковинская государственная сельскохозяйственная опытная станция Института сельского хозяйства Карпатского региона НААН – г. Черновцы, Полесье; Селекционно-генетический институт – Национальный центр семеноведения и сортоизучения – г. Одесса, южная Степь.

Обсуждение результатов. Оценку генотипов и сред исследований проводили методом GGE biplot, который позволил графически визуализировать результаты экологического испытания. Рекомендуем при создании сортов для разных зон Украины подбирать родительские формы, исходя из погодных условий: юг Украины – засухоустойчивые генотипы с высокой жаростойкостью (Holberg), Полесье – генотипы интенсивного типа (Первомайська, Місцева бомба 5), Лесостепь – стабильные генотипы с высокой засухоустойчивостью (Holberg, Надія, UD030104).

Выводы. По результатам GGE biplot анализа были определены пункты экологического испытания, которые позволяют в полной мере оценить адаптивный потенциал генотипа: Институт растениеводства им. В.Я. Юрьева НААН и Устимовская опытная станция рас-

тениеводства. В их условиях определены стабильные генотипы: Holberg, Отрада, UD0300104, Bogema, UD0300152, N 201-15 и Сінельниківська 8. Из них совмещали стабильность и высокую урожайность: Holberg, Отрада, UD0300104 и Сінельниківська 8. Приближались к «идеальному» генотипу Holberg и UD0300104.

Ключевые слова: *фасоль, генотип, середа, GGE biplot*

ENVIRONMENTAL TRIALS OF A MODEL POPULATION OF PHASEOLUS VULGARIS L. IN CONTRAST CLIMATES

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Purpose – assess the capacities of a particular genotype and to offer breeders starting material that is adapted to a region where a would-be variety will be created.

Materials and Methods. To accomplish this purpose, an environmental trial of collection bean (*Phaseolus* L.) accessions was carried out in four locations, which that differ in climatic characteristics: Plant Production Institute named after V.Ya. Yuriev NAAS – Kharkiv, eastern Forest-Steppe; Ustymivka Experimental Station of Plant Production of the Plant Production Institute named after V.Ya. Yuriev NAAS – Poltavska Oblast, southern Forest-Steppe; Bukovyna State Agricultural Experimental Station of the Institute of Agriculture of the Carpathian Region of NAAS – Chernivtsi, Woodlands; Plant Breeding and Genetics Institute -National Center of Seed and Cultivar Investigation – Odesa, southern Steppe.

Results and discussion. Genotypes and test environments were assessed by GGE biplot method, which made it possible to graphically visualize the environmental trial results. To create varieties for different zones of Ukraine, we recommend to select parents with due account for weather conditions: South of Ukraine – drought-resistant genotypes with high heat resistance (Holberg); Woodlands – intensive genotypes (Pervomaiska, Mistseva Bomba 5); Forest-Steppe –stable genotypes with high drought resistance (Holberg, Nadiia, UD030104).

Conclusions. From the GGE biplot results, the environmental trial locations, which allow one to fully assess the adaptability of a genotype, were identified: Plant Production Institute named after V.Ya. Yuriev NAAS and Ustymivka Experimental Station of Plant Production. In their conditions, stable genotypes were distinguished: Holberg, Otrada, UD0300104, Bogema, UD0300152, N 201-15 and Sinelnikivska 8. Of these accessions, Holberg, Otrada, UD0300104 and Sinelnikivska 8 combined stability and high performance, approaching the "ideal" genotypes Holberg and UD0300104.

Key words: *bean, genotype, environment, GGE biplot*