Uluslararası Tarım Araştırmalarında Yenilikçi Yaklaşımlar Dergisi
International Journal of Innovative Approaches in Agricultural Research 2020, Vol. 4 (1), 119-129
https://doi.org/10.29329/ijiaar.2020.238.12

Original article

Analysis of Relationships among Quantitative Traits in Broad Bean (*Vicia faba* L.) Accessions

Natalia Georgieva [a, *] & Valentin Kosev [b]

[a] Department of Forage Production and Animal Science, Institute of Forage Crops, Pleven, Bulgaria
[b] Department of Plant Breeding and Seeds Production, Institute of Forage Crops, Pleven, Bulgaria

Abstract

With an aim to establish phenotypic and genotypic correlations among main quantitative traits in broad bean accessions, a field experiment was conducted at the Institute of Forage Crops (Pleven, Bulgaria) during the period 2016-2018. Objects of the study were 17 accessions of broad bean (*Vicia faba* L.) originating in Spain, Portugal and Bulgaria. Plants were grown under organic farming conditions. The results of the conducted study showed that the phenotypic relationships between the quantitative traits of broad bean were slightly lower than the values of the genetic correlation coefficients. With significant medium to strong dependencies were distinguished the phenotypic and genotypic correlation coefficients between plant height and 1st pod height (r = 0.539, r = 0.655, r = 0.873, r = 0.530, r = 0.658, r = 0.878), and between 100 seeds mass and pod width (r = 0.644, r = 0.776, r = 0.751, r = 0.654, r = 0.781, r = 0.758). Phenotypic and genotypic manifestations of the studied quantitative traits were differently expressed depending on the environmental conditions. Under unfavorable conditions, some of the correlations changed their direction and value of the coefficient. The traits of 100 seeds mass (0.482) and pods number per plant (0.340) had a maximum positive direct effect on seed productivity. With the highest total effect was characterized the mass of 100 seeds (0.574), pod length (0.568) and plant height (0.411). The traits of pod length, seeds number per plant and 100 seeds mass were in positive regression dependence with seed productivity in broad bean.

Keywords: Broad bean, Phenotypic correlation, Genotypic correlation and Regression.

Received: 04 January 2020 * **Accepted:** 28 January 2020 * **DOI:** https://doi.org/10.29329/ijiaar.2020.238.12

* **Corresponding author:**

Georgieva N. is a professor in the Department of Forage Production and Animal Science at Institute of Forage Crops in Pleven, Bulgaria. Her research interests include the Organic farming, Allelopathy and Energy efficiency. She has lived and worked in Pleven, Bulgaria.
Email: imnatalia@abv.bg

INTRODUCTION

Selective-genetic studies require different methods for integral evaluation of the breeding material, since in the characterization of lines, hybrids and forms, are important not only the manifestations of the individual traits but also the relationships between them. These methods of assessment include correlation analysis and path analysis (Lihacheva, Gimaletdinova, and Kozionova, 2016).

According to Bulgakova and Syukov (2015), in the breeding process, a major importance has plant traits, which are considerably influenced by the changing environmental conditions. These conditions may cause variability not only of the traits but also of the relationships between them. In this connection, it is necessary to establish the dependencies in the variability of the relations between the main traits under changing the environmental conditions, as well as to determine the correlations in specific experimental conditions by years.

The fundamental question of the contribution of factors of heredity and environment in the formation of quantitative characteristics remains topical in general genetics and breeding. It is also ongoing the demand for new approaches to deal with the problem of effective breeding in terms of the quantitative traits (Skuridin and Koval, 2002).

Correlation coefficients are the most appropriate indicator to investigate the interrelationships between quantitative traits. The results of correlation studies are of interest in the development of adaptive genotypes with corresponding desirable characteristics. The data in the scientific literature on the relationships between the quantitative traits in leguminous crops are insufficient (Kuzeev, 2002).

Expanding the genetic basis of the existing assembly of cultivars and evaluating the selection material is a continuous process. The permanent accumulation, supplementation, and systematization of the obtained information create conditions for increasing the effectiveness of selective-improving activity (Baishya, Sarkar, Ansari, and Prakash, 2015).

The aim of the study was to establish the coefficients of phenotypic and genotypic correlations between the main quantitative traits in broad bean.

Materials and Methods

Objects of the study were 17 accessions of broad bean (*Vicia faba* L.) originating in Spain (BGE 002106, BGE 029055, BGE 032012, BGE 041470, BGE 043776, BGE 046721), Portugal (Fb 1896, Fb 1903, Fb 1929, Fb 2481, Fb 2486, Fb 3270) and Bulgaria (FbH 13, FbH 14, FbH 15, FbH 16, BGP). The experimental activity was carried out during the period 2016-2018, at the Institute of Forage Crops (Pleven). It was used a randomized block method (Barov, 1982). The broad bean accessions were grown under organic farming conditions, without the use of fertilizers and pesticides. The plant biometric characterization included the following traits: plant height, 1st pod height, pods number per plant, pod lenght, pod width, seeds number per plant, seed weight per plant, 100 seeds mass.

For statistical processing of data was used path-coefficient analysis (Singh and Chaudhary, 1979), correlation and regression analysis (Dimova and Marinkov, 1999), the software products MS Excel (2003) and GENES 2009.7.0 (Cruz, 2009).

Results

The meteorological conditions for the studied period were represented by the sum of rainfall and average daily air temperature (Table 1). The average daily air temperatures during the period March-June of the three experimental years had close values (from 15.6 to 15.9 °C). The average temperature during May and June ranged from 16.4 ° C to 23.0 ° C, without extreme high values typical for this time of year. With regard to precipitation, more favorable conditions for the broad bean development were observed in 2016 and 2017, although the sum of rainfalls in these two experimental years was generally insufficient. A particularly negative effect on plant productivity had a considerable amount of rainfalls at the end of the vegetation period during 2018, which led to lodging and a decline in seed productivity.

Table 1. Meteorological characteristics for the period 2016-2018

Years	Daily average temparatures, °C					Rainfalls, mm				
	III	IV	V	VI	average	III	IV	V	VI	sum
2016	8.5	15.3	16.4	23.0	15.8	76.60	73.10	76.50	45.80	272.0
2017	10.3	12.2	17.0	23.0	15.6	46.10	37.50	155.00	44.80	283.4
2018	5.3	16.9	19.6	21.8	15.9	98.10	19.60	47.70	155.20	320.6

Correlation analysis

The selection of the breeding material is based on certain characteristics. They give an idea of the suitability of a genotype for a specific breeding program. The most commonly used indicators in choice of source breeding material are the productivity and yield. Their magnitude presents a complex indicator depending on the manifestation of other quantitative traits. For clarifying interrelationships, determining the seed productivity and the other quantitative traits in broad bean were calculated correlation phenotypic and genotypic coefficients (Tables 2, 3 and 4).

The seed weight per plant (according to the values of the phenotypic correlation coefficient) was in positive relation to all studied traits over the three experimental years. Correlation relationships, determinant productivity in 2016 were these with plant height (r = 0.905) and pod length (r = 0.715) (Table 2). Relatively weaker was the correlation with seeds number (r = 0.305). The mass of 100 seeds had a medium level of interaction with pod width (r = 0.644) and plant height (r = 0.505). The correlation with pods number was weak (r = 0.215), but significant. The values of the correlation coefficient for plant height indicated that it correlated very well with most of the traits. The only negative correlation was found between seeds number and 1st pod height (r = -0.355), but it was statistically insignificant.

Table 2. Phenotypic (above the diagonal) and genotypic (under the diagonal) correlation coefficients (2016)

Traits	PlH	PH	PP	SP	PL	PW	SM	SWP
PlH		0.539**	0.730	0.365	0.799	0.810*	0.505**	0.905**
PH	0.53**		0.109	-0.355	0.276	0.529	0.168	0.411
PP	0.734	0.110		0.615	0.657	0.536	0.215*	0.557
SP	0.367	-0.363	0.623		0.581	0.222	0.507	0.305*
PL	0.799	0.276	0.663	0.582		0.909	0.753	0.715**
PW	0.811*	0.535	0.540	0.224	0.910		0.644**	0.770
SM	0.513**	0.170	0.219*	0.512	0.761	0.654**		0.540
SWP	0.911**	0.414	0.561	0.308*	0.720**	0.775	0.546	

PlH - plant height, PH - 1st pod height, PP - pods number per plant, SP - seeds number per plant, PL - pod lenght, PW - pod width, SM -100 seeds mass, SWP - seed weight per plant;

*; ** significant at 5% and 1% level of probability

In 2017, very strong phenotypic dependencies were observed between pods number and seeds number (r = 0.877), and between 100 seeds mass and pod width (r = 0.776) (Table 3). The phenotypic correlations regarding plant height with 1st pod height (r = 0.655), seeds number (r = 0.528), 100 seeds mass and pod length (r = 0.626) were slightly weaker. Compared to the previous year, a change in the interaction of the seed weight with the other characteristics was established. Correlation coefficients did not change the direction of their action (i.e. they were positive) but only their value or significance. The interaction with 100 seeds mass (r = 0.632) as well as with seeds number (r = 0.160), was significant.

Table 3. Phenotypic (above the diagonal) and genotypic (under the diagonal) correlation coefficients (2017)

Traits	PlH	PH	PP	SP	PL	PW	SM	SWP
PlH		0.655**	0.437	0.528**	0.526	0.481	0.510	0.318
PH	0.658**		0.040	0.096	0.212	0.262	0.420	0.338
PP	0.438	0.039		0.877**	0.827	0.411	0.138	0.159
SP	0.528**	0.094	0.879**		0.922	0.528	0.449	0.160*
PL	0.528	0.215	0.827	0.924		0.778	0.626*	0.455
PW	0.487	0.271	0.412	0.533	0.781		0.776**	0.700
SM	0.512	0.423	0.135	0.451	0.628*	0.781**		0.632**
SWP	0.319	0.339	0.158	0.162*	0.457	0.703	0.631**	

PlH - plant height, PH - 1st pod height, PP - pods number per plant, SP - seeds number per plant, PL - pod lenght, PW - pod width, SM -100 seeds mass, SWP - seed weight per plant;

*; ** significant at 5% and 1% level of probability

Climatic conditions in 2018 had an unfavorable influence on the accessions, which affected the correlation coefficient values (Table 4). Of the structural elements determining productivity, with the great importance and with good significance was the seeds number. It was in strong correlation with pod length (r = 0.882), pods number (r = 0.771), 100 seeds mass and pod width (r = 0.751). The trait of 1st pod height was in a slight positive correlation with pod length (r = 0.211) and pod width (r = 0.338), and in slight negative correlation with pods number (r = -0.076) and seeds number (r = - 0.017). It can be noted that plant height and 1st pod height showed a high degree of correlation with each other (r = 0.878).

The results presented in Table 4 showed a strong positive dependence of seed productivity with the pod width (r = 0.789), and medium dependence with 100 seeds mass (r = 0.605), both of which were insignificant. The influence of the other traits on the seed weight was significantly high. The strongest was its manifestation regarding pod length (r = 0.605).

The total number of phenotypic correlations at a statistically significant level varied over the years of study. It should be noted that they were all positive, but a considerable part of the identified relationships had low values and did not reach the level of statistical significance. Under unfavorable conditions, some of the correlations changed their direction and values. This indicates that the phenomenon of the weakening effect of so-called unaccounted factors is manifested.

Table 4. Phenotypic (above the diagonal) and genotypic (under the diagonal) correlation coefficients (2018)

Traits	PlH	PH	PP	SP	PL	PW	SM	SWP
PlH		0.873**	0.119*	0.249**	0.427**	0.471	0.360	0.067**
PH	0.878**		-0.076	-0.017	0.211**	0.338	0.079	0.084**
PP	0.118*	-0.075		0.771**	0.632**	0.323**	0.315	0.154**
SP	0.246**	-0.019	0.774**		0.882**	0.510	0.679	0.285**
PL	0.426**	0.211**	0.642**	0.891**		0.833**	0.793	0.605**
PW	0.477	0.344	0.336**	0.532	0.841**		0.751**	0.789
SM	0.360	0.079	0.313	0.688	0.796	0.758**		0.605
SWP	0.075**	0.092**	0.151**	0.312**	0.623**	0.797	0.613	

PlH - plant height, PH - 1st pod height, PP - pods number per plant, SP - seeds number per plant, PL - pod lenght, PW - pod width, SM -100 seeds mass, SWP - seed weight per plant;

*; ** significant at 5% and 1% level of probability

Similar to phenotypic manifestations, the genotypic manifestations of the studied quantitative traits were differently expressed depending on the peculiarities of the tested accessions and the environment. Positive and negative genotypic correlations were found. The seed productivity in 2016 was positively associated with plant height (r = 0.911), pod length (r = 0.720) and seeds number (r = 0.308). The trait of 100 seeds mass was in positive correlation with pod width (r = 0.654), plant height (r = 0.513) and pods number per plant (r = 0.219).

In 2017, a medium dependence of plant height with 1st pod height (r = 0.658) and seed number (r = 0.528) was established. The genotypic correlations of the pods number with seeds number (r = 0.879) and for 100 seeds mass with pod length (r = 0.628) were also high. It is noteworthy that the correlation coefficients between seed weight and the traits of plant height (r = 0.319), pods number (r = 0.158), seeds number (r = 0.162) and pod length (r = 0.457) were changed, which was expressed in weak dependences between them.

The significance of interrelated characters often had a specific manifestation. This depends both on the genotypic specificities of the breeding material investigated and on the differences in the conditions under which the studies are conducted. In the third experimental year (2018), unfavorable climatic conditions resulted in a general decline in the dependencies of seed weight with plant height (r = 0.075), 1^{st} pod height (r = 0.092) and pods number (r = 0.151), as well as a change in the level of their statistical significance. The relationships between the quantitative traits (with the exception of seeds number) and productivity showed instability over the years but did not change their sign in the opposite direction. It is noteworthy that the dependence between plant height and 1^{st} pod height under abiotic stress conditions was rising (r = 0.878) relative to the dependence found at better environmental conditions.

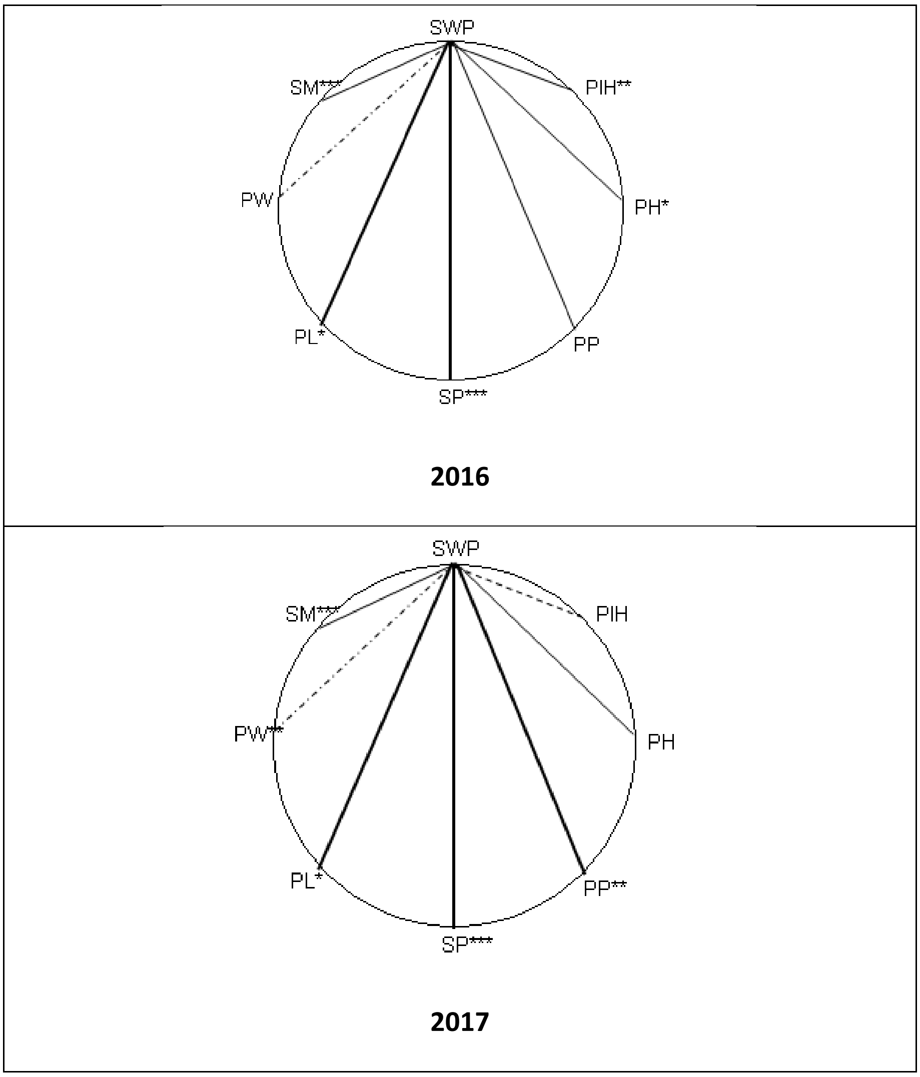
The analysis of the interrelations for the study period (2016-2018) showed that the phenotypic coefficients between the studied characteristics were similar (or slightly lower) compared to their corresponding genotypic correlation coefficients. Negligible higher genotypic correlation coefficients gave reason to consider that environmental conditions had a considerable impact on the manifestations of strong hereditary relationships. The presence of strong positive and significant genetic dependencies among some of the studied traits indicates that there are good opportunities for a successful selection simultaneously on several traits.

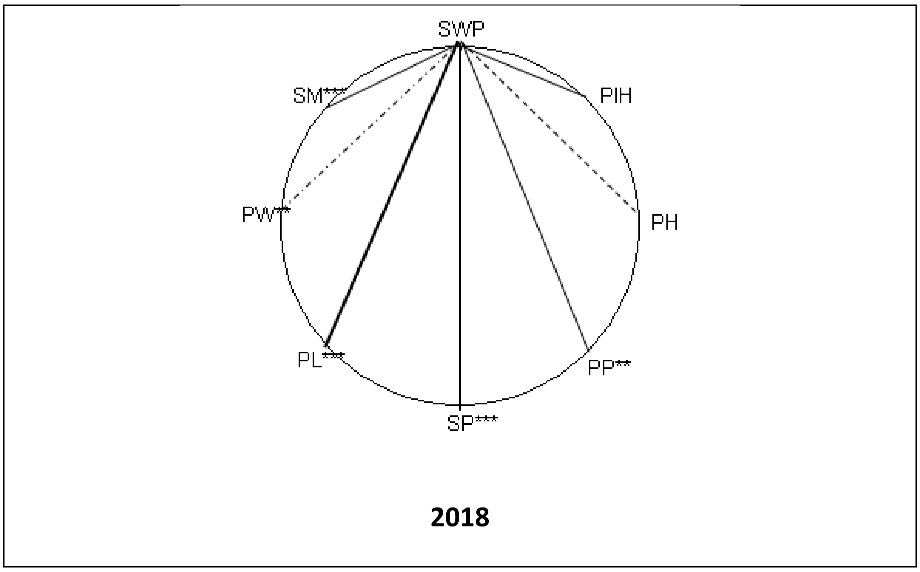
Regression dependencies

Figure 1 shows the relationships between seed weight and the quantitative traits of the studied broad bean accessions for each of the experimental years. The results of the correlation analysis were supported by the regression dependence established. Obviously, environmental conditions hada strong influence on the plant height and 1^{st} pod height, especially in the second and third year. The values of the regression coefficients for these signs indicated that they did not play an essential role in the final expression of productivity.

The resulting dependencies between productivity and pod length, seeds number and 100 seeds mass were positive and significant, although they were not high. Their value varied in not many wide limits, with a greater variation regarding seeds number and 100 seeds mass. On the other hand, the negative regression coefficients of the trait of pod width over the three experimental years indicated that the increase in pod width adversely affected the seed productivity.

Contrary to the previous indicator, an increase in the pods number would raise seed productivity. By the value of the regression coefficient, the first and the third year were close, and in the second year, it was almost four times higher. This indicates that a change is possible in the manifestation of the trait under changing the environmental conditions.





PlH - plant height, PH - 1st pod height, PP - pods number, PL - pod lenght, PW - pod width,

SP - seeds number, SWP - seed weight per plant, SM -100 seeds mass

strong ; medium ; slight ; negative

*, **, ***, significant at 5%, 1% and 0.1% level of probability

Figure 1. Regression dependencies of seed weight per plant with other quantitative traits in broad bean

Path-analysis

Pat coefficients (direct and indirect effects) of the quantitative traits were calculated against the seed productivity as a dependent variable (Table 5). The mass of 100 seeds (0.482) and pods number per plant (0.340) had a direct positive effect on seed productivity. Pod width (0.371) and plant height (0.066) also had a direct positive effect on productivity. The negative value of the direct effect of seeds number indicated that excessive increasing of their number will not have a positive effect on seed productivity.

The highest indirect effect had the mass of 100 seeds (through pod length /0.335/ and seeds number /0.254/), and pods number (through seeds number /0.255/ and pod length /0.240/). The plant height indirectly, through all other traits, had a slight but positive effect on seed productivity.

When raising the seed weight per plant, the traits with the highest total effect should also be taken into account. In the present study, these were 100 seeds mass (0.574), pod length (0.568) and plant height (0.411).

Table 5. Path analysis regarding seed prouctivity in broad bean

Traits	Direct effect	Indirect effect						Total effect
		PlH	PH	PP	SP	PL	PW	SM	
PlH	0.066		-0.057	0.133	-0.184	0.035	0.206	0.212	0.411
PH	-0.083	0.045		0.001	0.033	0.011	0.111	0.092	0.210
PP	0.340	0.026	0.001		-0.364	0.043	0.139	0.087	0.271
SP	-0.484	0.025	0.006	0.255		0.048	0.115	0.254	0.219
PL	0.061	0.038	-0.015	0.240	-0.384		0.293	0.335	0.568
PW	0.371	0.037	-0.025	0.127	-0.150	0.048		0.299	0.707
SM	0.482	0.029	-0.016	0.062	-0.255	0.042	0.230		0.574

PlH - plant height, PH - 1st pod height, PP - pods number per plant, SP - seeds number, PL - pod lenght, PW - pod width, SM -100 seeds mass, SWP - seed weight per plant

Discussion

A number of researchers (Vhris and Hartley, 2000; Bezuglova, 2015) considered that in the breeding work, the study of dependencies among traits played an essential role, as in the development of new cultivars they can determine the selection direction. The authors pointed out that most breeders are interested in quantitative characteristics, whose relationship may be due to genetic or physiological dependence.

Abdelmula and Abuanja (2007) noted that a close phenotypic relationship between the traits might be due to different gene effects as well as to the influence of environmental factors. In a study of broad bean genotypes, the authors found a negative dependence of pods number and seeds number with 100 seeds mass. They have suggested that this was due to compensatory reactions and mechanisms among the yield components during plant development.

According to some researchers (Adak et al., 2019), productivity and yield depended on the genetic potential of the individual and the influence of environmental factors. They believed that direct breeding (when choosing a high-yielded genotype) did not always result in desired success. Therefore, they recommended the use of Path analysis as an effective method for establishing the direct relationships between the traits determining the yield and the indirect relationships between them. Other researchers (Pivovarov and Dobrutskaya, 2005; Kadermas, 2014) recommended a visual representation of the interaction between the plant traits. The graphical interpretation of correlation dependencies allowed to trace the structure, direction and strength of the relationship between the individual traits. Established empirical correlations created a basis for forecasting, simplified the selection, and speeded up the breeding process. According to Pivovarov and Dobrutskaya (2005), correlations between quantitative characteristics had adaptive meaning and were less pronounced in accessions with high value in breeding on adaptability. The correlations established in the present study allow to determine the direct and indirect relationships between the quantitative traits of the studied broad bean accessions. From a breeding point of view, this information is of interest to carry out a selection by indirect traits.

Conclusion

The results of the conducted study showed that the phenotypic relationships between the quantitative traits of broad bean accessions were slightly lower than the values of the genetic correlation coefficients. With significant medium to strong dependencies were distinguished the phenotypic and genotypic correlation coefficients between plant height and 1st pod height (r = 0.539, r = 0.655, r = 0.873, r = 0.530, r = 0.658, r = 0.878), and between 100 seeds mass and pod width (r = 0.644, r = 0.776, r = 0.751, r = 0.654, r = 0.781, r = 0.758). Phenotypic and genotypic manifestations of the studied quantitative traits were differently expressed depending on the environmental conditions. Under unfavorable conditions, some of the correlations changed their direction and value of the coefficient.

The traits of 100 seeds mass (0.482) and pods number per plant (0.340) had a maximum positive direct effect on seed productivity. With the highest total effect was characterized the mass of 100 seeds (0.574), pod length (0.568) and plant height (0.411).

The traits of pod length, seeds number per plant and 100 seeds mass were in positive regression dependence with seed productivity in broad bean.

REFERENCES

Abdelmula, A.A. and I. K. Abuanja (2007). Genotypic responses, yield stability, and association between characters among some of Sudanese faba bean (*Vicia faba* L.) genotypes under heat stress. Conference on International Agricultural Research for Development, October 9-11, Tropentag 2007, University of Kassel-Witzenhausen and University of Göttingen.

Adak, A., H. Canci, N.E. Inci, F.O. Ceylan, D. Sari, H. Sari, T. Yildirim and C. Toker (2019). Essential selection criteria for dual uses of red pea (*Lathyrus cicera* L.). Legume Res., 42, 45-49.

Baishya, L., D. Sarkar, M. Ansari and N. Prakash (2015). Yield, quality and profitability of rice (*Oryza sativa* L.) varieties grown in the eastern Himalayan region of India. Afr. J. Agric. Res., 10, 1177-1183.

Barov, V. (1982). Analysis and schemas of the field trial. Sofia, Bulgaria: Academic Press.

Bezuglova, E.V. (2015). Source material for breeding of broad bean (*Vicia faba*) and impact of organic products on its economic valuable traits in the southern steppe of West Siberia. PhD Dissertation, Omsk, Russia.

Bulgakova, A.A. and V.V. Syukov (2015). Relationship between the trait of above-ground biomass and the quantitative traits of the cenosis. Young scientist, 22(2), 24-25.

Cruz, C. D. (2009). Programa Genes: Biometria. University of Federal Viçosa, Viçosa, Brazil.

Dimova, D. and E. Marinkov (1999). Experimental biometrics. Sofia, Zemizdat.

Kadermas, I.G. (2014). Formation of plant photosynthetic and symbiotic apparatus and its contribution to increase the productivity of pea (*Pisum sativum* L.). agrocenoses. PhD Dissertation, Omsk State Agricultural University, Russia.

Kuzeev, E.M. (2002). Fodder legumes in annual agrophytocenoses. Forage production, 6, 24-26.

Lihacheva, L.I., V.S. Gimaletdinova and E. G. Kozionova (2016). The conjugation of quantitative traits varieties of peas in the conditions of middle Urals. Journal of Pulses and Cereals, 3(19), 45-48.

Pivovarov, V.F. and E. G. Dobrutskaya (2005). Ecological bases of breeding and seed production of crops. Moscow, Russia: Academic Press.

Singh, R.K. and B. D. Chaudhary (1979). Biometrical methods in quantitative genetic analysis. New Delhi: Kalyni Publishing Co.

Skuridin, G.M. and S.F. Koval (2002). Identification of the genotype by phenotype through correlation traits. Inform. Bulletin No. 19, Ministry of Education and Scientific Research, Russia.

Vhris, V.K. and C. Hartley (2000). Agricultural management of grain legumes: Has it led to an increase in nitrogen fixation? Field Crop. Res., 65(2-3), 166-181.