UDC 575.630
https://doi.org/10.2298/GENSR1902571K
Original scientific paper

GENETIC ANALYSIS OF QUANTITATIVE TRAITS OF GRASS PEA (*Lathyrus sativus* L.) GENOTYPES

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Kosev V. and V. Vasileva (2019): *Genetic analysis of quantitative traits of grass pea (Lathyrus sativus L.) genotypes*.- Genetika, Vol 51, No.2, 571-584.

A comprehensive assessment of the quantitative traits of grass pea varieties and hybrids was done in order to inclusion in the selection process. A negative heterosis effect was found in almost all hybrids at two environment limits (seed density). The exception was LA5108 x BGE027129, which is characterized by a high heterosis effect on the number of nodules per plant. Dominant to over-dominant negative inheritance was found in F1 at BGE027129 x LA5108 for fresh root mass weight, aboveground mass weight and nodule weight per plant, and in LA5108 x BGE027129 for fresh leaves weight and fresh aboveground mass weight. LA5108 x BGE027129 shows a positive dominance and over-dominance in both, number and weight of nodules per plant. Non-allelic interactions occur in inheriting the number and weight of nodules in the hybrid combination BGE025277 x LA5108. The hybrids tested had the most pronounced positive transgressions on the fresh aboveground mass weight, number and weight of nodules. The common phenotypic manifestation of fresh root mass weight, fresh aboveground mass weight and nodule weight is highly genetically determined, and a larger effect can be expected from conducting mass selection on these signs in earlier hybrid offspring (F2 - F3). The assessment of the initial material makes it very likely to determine the appropriate productivity genotype and to speed up the process of creating new varieties of grass pea.

Keywords: grass pea, quantitative traits, dominant gene effect, heterosis, transgression, inheritance

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INTRODUCTION

Grass pea (*Lathyrus sativus* L.) is a one-year grain-leguminous crop with a high adaptive potential for cultivation in a wide range of different soil and climatic conditions (drought, rewetting, soil salinity, cool climate, high altitude, etc.) (KARADAG *et al*., 2004; TALUKDAR, 2011) a honey plant as well as a good nitrogen fixator is (SIDOROVA *et al*., 2013). Grass pea characterized by good resistance to abiotic and biotic stress (SILLERO *et al*., 2005; NUNES and CARICHAS, 2012).

Grass pea has relatively high protein content (27-29%) and is widely used as human and animal consumption (BISWAS and BISWAS, 1997; HANBURY *et al*., 2000; ULLOA and MERA, 2010).

At the present time, the grass pea is grown in some areas of southern and eastern Asia, in the Middle East, North Africa and southern Europe (CAMPBELL *et al*., 1994; GIRMA *et al*., 2011; PIERGIOVANNI *et al*., 2011).

In response to the growing demand for food and feed worldwide and the need to diversify crop cultivation systems, the *Lathyrus* genus receives more and more attention from breeders (MAKOI and NDAKIDEMI, 2011; TAMBURINO *et al*., 2012). In the selection point of view the breeding efforts are directed towards the creation of high yield grain varieties with low content of neurotoxins (POLIGNANO *et al*., 2009; TALUKDAR, 2009).

The genetic diversity of the *Lathyrus* genus is essential, especially for its increased potential in non-irrigated cultivation in many countries (SHEHADEH, 2011).

The symbiotic nitrogen fixation as a result of the *Rhizobium* – legume association is part of the complex interactions between the host plant and the microsymbiont. Understanding the nature of specific genetic features that affect symbiosis and nitrogen fixation will lead to clarification of important biological processes of symbiosis and will contribute to better practical use of nitrogen-fixing legumes. There is no information on how many genes affect the nitrogen fixation properties in the host plant-bacteria relationship (PARRA-COLMENARES, 2003).

The purpose of the present study is to analyze some quantitative traits of grass pea genotypes in breeding point of view.

MATERIALS AND METHODS

The study was conducted in 2014-2016 in the experimental field of the Institute of Forage Crops, Pleven, Bulgaria. The following crossings between the grass pea varieties BGE027129 x LA5108, BGE025277 x LA5108), and their reciprocal combinations have been done (Table 1). Parent forms (P1 and P2) and first and second hybrid generations (F1 and F2) have been studied. The sowing of the selection materials is carried out manually under the scheme P_1, P_2, F_1, F_2 in optimal time according to the technology of cultivation of the crop at two limits of the environment, namely a seeding distance of 50/5 cm (dense sowing) and 50/10 cm (rare sowing) at a depth of 5 cm. Plant material from aboveground and root biomass of parent and hybrid forms was analyzed. Biometric measurements were made on 10 plants of each genotype. The following characteristics have been assessed in the beginning of flowering stage: aboveground mass weight (g), leaf fresh weight and after soil monoliths taking and washing the roots of the plants with water - fresh root mass weight (g), nodule number per plant and nodule weight per plant (g).

For all the characteristics studied: an average arithmetical (x); heterosis effect in F1 - (hypothetic and true), inbred depression by OMAROV (1975); degree of dominance in F1 (hp1)

and in F2 (hp2) by ROMERO and FREY (1973). Using method of SOBOLEV (1976) the characteristic of transgression (Tn); number of genes, in which the parents differ (N); dominance (D); epistasis (E), coefficient of inheritance in broad sense (H2) and coefficient of effectiveness of the mass of genotypes by phenotypical performance of the trait (Pp) and cytoplasmatic effect (re) in REINHOLD (2002) were found. The positive value of re (re > 0) means that a greater influence on the expression of the signs is the paternal inherited factors, and the negative (re < 0) influence of maternal cytoplasmic heredity (cytoplasmatic effect). The method of orthogonal regression to identify the phenotype by genotype described by Kramer (DRAGAVCEV, 1995) was applied, indicating the possibility of assessment of white lupine hybrids in genetics-physiological systems at different limits of the environment. Moreover, the relative proportion of the genotype and the environment shall be quantified in a scale of the actual measurements of the attribute.

All experimental data were processed statistically using the computer software SPSS 13 and Excel for Windows XP.

Table 1. Distinctive features of the investigated genotypes

Traits/Variety	1-BGE027129	2-BGE025277	4-LA5108
		For dense sowing	
Fresh root mass weight (g)	0.24a	0.65c	0.41b
Fresh leaves weight (g)	14.21b	9.12ab	4.19a
Fresh aboveground mass weight (g)	10.74a	5.23a	7.86a
Number of nodules per plant	9.78a	25.61a	10.63a
Nodule weight per plant (g)	0.09a	0.11a	0.21a
		For rare sowing	
Fresh root mass weight (g)	0.42a	0.53ab	0.69b
Fresh leaves weight (g)	6.06b	13.85c	1.78a
Fresh aboveground mass weight (g)	4.74a	11.74b	3.47a
Number of nodules per plant	5.46a	17.61b	5.93a
Nodule weight per plant (g)	0.03a	0.14b	0.07a

Mean followed by the same letter(s) did not differ significantly at 5 % level

RESULTS

In conventional breeding programs, different strategies are implemented to achieve combinatorial variability in hybrid plants. The method of artificial sexual hybridization is used to successfully combine the positive characteristics of the parental components in the hybrids (POLIGNANO *et al*., 2009).

In the tandem selection-nitrogen fixation-productivity of grass pea varieties, in addition to the presence of valuable genes associated with signs determining the productivity of the aboveground mass of the plant, it is necessary to pay attention to the characteristics determining the specific nodulation capability the number and weight of nodules, root length and weight, and so on. Therefore, in our study, we analyzed F1-F2 hybrids and their parental forms in order to establish the mode of inheritance of the signs tested.

From the data presented in Table 2 it can be seen that in the case of dense sowing, for the signs of fresh root mass weight, fresh leaves weight, aboveground biomass and nodule weight a negative true heterosis was found. An exception is the cross between the samples LA5108 and

BGE027129, in which the true heterosis is positive for the number of nodules. The offsprings of this cross, as well as its reciprocal, have the highest level of depression.

The fresh root mass weight of a plant is positively dominant inherited in LA5108 x BGE025277 (0.92), intermediate at LA5108 x BGE027129 (0.18). In the inheritance of the feature, with the exception of BGE027129 x LA5108, the other hybrid combinations play a major role in epitstatic gene interactions. Negative over dominance is characterized by inheritance of the fresh leaves weight and aboveground biomass per plant at LA5108 x BGE027129, regardless of the direction of crossing. A similar type of inheritance is the hybrids obtained from the crossing of LA5108 with BGE025277.

Table 2. Biometrical data of the quantitative traits of the investigated crosses dense sowing

Hybrids	F_1	F_2	Heterosis F_1 (%)		Depression F_2 (%)	Degrees of dominance	
	x	x	hypothetical	real		in F_1 (h_{p1})	in F_2 (h_{p2})
Fresh root mass weight (g)							
LA5108xBGE027129	0.34b	0.59c	4.62	-17.07	-73.53	0.18	6.24
BGE027129xLA5108	0.15a	0.19a	-53.85	-63.41	-26.67	-2.06	-3.18
LA5108xBGE025277	0.64b	1.32d	20.75	-1.54	-106.25	0.92	13.17
BGE025277xLA5108	0.209c	0.435b	-60.57	-67.85	-108.13	-2.68	-1.58
Fresh leaves weight (g)							
LA5108xBGE027129	3.304a	4.323ab	-64.09	-76.75	-30.84	-1.18	-1.95
BGE027129xLA5108	3.95a	7.14b	-57.07	-72.20	-80.76	-1.05	-0.82
LA5108xBGE025277	4.658b	3.021a	-30.01	-48.93	35.14	-0.81	-2.95
BGE025277xLA5108	7.701c	4.995ab	15.72	-15.56	35.14	0.42	-1.35
Fresh aboveground mass weight (g)							
LA5108xBGE027129	4.761a	8.655b	-48.81	-55.67	-81.79	-3.15	-0.90
BGE027129xLA5108	2.622a	6.338ab	-71.81	-75.59	-141.72	-4.64	-4.11
LA5108xBGE025277	7.518b	4.11a	14.87	-4.35	45.33	0.74	-3.70
BGE025277xLA5108	5.505b	3.01a	-15.89	-29.96	45.32	-0.79	-5.38
Number of nodules per plant							
LA5108xBGE027129	31.5b	16.5a	208.67	196.33	47.62	50.11	29.62
BGE027129xLA5108	10.408a	3.845a	1.99	-2.09	63.06	0.48	-29.93
LA5108xBGE025277	14.5b	51.5b	-19.98	-43.38	-255.17	-0.48	8.91
BGE025277xLA5108	3.379a	12a	-81.35	-86.81	-255.13	-1.97	-1.63
Nodule weight per plant (g)							
LA5108xBGE027129	0.183bc	0.198bc	22.22	-23.42	-8.20	0.37	-1.21
BGE027129xLA5108	0.07a	0.044a	-59.62	-74.7	37.14	-1	-2.86
LA5108xBGE025277	0.126ab	0.52c	-25.04	-48.72	-333.33	-0.54	7.2
BGE025277xLA5108	0.028a	0.115ab	-82.53	-88.05	-310.71	-1.79	-1.64

Mean followed by the same letter(s) did not differ significantly at 5% level

When changing the limit of the environment (dense and rare sowing) (Table 3) there are also some differences in the reaction of the hybrid plants to the growing conditions. On the fresh root mass weight, the fresh leaves weight and the fresh aboveground mass weight, the true heterosis is negative, analogous to the limit of the environment at the dense sowing. Negative dominance was the LA5108 x BGE027129 and LA5108 x BGE025277 crosses on fresh root mass weight.

Table 3. Biometrical data of the quantitative traits of the investigated crosses in rare sowing

Hybrids	F_1	F_2	Heterosis F_1 (%)		Depression F_2 (%)	Degrees of dominance	
	x	x	hypothetical	real		in F_1 (h_{p1})	in F_2 (h_{p2})
Fresh root mass weight (g)							
LA5108xBGE027129	0.46b	0.936b	-17.12	-33.33	-103.48	-0.70	5.64
BGE027129xLA5108	0.112a	0.306a	-79.82	-83.77	-173.21	-3.28	-3.69
LA5108xBGE025277	0.333ab	0.989b	-45.41	-51.74	-197.00	-3.46	9.48
BGE025277xLA5108	0.109a	0.323a	-82.13	-84.20	-196.33	-6.26	-7.18
Fresh leaves weight (g)							
LA5108xBGE027129	2.392a	2.616a	-38.98	-60.53	-9.36	-0.71	-1.22
BGE027129xLA5108	5.462ab	4.325ab	39.34	-9.87	20.82	0.72	0.38
LA5108xBGE025277	4.749ab	6.512b	-39.23	-65.71	-37.12	-0.51	-0.43
BGE025277xLA5108	7.85b	10.767c	0.45	-43.32	-37.16	0.01	0.98
Fresh aboveground mass weight (g)							
LA5108xBGE027129	3.58a	3.485a	-12.79	-24.47	2.65	-0.83	-1.95
BGE027129xLA5108	3.487a	2.552a	-15.05	-26.43	26.81	-0.97	-4.89
LA5108xBGE025277	8.037b	8.401c	5.68	-31.54	-4.53	0.10	0.39
BGE025277xLA5108	5.885ab	6.152b	-22.62	-49.87	-4.54	-0.42	-0.70
Number of nodules per plant							
LA5108xBGE027129	44.667b	44.75a	684.32	653.24	-0.19	165.84	332.38
BGE027129xLA5108	7.34a	10.427a	28.88	23.78	-42.06	7.00	40.27
LA5108xBGE025277	15.667a	73.667b	-6.10	-11.03	-370.20	-1.10	123.14
BGE025277xLA5108	3.65a	17.165a	-78.12	-79.27	-370.27	-14.08	1.04
Nodule weight per plant (g)							
LA5108xBGE027129	0.318b	0.253a	536.00	354.29	20.44	13.40	20.30
BGE027129xLA5108	0.04ab	0.056a	-20.00	-42.86	-40.00	-0.50	0.60
LA5108xBGE025277	0.079ab	0.43b	-24.76	-43.57	-444.30	-0.74	18.57
BGE025277xLA5108	0.018a	0.095a	-82.86	-87.14	-427.78	-2.49	-0.57

Mean followed by the same letter(s) did not differ significantly at 5% level

The value of the degree of dominance in F1 of crossing LA5108 x BGE027129 indicates that inheritance of the fresh leaves weight attribute is of the negative dominance type and in the reciprocal crossing BGE027129 x LA5108, the inheritance is positively dominant.

By reference to the fresh biomass from a plant, it is noticeable that the hybrid plants derived from the crossing of LA5108 with BGE025277 are not depressed, whereas those resulting from the crossing of LA5108 with BGE027129, especially BGE027129 x LA5108, have a high degree of depression, despite the favorable growing environment (rare sowing). The plants of crossing BGE027129 x LA5108 in the unfavorable environment (dense sowing) showed lack of depression and non-allelic type inheritance.

By weight of the nodules in both cultivation conditions, the hybrids exhibit a negative true heterosis. The exception is crossing; LA5108 x BGE027129, which has high heterosis (354.29) and predominant epistatic gene interactions at crop dilution.

The transgression coefficients (Tn) for fresh root mass weight (Table 4) are positive for the LA5108 x BGE025277 combination, with the reciprocal cross almost twice as high (2.42) at the rare sowing (Table 5). At the same sowing rate, the plants of hybrid combination; LA5108 x BGE027129 and its reciprocal have a negative sign of the transgression coefficient. In hybrid combination; LA5108 x BGE025277, regardless of the direction of crossing and the limit of the environment, the parents differ by 1-2 genes. Negative values of the epistatic gene interactions in a part of the crosses when changing the conditions of growing indicate suppression of the manifestation of the dominant alleles resulting in lower phenotypic expression of the sign. The values of the coefficient of inheritance in wide sense (H2) and the coefficient of effectiveness of the mass of genotypes by phenotypical performance of the trait (Pp) are high in LA5108 x BGE025277, indicating that in the general phenotypic manifestation of this feature, the genotype has a relatively high proportion, both in dense and rare sowing. In hybrid plants of this cross, the phenotype selection may begin early in the early generations (F2 - F3). With LA5108 x BGE027129 with seed dilution, the parameter (Pp) for the effectiveness of the selection has a negative sign indicating that despite the high coefficient of inheritance, the selection of this feature will be effective in later hybrid generations (F5 - F6).

With regard to fresh leaves weight, positive transgression (Tn) was found in all combinations in dense sowing. In the LA5108 x BGE025277 combination and its reciprocal the transgression is higher than other hybrid crosses, even in the case of rare sowing, where all values of this indicator are negative. The samples included in crosses differ significantly in the number of genes (N), determinating the sign - from 2 at BGE025277 x LA5108 to 26 at LA5108 x BGE027129. In dense sowing the parental forms differ insignificantly from the number of genes defining the expression of the sign.

The positive values of the epistatic interactions (E) prevail at the LA5108 x BGE025277 crosses, as a result, a high proportion of individuals from the generations of the disintegrating populations with enhanced phenotypic manifestation of the attribute can predict. In combination LA5108 x BGE027129 also maintains the type of gene interactions. Negative epistatic interactions imply a reduction in the degree of phenotypic manifestation of this trait compared to complete additive inheritance. The genetic part in total phenotypic expression is high, especially in dense sowing, which is evidenced by the relatively high inheritance coefficient (0.150 to 0.983). These data, as well as the relatively high values of selection performance coefficients (Pp) in hybrid combinations: BGE027129 x LA5108 (0.49-0.67) and BGE025277 x LA5108 (0.50-0.48) indicate that the selection by fresh leaves weight will be effective and can be carried

out in earlier hybrid generations (F2 - F3).

Table 4. Values of the gene parameters for the quantitative traits of the investigated crosses in F_2 generation dense sowing

Crosses/ Indicators	T_n	N	D	E	H^2	Pp
Fresh root mass weight (g)						
LA5108 x BGE027129	3.55	0.10	0.15	-0.18	0.914	0.49
BGE027129 x LA5108	1.27	7.37	2.71	-2.47	0.933	0.16
LA5108 x BGE025277	2.53	0.42	0.40	-0.39	0.91	0.47
BGE025277 x LA5108	2.10	0.03	-0.17	0.09	0.987	0.47
Fresh leaves weight (g)						
LA5108 x BGE027129	6.27	0.01	0.68	-0.02	0.987	0.40
BGE027129 x LA5108	8.17	0.07	0.08	0.16	0.914	0.49
LA5108 x BGE025277	11.45	2.59	-2.12	1.20	0.929	0.14
BGE025277 x LA5108	14.64	0.17	-0.31	-0.23	0.980	0.50
Fresh aboveground mass weight (g)						
LA5108 x BGE027129	9.10	11.45	-4.49	3.55	0.983	-0.19
BGE027129 x LA5108	12.16	6.62	-2.69	2.30	0.93	0.12
LA5108 x BGE025277	10.79	1.05	0.21	-0.69	0.931	0.61
BGE025277 x LA5108	21.81	0.03	-0.26	-0.07	0.975	0.46
Number of nodules per plant						
LA5108 x BGE027129	3.84	34.59	6.10	-8.03	0.41	-0.03
BGE027129 x LA5108	22.02	36.95	9.32	-9.14	0.98	-1.27
LA5108 x BGE025277	0.68	101.10	3.53	15.81	0.10	-3.73
BGE025277 x LA5108	28.05	1.71	-0.90	0.91	0.94	0.29
Nodule weight per plant (g)						
LA5108 x BGE027129	6.65	0.00	-0.03	0.01	0.925	0.49
BGE027129 x LA5108	0.01	49.80	11.41	-11.78	0.79	-1.52
LA5108 x BGE025277	5.19	0.00	0.03	-0.03	0.91	0.50
BGE025277 x LA5108	4.24	0.01	-0.08	0.06	0.945	0.49

Table 5. Values of the gene parameters for the quantitative traits of the investigated crosses in F_2 generation in rare sowing

Crosses/ Indicators	T_n	N	D	E	H^2	Pp
Fresh root mass weight (g)						
LA5108 x BGE027129	-5.12	33.01	-14.14	9.23	0.940	-1.89
BGE027129 x LA5108	-4.70	20.07	-9.68	5.99	0.977	-1.21
LA5108 x BGE025277	1.25	0.07	-0.51	0.11	0.982	0.41
BGE025277 x LA5108	2.42	1.25	0.71	-0.75	0.970	0.45
Fresh leaves weight (g)						
LA5108 x BGE027129	-2.99	26.08	7.39	-6.84	0.710	-0.85
BGE027129 x LA5108	-3.49	6.18	0.65	-2.00	0.310	0.67
LA5108 x BGE025277	-0.37	2.66	-2.09	1.22	0.929	0.21
BGE025277 x LA5108	-0.79	2.30	0.06	1.09	0.150	0.48
Fresh aboveground mass weight (g)						
LA5108 x BGE027129	12.86	0.49	-0.65	0.41	0.980	0.41
BGE027129 x LA5108	1.54	0.49	-0.70	0.41	0.979	0.50
LA5108 x BGE025277	19.42	0.18	-0.28	0.25	0.983	0.47
BGE025277 x LA5108	2.32	0.62	-0.66	0.48	0.913	0.59
Number of nodules per plant						
LA5108 x BGE027129	42.36	0.05	0.14	-0.13	0.99	0.62
BGE027129 x LA5108	163.95	0.20	0.33	-0.25	0.99	0.65
LA5108 x BGE025277	4.49	8.67	3.20	-2.81	0.76	0.08
BGE025277 x LA5108	17.38	11.21	5.92	-3.65	0.98	-0.99
Nodule weight per plant (g)						
LA5108 x BGE027129	2.12	0.01	-0.23	0.03	0.952	0.46
BGE027129 x LA5108	0.08	30.56	6.63	-7.48	0.510	-0.28
LA5108 x BGE025277	2.61	0.00	0.00	-0.01	9.060	0.50
BGE025277 x LA5108	4.06	0.01	0.10	-0.03	0.915	0.48

Positive values of the transgression indicator allow the sampling of homozygous genotypes to be determined with the maximum and minimum possible meanings for the fresh aboveground mass weight that can be obtained by combining the parental components. Crosses where LA5108 is the mother form in rare sowing, better transgressions can be expected due to the higher values of the transgression indicator. Reciprocal crosses are better at elevating the sowing rate. The number of genes (N) in which the parental forms differ in terms of the productivity of fresh aboveground biomass weight is not large (1-2). The exception is combination; LA5108 x BGE027129 and its reciprocal crossing in dense sowing (6-11). In this hybrid combination, maternal cytoplasm was implicated in the inheritance of the sign (Figure 1), irrespective of the sowing of the plants (-0.74, -0.07). Cytoplasmic effect also occurs in hybrid combination; BGE025277 x LA5108, but only at rare sowing.

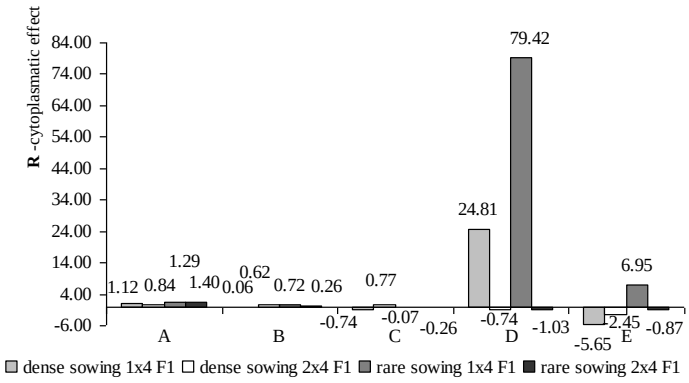

Figure 1. Cytoplasmatic effect (re) in inheritance of signs tested in first hybrid generation 1x4 F1 - BGE027129 x LA5108; 2x4 F1 - BGE025277 x LA5108;
A - Fresh root mass weight (g); B - Fresh leaves weight (g); C - Fresh aboveground mass weight (g); D - Number of nodules per plant; E - Nodule weight per plant (g)

In the present study, negative values for the D indicator shows that dominant alleles determine a lower aboveground mass per plant. Positive values for epistatic gene interactions (E) are only observed when crossing variety LA5108 with BGE027129 by enhancing the effect of dominant alleles and resulting in stronger phenotype expression. The high inheritance coefficients (H2> 0.90) and coefficient of effectiveness (Pp) for hybrid combinations; LA5108 x BGE025277 and BGE025277 x LA5108 from 0.46 to 0.61, give reason to predict that under this sign the selection will be effective in early hybrid generations.

Data on number of nodules show that the number of genes from which the parent parental form differs varies widely (N from 1 to 11 in the rare sowing and from 1.7 to 101 in the case of sense sowing). The dominant alleles of the indicated genes (D) act in the direction of determining a greater number of nodules per plant (except BGE025277 x LA5108).

The highest transgression indicators (Tn) were found in the hybrid plants of the combination LA5108 x BGE027129. Predominantly negative values for epistapic interactions (E) show a potential for lower phenotypic expression of the trait in subsequent generations. In the present study, the coefficients of inheritance (H2) are high in all crosses except for LA5108 x BGE025277 (0.10). Based on the values of the parameter (Pp), we can predict that a higher number of nodules per plant will be more effective in later generations (F5 - F6).

The values of the transgression coefficients (Tn) indicate that in the resulting F2 populations of the crosses LA5108 x BGE027129 and BGE025277 x LA5108, successful individuals may be selected to have a significantly higher weight of nodules per plant compared to the parental forms. The estimated number of genes by which parental forms differ by weight of nodules is too small, except for BGE027129 x LA5108 in both environments (30.56-49.80). Crossing of BGE025277 with LA5108 in the first hybrid generation determines the influence of maternal cytoplasm hereditary factors in inheriting the number and weight of nodules (Figure 1). At this cross, the dominant alleles of these genes act in the direction of increasing the weight of

nodules. Interletal Interactions (E) have positive, albeit low, values for the LA5108 x BGE027129 combination. Inheritance coefficients (H2) are relatively high and it can be assumed that the genetic fraction in the phenotypic expression of the attribute is greater. The values of parameter (Pp) for the effectiveness suggest that the selection of the forms with greater nodule weight should be effective in earlier generations, especially LA5108 x BGE025277 and BGE025277 x LA5108.

Figure 2 (A and B) shows the results of the test are 16 F1 hybrids at the limit of the environment expressed by two different sowing rates (dense and rare) for the signs of nodule weight and fresh aboveground biomass weight. In the case of dense sowing (Figure 2A), the most valuable hybrid is LA5108 x BGE025277 (1), followed by BGE025277 x LA5108 (3) and BGE027129 x LA5108 (3). These hybrids exhibit a good combination of adaptability and attraction genes (rapid displacement of plastics) in conditions of deterioration.

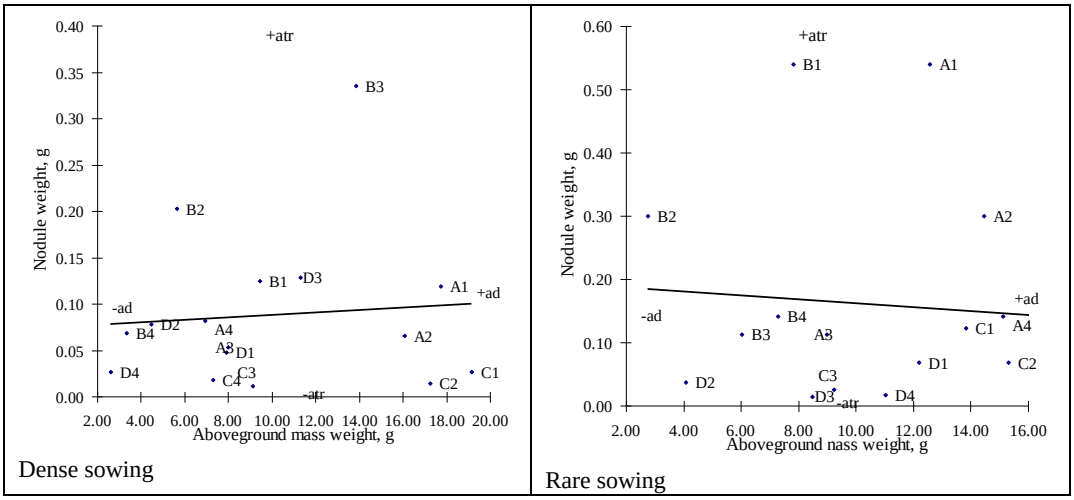

Figure 2. A - LA5108 x BGE025277; B - BGE025277 x LA5108; C- LA5108 x BGE027129; D - BGE027129 x LA5108; 1, 2, 3, 4 – individual plant from the respective hybrid

In the case of the rare sowing (Figure 2B), such a combination has hybrids LA5108 x BGE025277 (1) and LA5108 x BGE025277 (2) with positive values of attraction and adaptability. Hybrid A1 at both limits of the environment retains its place in the same quadrant, albeit changing its growing conditions. Under favorable growing conditions (dense sowing), this hybrid shows a maximum positive degree of attraction, suggesting that it is a carrier of strong attraction genes (genes for productivity of the signs tested).

Hybrids BGE025277 x LA5108 (3) and BGE027129 x LA5108 (3) have fallen into a quadrant determined by negative adaptability and attraction, indicating that genetic control over adaptability is redefined to a higher seed density for these hybrids. By genetically changing the attraction of grass pea hybrids, a strong polymorphism can be found, which suggests a good selective perspective for improving this culture.

Hybrid combination BGE025277 x LA5108 (1) similar to crossing LA5108 x BGE025277 (1) does not change its position relative to the quadrants, but also under strong conditions it shows a strong attractiveness. Hybrid combinations LA5108 x BGE027129 (1) and LA5108 x BGE027129 (2) adapt well to both limits of the environment. They are characterized by positive values by adaptability and negative by attractiveness. Stable position in the negative part occupies other hybrids.

DISCUSSION

ZOLOTARYEVA (2012) reports of hybrid forms, where there was over dominance observed by the elements of seed productivity in the first generation (F1) and positive transgression in F2. According to the author in the F2-F5 hybrid generations, it is possible a selection of the plants that significantly outperforms the parents.

As a result of multi-annual studies on symbiotic genetics in *Pisum sativum* L., SIDOROVA *et al*. (2015) provide data showing that the inclusion of a new feature in the selection process - a symbiotic nitrogen fixation from the atmosphere is practically possible. They believe that in pea, which is a model culture in genetics, and in whose genotype are found many genes controlling symbiotic features, genes responsible for the noduler-forming ability are of particular importance for selection.

ULLOA and MERA (2010) report moderate to high inheritance coefficients in the broad sense, and low to moderate inheritance coefficients in the narrow sense for grain weight and grain size for grass pea genotypes obtained in the hybrid variability way. The authors have received desirable recombinant forms promising to improve these signs.

TICHONOVICH and PROVOROV (2014) consider that when the value of the inheritance coefficient for the attributes associated with nitrogen fixation is high, by these parameters the selection could be very effective. At the same time, in the selection process, it must be have in a mind that the nature of the inheritance of symbiotic activity depends on the species of the plant and on the analyzed trait. The authors found that in soybeans the high level of nitrogen fixation is a dominant feature, and in red clover, alfalfa and peas is recessive or incompletely dominant.

The importance of the additive component compared to the additive-dominant in the inheritance of the plant height and the length of the inter granulate is confirmed in other legume species (beans and lentils) (CHECA *et al*., 2006; VANDA *et al*., 2013).

KHODAMBASHI *et al*. (2012) reported a low inheritance coefficient in the narrow sense of the lens for signs of grain yield from a plant, pod length, number of seeds in pod and 1000 seeds weight, and an average inheritance level for most of the other quantitative signs. They also report that dominant gene effects play an important role in the inheritance of signs of seed weight, number of primary and secondary stem branches, pod length, and 1000 seeds weight.

VANDA *et al*. (2013) establish a high statistically significant additive component variance for all the features they investigate, being relatively high-inheritable, defining the signs of the days to flowering and the duration of the vegetation period. As low inheritable they characterize the number of pods per plant, the number of seeds in pod and seed weight, indicating that the environmental factors have a very strong influence on the manifestation of these signs.

CONCLUSIONS

A negative heterosis effect was found in almost all hybrids at two environment limits (seed density). The exception was LA5108 x BGE027129 hybrid combination, which is

characterized by a high heterosis effect on the number of nodules per plant.

Dominant to over-dominant negative inheritance was found in F1 of crossing BGE027129 x LA5108 for fresh root mass weight, aboveground mass weight and nodule weight per plant, and in combination: LA5108 x BGE027129 for fresh leaves weight and fresh aboveground mass weight. Hybrid combination; LA5108 x BGE027129 shows a positive dominance and over-dominance in both, number and weight of nodules per plant. Non-allelic interactions occur in inheriting the number and weight of nodules in the hybrid combination BGE025277 x LA5108.

The hybrids tested had the most pronounced positive transgressions on the fresh aboveground mass weight, number and weight of nodules.

The common phenotypic manifestation of fresh root mass weight, fresh aboveground mass weight and nodule weight is highly genotypically determined, and a larger effect can be expected from conducting mass selection on these signs in earlier hybrid offspring (F2 - F3). A universal donor (LA5108 x BGE025277) has been established between the hybrids for attractiveness and adaptability. The assessment of the initial material makes it very likely to determine the appropriate productivity genotype and to speed up the process of creating new varieties of grass pea.

Received, May 18th, 2018
Accepted May18th, 2019

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GENETIČKA ANALIZA KVANTITATIVNIH SVOJSTAVA GENOTIPOVA SASTRICE (*Lathyrus sativus* L.)

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Izvod

Urađena je sveobuhvatna procena kvantitativnih svojstava sorti i hibrida sastrice u cilju uključivanja u proces selekcije. Negativan efekat heterozisa je nađen kod gotovo svih hibrida u dve granične spoljašnje sredine. Izuzetak je bio hibrid LA5108 x BGE027129, koji je karakterisan visokim efektom heterozisa na broj nodula po biljci. Dominantna super-dominantna negativna naslednost je pronađena u F1 kod hibrida BGE027129 x LA5108 za svežu masu korena, nadzemnu masu i težinu nodula po biljci, kod LA5108 x BGE027129 za masu svežeg lišća i svežu nadzemnu masu. LA5108 x BGE027129 pokazalo je pozitivnu dominaciju i super-dominaciju kod broja i težine nodula po biljci. Ne-alelne interakcije se javljaju kod nasleđivanja broja i težine nodula u hibridnoj kombinaciji BGE025277 x LA5108. Testirani hibridi su imali najizraženije pozitivne transgresije na svežoj nadzemnoj masi, broju i težini nodula. Uobičajena fenotipska manifestacija sveže mase korena, sveže nadzemne mase i težine nodula je visoko genetski određena, a veći efekat se može očekivati od sprovođenja masovne selekcije na ovim osobinama u ranijem hibridnom potomstvu (F2 - F3). Procena početnog materijala čini vrlo verovatnim da se odredi odgovarajući produktivan genotip i da se ubrza proces stvaranja novih sorti sastrice.

Primljeno 18.V.2018.
Odobreno 18. V. 2019.