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Research Articles

Comparative biological characteristics of pea (*Pisum sativum*) varieties

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ABSTRACT

Some basic quantitative signs and phenological indicators were analyzed for samples of seven forage peas (*Pisum sativum* L.) of different origins. Plant material from both, aboveground and root biomass was analyzed: i) in the beginning of flowering stage: plant height (cm), fresh stem weight (g), dry stem weight (g), root length (cm), fresh root mass weight (g), dry root mass weight (g), nodules per plant and nodule weight per plant (g); in the technological maturity of seeds stage: number of pods per plant, number of seeds per plant, seed weight per plant (g), number of seeds per pod and seed weight per pod (g). Broad sense heritability (Hbs) was calculated. Hierarchical cluster analysis was applied for the grouping of genotypes by similarity and correlation analysis for the finding the relationships between the signs and their variability. Specimens which meet the highest plant length requirements, green mass yield root length, number and weight of nodules were shown. They are considered as suitable for inclusion as parent components in future breeding programs. Some correlations were found, i.e. between the fresh stem weight and the nodules (r = +0.951), between the nodule number and the root length (r = +0.949) and between the weight and the number of seeds (r = +0.950). The findings could be of use for the breeding process in peas.

Keywords: Correlation, Genetic diversity, Inheritance, Pea

Field pea (*Pisum sativum* L.) is one of the major grain legumes, having a wide spread, and diverse use. This crop is used in crop rotation as it contributes to soil fertility and is a factor in the biological intensification of plant production. The strategy for the development of crop selection and seed production involves the need to create high yield varieties that can withstand environmental stressors (Shchur *et al.* 2016, Vinogradov *et al.* 2018). The current upgrading of existing and the development of new technologies in the selection process is linked to the use of modern methods of research, bioengineering, effective donors and sources of valuable signs.

A selection of pea varieties aimed at increasing the symbiotic activity of the crop without reducing the level of productivity, the question of choosing the appropriate initial material must be resolved first. This problem becomes particularly significant in the creation of high-yielding pea varieties, as the researchers have not reached a single opinion on the responsiveness of the plant to the factors of the external environment (Solovov 2006). The purpose of the study is to assess the biological potential of varieties of forage peas on basic quantitative signs.

MATERIALS AND METHODS

The study was carried out during 2014–2016 at the experimental farm of the Institute of Forage Crops, Pleven, Bulgaria. Sowing was carried out manually in optimal time according to the technology of cultivation of the crop. Plant material from aboveground and root biomass of 7 pea varieties, i.e. spring – X07P54 (afila leaf type), X06PWY, NDPO80138-B-2, CA1P (afila leaf type), winter - L020140, Wt6803 and Mir was analyzed. The following characteristics were assured: i) in the beginning of flowering stage: plant height (cm), fresh stem weight (g), dry stem weight (g), root length (cm), fresh root mass weight (g), dry root mass weight (g), nodules per plant and nodule weight per plant (g); ii) in the technological maturity of seeds stage: number of pods per plant, number of seeds per plant, seed weight per plant (g), number of seeds per pod and seed weight per pod (g). Biometric measurements were made in 10 plants of each variety. During the vegetation all observations were done for phenological periods from sowing to beginning of flowering and sowing to technical maturity and the degree of earliness (Kuzmova 2002). Criteria for assessing the degree of earliness was adopted for the date of the beginning of flowering, and for the quantitative assessment the coefficient of earliness was used. For ultra early varieties the value of this coefficient was from 1.00 to 1.17, for the early varieties from 1.17 to

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1.33, for middle-early ones from 1.34 to 1.66 and for the late varieties was greater than 1.66. For all traits Broad sense heritability (Hbs) was calculated using the formula proposed by Mahmud and Kramer (1951).

The next statistical methods were used to process the experimental data: hierarchical cluster analysis by the method of Ward (1963); correlation analysis (Dimova and Marinkov 1999). All experimental data were processed statistically with using the computer software STATGRAPHICS Plus for Windows Version 2.1. and GENES 2009.7.0 for Windows XP (Cruz 2009).

RESULTS AND DISCUSSION

The two-factor analysis of the variants for genotypes and environments (years) shows a lack of statistically significant differences for genotypes in terms of fresh and dry weight of root mass, weight of nodules and seed weight. The variation due to the environment is highly reliable for all other traits as well as for the interaction of genotype × environment with the exception of the nodule number and number of seeds. Using the sums of the squares of the analysis (Fig 1) it was found that under the conditions of the years, 80-63% of the total variation was due to the fresh and dry weight of the plant stem, and to the genotypes 8-2%, respectively. The genotype factors and the genotype × environment interaction had a decisive contribution to the overall variation in root length, number and weight of plant seeds, and number of seeds. Zelenov (2017) reported that for pea, the greatest selection effect was achieved by introducing into the genome genes that determined a lower stem and a lack of leaves. As a result, the realization of the genetic potential of the plants under agrophytocenosis has increased due to the increased resistance to depression. At the same time, the bioenergy potential of plants has not increased. The authors argue that the increase in yields is the result of the intensification of the production process, which is manifested in an increase in the tension between the donor-acceptor relationship between the vegetative and reproductive organs and the increase of the biological potential to the possible limit.

The results of the three years observations show slight differences in the duration of the sowing to beginning of flowering period (62-63 days) in the varieties X07P54, X06PWY and NDPO80138-B-2. This period for CA1P (58 days) and the coefficient of earliness was 1. The difference in the duration of the phenological phase sowing to the beginning of flowering in the wintering samples is from 6 days (Mir) to 9 days (Wt6803). The shortest period (195) is distinguished by variety L020140 and the longest Wt6803 (204 days). The same sequence is also maintained with regard to the sowing to technical maturity, this period varies within 234-243 days. The coefficient of earliness determines variety L020140 as early (1), while Wt6803 as late maturing. The results of Tiurin (2014) in vetch showed that the more the plant forms a leaf-stem mass, so the period of germination to flowering is longer. This shows that the selection of earliness due to the shortening of the interphase period of germination to the beginning of flowering without compromising the productivity of the green mass will be associated with a number of difficulties.

Mustache (afila leaf type) varieties of peas have undeniable advantages over the other morphotypes in terms of the resistance to lodging. Nevertheless, Novikova (2012) consider that the afila leaf types can only fully realize its productive potential in favorable soil and climatic conditions.

The mean values of the characteristics of the pea varieties studied are presented in Table 1. At the beginning of flowering, maximum growth in height of the plant was recorded in Mir (92.06 cm) and Wt6803 (89.63 cm). It can be seen that variety L020140 is also characterized by a large plant height (82.06 cm). Differences between the other samples are insignificant and range from 46 to 53 cm. The length of the stem influences its weight. According to the results, the highest stem weight was found in plants of Mir and Wt6803, followed by L020140 and NDPO80138-B-2. Data on dry weight of the stems show less variation of this indicator. It is noteworthy that the genotype CA1P (3.05 g), which is semi- mustache type with respect to leaves, retreats only on Wt6803 (3.18 g) the difference being unreliable. The control variety Mir occupies a third position with a leaf weight of 3.02 g. Genotypes X07P54, X06PWY, NDPO80138-B-2 and CA1P are characterized by lower values of the root mass indices. Their root length did not exceed 13-14 cm, and the fresh roots weight of NDPO80138-B-2 (0.91 g) was close to that of L020140, which had the lowest weight among the wintering peas. These attributes showed a certain superiority of Wt6803 and Mir to all other varieties. The formation of nodules on the roots

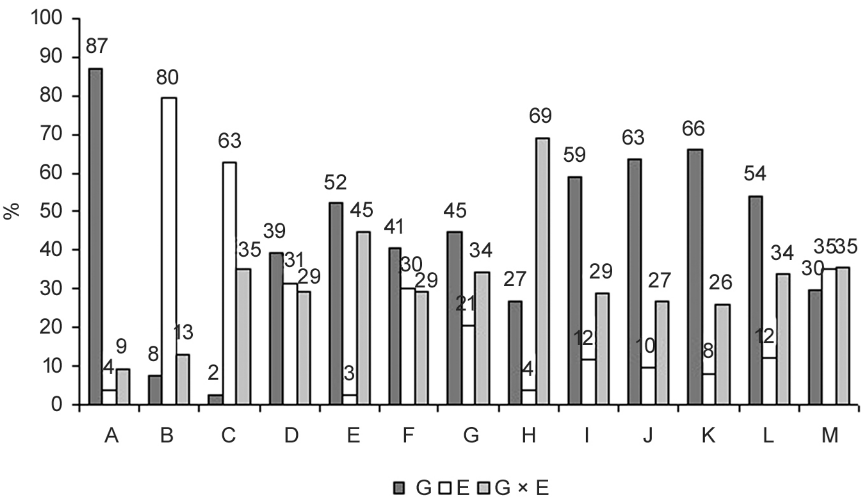

Fig 1 Percent of total variation. A-M (Same as footnote in Table 2). (G), Genotypes; (E), Environments; (G × E), Genotypes × Environments Interactions.

Table 1 Distinctive features of the investigated cultivars for beginning of flowering stage

Cultivar	Beginning of flowering stage							
	Aboveground mass			Root mass			Nodules	
	height (cm)	Stem fresh weight (g)	Stem dry weight (g)	Length (cm)	Fresh weight (g)	Dry weight (g)	Number	Weight (g)
X07P54	46.93	13.66	2.62	10.47	0.54	0.11	10.56	0.08
X06PWY	48.04	14.00	2.57	13.03	0.76	0.18	14.82	0.08
NDPO80138-B-2	47.11	15.14	2.97	11.79	0.91	0.18	24.55	0.21
CA1P	53.31	14.80	3.05	12.93	0.72	0.15	25.02	0.12
L020140	82.06	16.14	2.91	15.21	0.92	0.22	34.54	0.22
Wt6803	89.63	19.44	3.18	23.22	1.69	0.26	54.11	0.26
Mir	92.06	20.20	3.02	19.22	1.05	0.27	45.81	0.39
$LSD_{0.05}$	14.88	7.40	1.88	8.56	0.74	0.11	30.33	0.38
$LSD_{0.01}$	20.86	10.37	2.64	12.01	1.04	0.15	42.52	0.53
$LSD_{0.001}$	29.49	14.67	3.73	16.97	1.47	0.21	60.11	0.76

	Technical maturity of seeds stage				
	Number of pods/ plant	*Number of seeds/ plant*	*Seed weight/plant (g)*	*Number of seeds per pod*	*Seed weight per pod (g)*
X07P54	8.00	26.00	5.25	4.00	0.82
X06PWY	12.00	40.00	5.01	3.00	0.53
NDPO80138-B-2	17.00	74.00	7.56	4.00	0.44
CA1P	12.00	52.00	6.24	4.00	0.54
L020140	18.00	88.00	9.87	5.00	0.55
Wt6803	6.00	18.00	3.01	3.00	0.50
Mir	8.00	34.00	5.66	5.00	0.82
$LSD_{0.05}$	7.06	36.32	2..95	1.33	0.36
$LSD_{0.01}$	9.89	50.92	4.13	1.87	0.51
$LSD_{0.001}$	13.99	71.98	5.84	2.64	0.72

of legumes is an important factor and a prerequisite for subsequent symbiotic nitrogen fixation. The highest weight of the nodules was in the Mir variety. On the basis of these two characteristics of the spring specimens, the best was NDPO80138-B-2, forming about 24-25 nodules per plant weighing 0.21 g.

The analysis of biometric performance in technical maturity indicates a significant diversity. The number of pods is functionally related to the productivity of peas. The L020140 (18) and NDPO80138-B-2 (17) were distinguished by the highest number of pods. The number of seeds is an important feature in the yield structure. For L020140 (88) and NDPO80138-B-2 (74) were found on an average with the maximum number of seeds per plant. This characteristic depends not so much on the variety features but on the factors of the external environment. The seed weight (productivity) is a complex feature, which is determined by the ratio of many components, with the value of its influence primarily being the number of seeds and the 1000 seeds weight. The number of seeds per plant is also a complex feature defined by the number of productive nodules, number of pods on productive nodes and number of seeds in pod. L020140 (9.87 g) variety was found best. The number of seeds in pod depends on the number of seedlings and on the ability to form seeds in the pods. The environment also has a significant impact on this feature. L020140 and Mir managed to form on an average 5 seeds per pod and proved to exceed the remaining varieties, which formed 3-4 seeds in pod. In terms of seed weight the samples X07P54 and Mir are of interest. In their studies, Shurhaeva and Fadeeva (2015) found that, in general, genotypes with stable and high yields over the years may be of interest to the selection, but not less valuable are samples yielding maximum yields in individual years in extreme environmental conditions.

Due to the significant effect of interaction genotype × environment for most signs in the conditions of each year, a different grouping of samples of similarity and difference was established. This phenomenon shows that different genotypes have different genetic formulae, defining the expression of each sign. The phenomenon is known as redefinition of the genetic formula of the sign in changing the limits of the environment (Dragavtsev and Averyanova 1983).

The phenotypic variability of the pea specimens on the tested signs is represented by the values of the variation coefficient (CV %) (Fig 2). More strongly ecologically

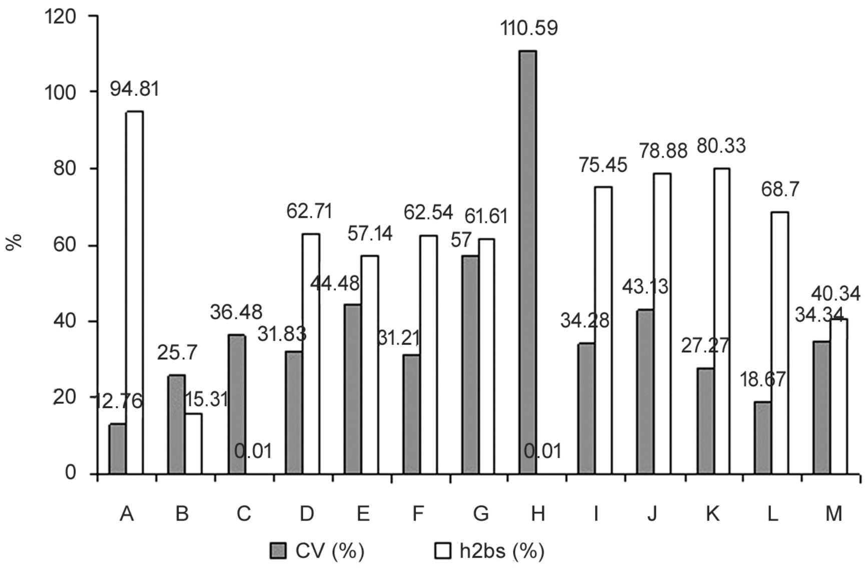

Fig 2 Variation coefficient and coefficient of inheritance in a broad sense for the signs studied. A-M (Same as footnote in Table 2).

dependent are the weight of the nodules (110.59%), the number of nodules (57%) and the fresh root mass weight (44.48%) exhibiting the highest variability. It was found that the dry stem weight, root length, number of pods and number of seeds per plant, seed weight per pod, seed weight per plant and fresh leaf weight were also highly variable. This would make choosing plants as parental forms one way only. Therefore, the selection must be based on a complex of signs. A relatively lower coefficient of variation was found for the plant height (12.76%) and number of seeds in pod (18.67).

It is important for breeders to know what elements of productivity have the greatest impact on yield, and also to what extent they vary depending on changes in climatic conditions. This would make it easier to create new high yield varieties. Determination of the coefficients of inheritance and variation in the pea samples allows us to assume the effectiveness of the selection according to the desired indicators. In our study, the genetic share in the total phenotypic expression of plant height (94.81%), seed weight (80.33%), seed number (78.88%) and number of pods per plant (75.45%) was high and the values of the coefficients of inheritance were relatively high. According to Amelin (1993) most modern varieties of peas are with two pods on a fertile knot, but there are enough speeches about the possibility of increasing grain yields on the basis of the forms forming more than two pods of a fertile knot. Increasing the number of pods per plant node is one of the effective ways to increase seed productivity in peas. The lowest inheritance coefficient is characterized by the dry and fresh weight of the stems, and the weight of the nodules, indicating that in the general phenotypic manifestation of this sign, the genotype has a relatively smaller share.

It is noteworthy that the signs determined at the beginning of flowering correlate positively with each other, whereas a significant part of the correlation coefficients with signs determined in technical maturity are negative, although statistically insignificant. The fresh stem weight is strongly dependent on the number of nodules (r = +0.951), the root length (r = +0.921), the dry root weight (r = +0.921) and the nodule weight (r = +0.926) (Table 2). Strong positive

Table 2 Correlation coefficients for the investigated signs in pea varieties

	A	B	C	D	E	F	G	H	I	J	K	L
B	0.920**											
C	0.623	0.716										
D	0.892**	0.921**	0.678									
E	0.735	0.800*	0.717	0.927**								
F	0.900**	0.922**	0.614	0.891**	0.807*							
G	0.922**	0.951**	0.835*	0.949**	0.896**	0.914**						
H	0.839*	0.926**	0.670	0.725	0.615	0.876**	0.847*					
I	-0.248	-0.394	-0.056	-0.455	-0.307	-0.136	-0.251	-0.129				
J	-0.121	-0.281	0.047	-0.385	-0.282	-0.057	-0.148	-0.001	0.982**			
K	-0.064	-0.271	-0.054	-0.431	-0.414	-0.105	-0.194	0.029	0.897**	0.950**		
L	0.122	0.005	0.095	-0.285	-0.440	0.024	-0.039	0.301	0.559	0.685	0.822*	
M	0.173	0.168	-0.290	-0.030	-0.313	-0.071	-0.082	0.193	-0.547	-0.453	-0.164	0.239

* /** Correlation is significant at the 0.05/0.01 level. A, Plant height (cm); B, fresh stem weight (g); C, dry stem weight (g); D, root length (cm); E, fresh root weight (g); F, dry root weight (g); G, nodule number per plant; H, nodule weight per plant (g); I, number of pods per plant; J, number of seeds per plant; K, seed weight (g); L, number of seeds per pod; M, seed weight per pod (g).

correlations were found between plant height and number of nodules (r = +0.922), fresh stem weight (r = +0.920) and fresh weight of root mass (r = +0.900). There is a positive relationship between the number of nodules with the root length (r = +0.949), the dry weight of the roots (r = +0.914) and the fresh root weight (r = +0.896), indicating that the number of nodules in a significant degree is influenced by the formation of these signs. Positive dependence is established between root length and fresh weight of root mass (r = +0.927). A similar trend is also found between the signs of grain productivity.

The resulting analysis revealed very strong correlation between the number of pods with the number of seeds per plant (r = +0.982) and the seed weight (r = +0.897). A strong influence on the productivity (seed weight) of the pea samples shows the number of seeds per pods (r = +0.822) and the number of seeds per plant (r = +0.950). Similarly, many researches reported that correlation between seed yield and biological yield was stronger than that of the other seed yield components in various annual legume forage species (Sayar and Anlarsal 2008). Zelenov (2011) and other authors consider that when creating new varieties, it is of great importance to determine the dependencies between quantitative signs at the genotypic level, with particular attention being paid to the links of the group of signs defining a given parameter with a certain level of correlation coefficients.

The Mir and Wt6803 varieties are suitable for inclusion as parent components in future selection programs. They meet the highest plant length requirements, green mass yield, root length, both, number and weight of nodules. The L020140 and NDPO80138-B-2 varieties may be used in the combinatorial selection for the production of forms with higher number of pods, higher number of seeds and seed weight. The CA1P and L020140 samples shows coefficient of earliness 1 and they are suitable as donors to produce genotypes with earlier flowering.

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