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ADAPTIVE ABILITIES OF BROAD BEAN (*VICIA FABA* L.) ACCESSION IN TERMS OF MAIN QUANTITATIVE TRAITS

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The experimental activity was conducted at the Institute of Forage Crops (Pleven) during the period 2016 – 2018. The adaptive ability of 10 broad bean accessions was determined with respect to main quantitative traits based on parametric and nonparametric analysis. The environment influences to the highest degree the traits of 1st pod height, pods number and seed weight per plant. The plant height and seeds number were strongly influenced by the genotype, and the mass of 100 seeds was determined by the genotype × environment interaction. The broad bean accessions can be distributed as follows: Fb 1929 has a high value of the 1st pod height (34 cm) and is characterized by high plasticity and stability; BGE 029055 and Fb 1896 are stable and form a large number of pods per plant (11 – 15); Fb 1896 and Fb 2486 are distinguished with good adaptability and stability, increased seed weight (28.01 and 30.28 g, respectively) and 100 seeds mass (105.48 g and 91.31 g). Accessions BGE 032012 and Fb 2481 represent a selection value in terms of plant height (61.36 and 65.83 cm); Fb 1929 – in 1st pod height (32.46 cm); and BGE 029055, Fb 1896 and Fb 2486 – in pods number (10.59, 9.67 and 11.89). Fb 1896, Fb 2486 and BGE 041470 can be used to develop a new genetic diversity in breeding aimed at increasing the mass of 100 seeds and seed productivity.

Key words: adaptability, selection value, trait, broad bean

Broad bean (*Vicia faba* L.) is a diploid species with 2n = 12 chromosomes. It belongs to the family of Fabaceae, subfamily of *Papilionoideae*, genus of *Vicia*. It is considered that broad bean is an important protein-rich food for animals and humans. It covers the requirements for a nutritional rate. Fortunately, the genetic variability of this species is large. Based on differences regarding seed weight, shape and size, most researchers focus on the following varieties: *V. faba paucijuga*, *V. faba major*, *V. faba equina* and *V. faba minor* (Fernandez *et al.* 1996; Ouji *et al.* 2011).

Such as other crops, the broad bean is exposed to biotic and abiotic stresses which decrease yield and affect stability. Abiotic stresses such as high temperature and drought mainly limit crop productivity (Pandey *et al.* 2017). The demand for genotypes with high yield and stability is a key aspect in breeding programs that aim to develop cultivars with high performances under different growing areas. The interaction of genotype × environment strongly affects genotype manifestations, making the creation of new cultivars difficult. One way to use this interaction is to identify genotypes with high productive capacity and phenotypic stability in various environments (Milioli *et al.* 2018).

Numerous methods for studying the stability and productivity of genotypes are described in the scientific literature. These methods differ in the estimated parameters and statistics. Investigations compar-

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ing different methods have already been conducted in different crops such as wheat (Bornhofen *et al.* 2017), maize (Cargnelutti *et al.* 2009), common beans (Pereira *et al.* 2009), cowpea (Torres *et al.* 2016) and others. Among the basic methods applied to study the phenotypic stability of genotypes are univariate parametric models (Eberhart & Russell 1966), multivariate parametric models (Zobel *et al.* 1988; Yan 2001), nonparametric models (Lin & Binns 1988) and mixed models (Resende 2006).

The purpose of this study was to determine, by applying appropriate methods, broad bean accessions adapted to the local climatic conditions for the needs of combinative breeding.

MATERIAL AND METHODS

The experimental work was conducted at the Institute of Forage Crops (Pleven) during the period 2016 – 2018. The collection included 10 accessions of broad bean (*Vicia faba* L.), originating in Portugal (Fb 1896, Fb 1903, Fb 1929, Fb 2481, Fb 2486, Fb 3270) and Spain (BGE 002106, BGE 029055, BGE 032012, BGE 041470). It was used a randomized block method (Barov 1982). The sowing was done by hand, with a rate of 30 seeds/m^2, a plot size of 4 m^2 and three replications. Broad bean was grown under organic farming conditions without the use of fertilisers and pesticides. The biometric characteristics of the accessions included the following traits: plant height [cm], 1st pod height [cm], pods number per plant, pod length [cm], pod width [cm], seeds number per plant, seed weight per plant [g], 100 seeds mass [g].

The obtained data were processed by two-factor analysis of variance for each trait for determine of the influence of the factors of genotype (accessions) (G) and environment (E). For quantitative assessment of the stability and plasticity parameters was used the methodology of (Kilchevskiy & Hotyleva 1985a) and (Kilchevsky & Hotyleva 1985b) based on cultivar testing in different environments and allowing determination of: general (GAA) and specific adaptive ability (SAA), relative stability of the genotypes (Sgi), their interaction with environment (G×Egi) and reaction to the environment (Igi), as well as selective value of genotype (SVG) with an aim selecting high-productive and stable forms. The adaptability of the broad bean accessions was also determined by means of non-paramedical (rank) analysis (Nascimento *et al.* 2009), index of stability (IS) of the genotype (Nettevich 2001) and the stability parameter "bi" (Finlay & Wilkinson 1963)

All experimental data were processed statistically using the computer software GENES 2009.7.0 for Windows XP (Cruz 2006).

RESULTS

The results of the data on the variance of the productivity elements in the broad bean accessions were presented in Table 1. The environment (year), to the greatest degree, was a decisive factor for the performance of the traits of 1st pod height, pods number and seed weight per plant. The formation of plant height and seeds number was more strongly influenced by genotype than by the year. The mass of 100 seeds in the studied group of accessions was determined by the interaction genotype × environment, which occupied a major share in the total variation of this trait.

With regard to the trait of plant height (Figure 1), the average for the study period, accessions Fb 3270, Fb 1896 and BGE 032012 formed higher plants than others. Data on stability and adaptability showed that not all accessions whose plants were higher exhibited instability. According to the parameter „bi" BGE 032012 was very stable (bi = 0.18), while Fb 1896 and Fb 1903 were unstable under unfavorable environmental conditions (Table 2).

The adaptability of genotype under specific environmental conditions, expressed by the values of SAA and Sgi, showed that the BGE 029055 and Fb 2486 were the least variable, but their plants were one of the lowest (65 – 68 cm). In terms of GAA, Fb 3270 was standing out, followed by Fb 1896 and Fb 1929. The higher the general adaptive ability, the better the genotype was adapted to different environmental conditions. The selective value of genotype was an aggregated indicator combining productivity and adaptability, more pronounced in BGE 032012 (61.36) and Fb 2481 (65.83).

The results of the biometric analysis showed a high-situated 1st pod (33 – 35 cm) in Fb 2481, Fb

1929 and Fb 3270, and respectively a low-located 1st pod (22 – 24 cm) in BGE 029055 and Fb 2486. The coefficient of regression (bi) gave similar information with the parameter Sgi regarding the trait variability under different environmental conditions. In terms of 1st pod height, no one of the accession was close to the "ideal" type (bi ≈ 1). Accessions BGE 002106, BGE 032012, Fb 2481, Fb 1903 and BGE 041470 had regression coefficients considerably exceeding one (bi > 1). Fb 2486 and Fb 3270 could be characterized as ecologically stable (bi < 1), but with a very low-situated 1st pod. Fb 1929 was manifested as stable both with respect to the regression coefficient and the values of the other parameters. The combination of good stability and high-situated 1st pod defined this accession as the most valuable one. According to the parameter SVG, Fb 2481 (31.18 cm) and BGE 032012 (30.59 cm) were also of interest.

Judging by the results regarding pods number per plant, accessions BGE 029055 and Fb 1896 were distinguished by the formation of more pods. For this trait, they were defined as stable, with coefficient „bi" < 0.3. BGE 002106 and BGE 041470 were also stable (bi = 0.34; bi = 0.26) but did not succeed to form more than 8 – 10 pods. Fb 2486 was unstable, but responsible and placed under favorable environmental conditions could form up to 10 pods per plant.

The accessions studied (with the exception of Fb 3270) were similar in GAA, and the values of this parameter were very close. Expression of the behavior of genotype in given environmental conditions is presented by the parameter of specific adaptive ability (SAA). More stable genotypes have low values for SAA. With such characteristics were Fb 2486 (0.04), BGE 032012 (0.19) and Fb 1896 (0.24). The ability of a genotype to maintain a certain level of the trait at a different background of the environment is represented by the parameter of relative stability (Sgi). This indicator as an interpretation is analogous to the coefficient of variation. According to the data obtained for Sgi, GAA, and SVG, selective valuable accessions were BGE 029055 (10.59), Fb 1896 (9.67) and Fb 2486 (11.89) (Table 2).

The accessions included in the study differed in the number of seeds formed (Figure 1) – from 22 (Fb 1929 and Fb 2481) to 41 (BGE 029055). BGE 029055 was one of the most stable (bi = 0.17) in this study. With a value for "bi" slightly above one was BGE 002106, which formed seeds above the average number for the group and can be referred to the plastic genotypes forming a sufficient number of seeds in both favorable and unfavorable environmental conditions. The accessions were characterized by different specific adaptive abilities, best shown regarding Fb 2481 (2.07), Fb 1929 (2.84) and Fb 1896 (6.71). With high values for SVG were Fb 2486 and BGE 041470 (26.19, 29.39).

When analyzing adaptability regarding 100 seeds mass, the broad bean accessions can be divided into

T a b l e 1

Analysis of variance regarding the studied traits in broad bean accessions

Source of variation	*df*	Mean squares					
		plant height	1st pod height	pods number	seeds number	100 seeds mass	seed weight
Year	2	0.514	178.484++	78.698++	123.698++	1.400++	0.506++
Replication ×Year	6	1.993	0.669	0.171	2.707	0.095	0.012++
Accession	9	206.613++	170.302++	43.560++	698.853++	10.677++	0.217++
Accession × Year	18	174.118++	68.676++	37.603++	182.961++	12.209++	0.091++
Error	54	2.792	2.154	0.202	2.499	0.087	0.002
Corrected Total	89	–	–	–	–	–	–

+ – significant at $P < 0.05$, ++ – significant at $P < 0.01$

several groups. Definitely stable (bi < 1) were BGE 041470 and Fb 1896 which had a high value for this trait, as well as BGE 032012, Fb 2486 and BGE 029055, which were with relatively lightweight seeds. Accessions Fb 1903, Fb 2481, Fb 3270 and BGE 002106 differed considerably in the performance of this trait, but they all showed very strong instability. However, an advantage can be given to Fb 3270, with a mass of 100 seeds over 102 g. Generally, in terms of general and specific adaptability, attention was paid to Fb 1896, which had the heaviest seeds. With higher requirements for specific environmental conditions were characterized accessions Fb 1903 (SAA = 17.31), BGE 041470 (SAA = 39.72) and Fb 2486 (SAA = 52.31). Fb 2486, BGE 041470 and Fb 1896 were distinguished by high values of the parameter SVG (24.89 – 30.97).

According to the shown stability level of seed weight, most of the low and medium-productive accessions (such as Fb 1929, Fb 3270 and BGE 032012) could be evaluated as stable, with the regression coefficient less than one (bi < 1) (especially

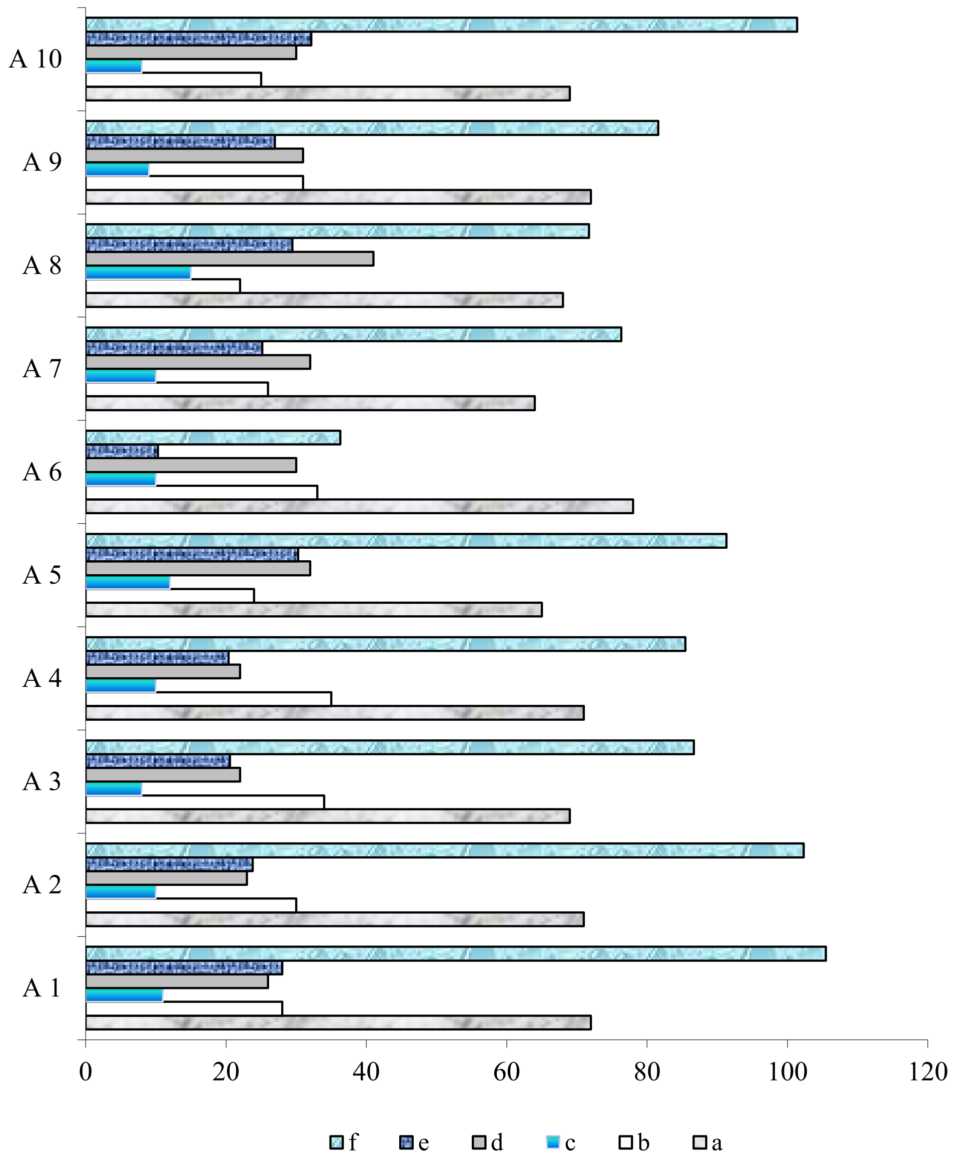

Figure 1. Quantitative traits in investigated accessions of broad bean

a – plant height; b – 1st pod height; c – pods number; d – seeds number; e – seed weight; f – 100 seeds mass
A1-Fb 1896, A2-Fb 1903, A3-Fb 1929, A4-Fb 2481, A5-Fb 2486, A6-Fb 3270, A7-BGE 002106,A8-BGE 029055, A9-BGE 032012, A10-BGE 041470

T a b l e 2

Adaptive ability of quantitative traits in broad bean accessions

Accessions	b_i	G×Egi	SAA	GAA	Sgi [%]	Igi	SVG
Plant height							
Fb 1896	20.44	25.33	17.43	16.19	22.52	1.45	32.75
Fb 1903	5.42	64.04	23.28	4.29	6.01	2.75	61.03
Fb 1929	7.29	25.34	11.47	11.28	16.38	2.21	41.57
Fb 2481	0.34	29.39	10.77	2.03	2.87	2.73	65.83
Fb 2486	19.85	1.16	1.71	0.93	1.42	0.68	62.97
Fb 3270	6.64	240.31	116.96	116.86	149.12	2.05	–204.14
BGE 002106	31.29	21.92	14.04	0.58	0.91	1.56	62.59
BGE 029055	0.56	1.27	0.75	0.71	1.05	1.70	66.41
BGE 032012	0.18	6.67	4.68	4.42	6.14	1.42	61.36
BGE 041470	27.31	14.80	6.36	0.29	0.41	2.33	68.23
1st pod height							
Fb 1896	0.76	4.68	1.72	0.65	2.30	2.72	27.27
Fb 1903	1.58	7.52	3.54	3.48	11.59	2.13	24.5
Fb 1929	0.84	30.26	12.51	0.68	2.03	2.42	32.46
Fb 2481	1.74	29.07	21.41	2.32	6.67	1.36	31.18
Fb 2486	0.08	4.96	1.80	0.80	3.26	2.75	23.21
Fb 3270	0.19	80.89	42.13	42.08	127.97	1.92	–33.80
BGE 002106	2.44	20.75	21.18	10.47	40.06	0.98	9.54
BGE 029055	0.38	38.87	34.91	25.93	118.74	1.11	–19.25
BGE 032012	2.02	10.87	5.55	0.10	0.01	1.96	30.59
BGE 041470	1.24	3.63	1.36	0.73	2.91	2.68	23.81
Pods number							
Fb 1896	0.01	0.39	0.24	0.23	2.08	1.63	9.67
Fb 1903	2.17	5.87	4.17	0.39	4.05	1.41	6.96
Fb 1929	1.18	1.32	0.59	0.02	0.19	2.25	7.93
Fb 2481	0.64	2.03	1.17	0.02	0.18	1.73	9.39
Fb 2486	2.97	0.05	0.04	0.03	0.28	1.42	11.89
Fb 3270	0.93	14.97	6.30	6.06	61.35	2.38	–30.99
BGE 002106	0.34	0.31	0.35	0.19	1.87	0.89	8.71
BGE 029055	0.20	0.97	0.62	0.60	4.09	1.58	10.59
BGE 032012	1.32	0.37	0.19	0.01	0.01	1.91	9.44
BGE 041470	0.26	0.90	0.51	0.01	0.03	1.77	8.30
Seeds number							
Fb 1896	0.14	13.51	6.71	6.70	25.5	2.01	21.96
Fb 1903	3.17	34.39	18.05	0.02	0.09	1.90	22.91
Fb 1929	0.60	5.69	2.84	0.02	0.11	2.01	22.09
Fb 2481	0.07	4.88	2.07	0.21	0.94	2.36	21.89
Fb 2486	0.18	22.60	9.61	9.20	28.66	2.35	26.19
Fb 3270	3.20	269.46	143.29	142.81	468.48	1.88	–61.23
BGE 002106	1.26	58.53	51.49	39.16	121.49	1.14	7.08
BGE 029055	0.17	64.76	44.53	41.08	101.26	1.45	14.19
BGE 032012	2.85	50.90	17.14	8.22	26.58	2.97	25.66
BGE 041470	2.45	38.73	14.94	1.64	5.40	2.59	29.39

Table 2 continue

Seed weight							
Fb 1896	0.85	6.77	7.05	4.38	15.63	0.96	24.89
Fb 1903	2.11	51.04	17.31	6.77	28.45	2.95	18.99
Fb 1929	0.42	11.15	5.61	0.01	0.04	1.99	20.57
Fb 2481	1.07	4.74	2.34	0.03	0.16	2.03	20.35
Fb 2486	0.51	71.91	52.31	5.55	18.33	1.37	26.33
Fb 3270	0.30	107.68	63.71	62.22	604.6	1.69	–33.95
BGE 002106	1.01	1.33	0.61	0.27	1.06	2.19	24.99
BGE 029055	1.46	6.49	6.72	2.44	8.29	0.97	27.71
BGE 032012	0.10	27.83	9.52	5.81	21.55	2.92	22.83
BGE 041470	2.38	94.79	39.72	1.65	5.12	2.39	30.97
100 seeds mass							
Fb 1896	0.51	4.04	7.05	4.38	15.63	0.57	24.89
Fb 1903	6.11	48.31	17.31	6.77	28.45	2.79	18.99
Fb 1929	0.77	8.42	5.61	0.01	0.04	1.50	20.57
Fb 2481	6.22	2.01	2.34	0.03	0.16	0.86	20.35
Fb 2486	0.50	69.18	52.31	5.55	18.33	1.32	26.33
Fb 3270	3.74	104.95	63.71	62.22	604.6	1.65	–33.95
BGE 002106	3.72	–1.40	0.61	0.27	1.06	–2.30	24.99
BGE 029055	0.53	3.76	6.72	2.44	8.29	0.56	27.71
BGE 032012	0.11	25.1	9.52	5.81	21.55	2.64	22.83
BGE 041470	0.14	92.06	39.72	1.65	5.12	2.32	30.97

b_i – regression coefficient according to Finlay and Wilkinson (1963); (G×E)gi – criterion for estimation of the genotype ability to interact with environment; SAA – specific adaptive ability; GAA – general adaptive ability; Sgi – relative stability of the genotypes; Igi – reaction to the environment; SVG – selective value of genotype

T a b l e 3

Adaptability determined by nonparametric analysis (Nascimento *et al.* 2009) in broad bean accessions

Accessions	Plant height	1st pod height	Pods number	Seeds number	100 seeds mass	Seed weight
Fb 1896	V	V	V	V	VI	V
Fb 1903	V	V	V	IV	VII	VII
Fb 1929	V	V	IV	IV	V	V
Fb 2481	V	VI	V	IV	V	V
Fb 2486	IV	IV	V	V	V	V
Fb 3270	II	II	III	III	IV	IV
BGE 002106	IV	V	V	V	V	V
BGE 029055	V	IV	VII	VI	V	VII
BGE 032012	V	V	V	V	V	V
BGE 041470	V	IV	IV	V	VII	VII

I: high general adaptability; II: adaptability under favorable conditions; III: adaptability under unfavorable conditions; IV: low adaptability; V: average general adaptability; VI: adaptability under average favorable conditions; VII: adaptability under average unfavorable conditions

BGE 032012 and Fb 3270). Fb 2486 (by the value of the trait) occupied the third position, with a seed weight of about 30 g. It had good stability (bi = 0.51) and, together with Fb 3270 and BGE 041470, interacted better with environmental conditions as compared to the rest of accessions.

On the basis of the parameters „bi" and „G×Egi", accession BGE 029055 reacted positively to changes in the environmental conditions and combined high productivity (29.45) and favorable general (2.44) and specific adaptive ability (6.72). Among the accession studied, Fb 1929, Fb 2481 and BGE 002106, were distinguished by lower values of the parameter Sgi. The values obtained regarding Igi for Fb 1896 and BGE 029055 assume that they will have a linear response to environmental changes. Accessions Fb 1896, Fb 2486, BGE 029055 and BGE 041470 were the compromise variant combining stability and high selection value of the genotype (24.89, 26.33, 27.71, 30.97).

T a b l e 4

Index of stability (IS) (Nettevich 2001) of broad bean accessions

Accessions	Plant height	1^{st} pod height	Pods number	Seeds number	Seed weight	100 seeds mass
Fb 1896	3.638	1.446	0.455	1.566	0.927	0.551
Fb 1903	2.636	1.246	0.280	0.551	0.747	0.529
Fb 1929	3.032	1.359	0.228	0.724	0.447	0.347
Fb 2481	2.672	1.250	0.325	0.687	0.703	0.344
Fb 2486	2.452	0.991	0.609	2.117	0.393	0.551
Fb 3270	1.931	0.824	0.474	0.786	0.404	0.238
BGE 002106	2.361	6.200	0.383	0.735	0.321	0.514
BGE 029055	2.608	2.702	0.681	1.154	0.576	0.633
BGE 032012	2.468	1.793	0.368	0.854	0.383	0.477
BGE 041470	2.512	1.179	0.273	0.983	0.547	0.635

T a b l e 4

Correlation dependencies in broad bean accessions

Parameters	b_i	(G×E)gi	SAA	GAA	Sgi	Igi	SVG
(G×E)gi	0.143						
SAA	–0.064	0.945^{++}					
GAA	–0.332	0.640^{+}	0.698^{+}				
Sgi	–0.330	0.617	0.676^{+}	0.997^{++}			
Igi	0.203	0.154	–0.103	–0.104	–0.114		
SVG	0.381	–0.524	–0.579	$–0.974^{++}$	$–0.981^{++}$	0.048	
Seed weight per plant	–0.296	0.282	0.344	0.156	0.159	0.072	–0.119

$^{+}$ / $^{++}$ significant at 0.05/0.01
(G×E)gi – criterion for estimation of the genotype ability to interact with environment; SAA – specific adaptive ability; GAA – general adaptive ability; Sgi – relative stability of the genotypes; Igi – reaction to the environment; SVG – selective value of genotype

The results of the adaptability assessment obtained by applying the nonparametric method (Table 3) showed that following accessions had the worst adaptation: Fb 1929 – in terms of pods and seeds number, Fb 3270 – in 100 seeds mass and seed weight, Fb 2486 and BGE 002106 – in plant height. BGE 032012 can be defined as a genotype with a relatively good average general adaptability in terms of almost all traits. Similar behavior had Fb 1896, which (in contrast to BGE 032012) regarding 100 seeds mass was more responsive under environmental improving. On the other hand, adaptability under unfavorable conditions showed Fb 3270 (by pods and seeds number per plant), BGE 029055 (by pods number and seed weight), Fb 1903 and BGE 041470 (by 100 seeds mass and seed weight).

Based on the index of stability (IS) (Table 4), the accession assessment allows the selection of a suitable genotype with the highest value of the studied trait and adequate response to the environmental conditions. In plant height, Fb 1896 and Fb 1929 showed better stability, but in essence, they did not exceed considerably the remaining accessions, except for Fb 3270 (1.931).

In addition, Fb 1896 showed stability also in terms of seeds number, seed weight, and 100 seeds mass. Regarding 1st pod height, BGE 002106 stands out, followed by BGE 029055, which together with Fb 2486 showed stability in the number of pods and seeds per plant. Despite the fact that there is a certain discrepancy with the previous parameters, IS as a whole gives further information about the behavior of the broad bean accessions during the experimental period.

The information obtained from the dependencies between stability (adaptability) and productivity (seed weight) is important in the breeding process. The results of the correlation analysis (Table 5) showed that the seed weight was in a weak positive and insignificant correlation with G×Egi (r = 0.282), GAA (r = 0.156) and Igi (r = 0.072), and in mean correlation with SAA (r = 0.344).

A positive mean and high dependence was established regarding G×Egi with SAA (r = 0.945) and GAA (r = 0.640), and for GAA with Sgi (r = 0.997). A negative and statistically significant correlation coefficient was observed between SVG with GAA (r = –0.974) and Sgi (r = –0.981).

DISCUSSION

In the present study, the year factor had a strong influence on 1st pod height, pods number and seed weight per plant. Similar results were obtained by Mulusew *et al.* (2008), which reported that grain yield (productivity) was significantly affected by changes in the environment, followed by G × E interaction and genotype effects. The authors considered that G × E interaction minimizes the utility of genotypes by confounding their yield performances. Thus, it is very important to study in depth the yield levels, adaptation patterns and stability of faba bean genotypes in multiple environments.

Also, in our study, effects due to interactions between the genotype (accession) and the year for all the traits were significant ($P < 0.01$). This effect was particularly strong on 100 seeds mass as well as on plant height. The obtained results were in support of the studies of Temesgen *et al.* (2015). In a combined analysis of variance for grain yield of 16 faba bean genotypes, the authors established that the environment effect accounted for 89.27%, whereas genotype and G × E interaction effects presented 2.12% and 3.31% of the total variation, respectively. The results of the conducted study were in line with those obtained by Sharifi (2018) who reported that the largest influence factor for signs as grain productivity, pods per plant and pod length was the environmental factor, followed by the genotype factor.

Similar results were reported by Abrosimova and Fadeeva (2015). In collection accessions of peas, the trait of seed mass was strongly influenced by the genotype-environment interaction factor, and the genotype occupied the second position. It was established that regarding the parameter of general adaptation with priorities were the leaf and heterophilic pea forms (0.19 – 0.92). The authors found a high positive correlation of the general adaptive ability with the breeding value of the genotypes by this trait and negative (but nonsignificant) correlation with the relative stability of the genotype. This suggests that there are relatively stable high- and low-yielded cultivars in the studied group.

In determining the breeding value of broad bean genotypes, our research complements this one conducted by Bezuglova and Kazydub (2017), who have identified valuable genotypes for their breeding program. These genotypes were characterized with increased values of seeds number, 1,000 seeds mass and weight of seeds per plant. The authors indicated that the development of new broad bean varieties should be based primarily on the adaptability and stability of signs as number and weight of seeds per plant.

In earlier studies, Anohina and Mazuka (2006) found a specific variety response in estimation of bean genotypes in terms of adaptability and stability of main quantitative traits, which was confirmed in the present investigation.The authors used the general adaptive ability as a selection criterion and reported that cultivars with the highest average yields were also characterized by a high value of this parameter. According to their results for the number of seeds, the total adaptive capacity ranged from –38.94 to 27.26, and for the weight of seeds per plant – from 8.90 to –8.90. In regard to the parameter of breeding value of the genotype, the accessions showed the presence of polymorphism (–17.38 to 24.20).

In some other crops, such as wheat (Strizhkova 2003), the 1,000 seeds mass was found to be most consistent with the criterion of adaptability. This trait was an integrative and combining the final result of the interaction genotype-environment in the process of ontogenetic formation of productivity.

Singh *et al.* (2012) stated that plant breeding had the resource and could create new cultivars that adequately responded to changing climatic conditions. They considered that this ambitious task could be achieved by applying various methods, including from an initial selection of plants with desirable characteristics to more complicated classical or molecular techniques and approaches. With the development of modern biotechnology and its application in plant breeding, the creation of new adapted cultivars is a faster and more precise process.

According to some researchers as Potanin *et al.* (2014) in order to increase the efficiency of the breeding process in the development of new varieties with high productivity and environmental adaptability, it is necessary to apply non-traditional approaches for processing and analysis of the obtained information.

Nikiforova (2015) received data suggesting no significant relationship between plant productivity and relative stability of the genotype as a result of correlation analysis. This was due to the fact that in a group of accession (cultivars or populations) there may be both relatively stable and unstable, as well as high-productive and low-productive genotypes.

CONCLUSIONS

The analysis of variance regarding the productivity elements in the studied broad bean accessions showed that the environment influenced to the highest degree the traits of 1st pod height, pods number and seed weight per plant. The formation of plant height and seeds number was more strongly influenced by the genotype, and the mass of 100 seeds was determined by the genotype × environment interaction, which occupied a major share in the total variation of this trait.

According to the complex assessment of the adaptability and stability parameters, the broad bean accessions can be distributed as follows: BGE 032012 combines high stability (bi = 0.18), productivity and plant height (72 cm); Fb 1929 has a high value of the 1st pod height (34 cm) and is characterized by high plasticity and stability (bi = 0.84); BGE 029055 and Fb 1896 are stable (bi < 1) and form a large number of pods per plant (11 – 15); Fb 1896 and Fb 2486 are distinguished with good adaptability and stability, increased seed weight (28.01 and 30.28 g, respectively) and 100 seeds mass (105.48 g and 91.31 g, respectively).

Accessions BGE 032012 and Fb 2481 represent a selection value in terms of plant height (61.36 and 65.83 cm, respectively); Fb 1929 – in 1st pod height (32.46 cm); and BGE 029055, Fb 1896 and Fb 2486 – in pods number (10.59, 9.67 and 11.89). Fb 1896, Fb 2486 and BGE 041470 can be used to develop a new genetic diversity in breeding aimed at increasing the mass of 100 seeds and seed productivity.

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