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COMPARATIVE BIOLOGICAL CHARACTERISTICS OF WINTER VETCH VARIETIES

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SUMMARY

The creation of varieties which to a bigger extent realize their biological capabilities in a wide range of environments is considered as an important task for the breeding of vetches. In this study winter vetch varieties of different origin have been tested on basic quantitative signs and indicators in a three year field experiment. Both, aboveground and root biomass of plants were analyzed. The hierarchical cluster analysis was applied to group the genotypes by similarity. Relationships between the signs tested were found after correlation analyses. A significant variability was found of nodule weight per plant (110.39%), aboveground mass fresh weight/root mass fresh weight ratio (74.67%), number of nodules per plant (66.56%), fresh stem weight (59.45%) and fresh root weight (58.38%). The stem length (9.14%) and root length (11.58%) are characterized by a higher stability. High coefficient of inheritance was obtained for the plant height (65.2%), nodule number per plant (33.37%) and root length (28.59%) signs. However, for the purposes of selection the BGE004222, BGE000643 and BGE001383 varieties could be used as parental forms for the creation of genotypes with an increased both number and weight of nodules per plant.

Key words : nodulation, winter vetch, productivity, earliness

Legumes improve soil fertility and are very good ancestors for subsequent crops in rotation. This also contributes to limiting the use especially of mineral fertilizers and is a prospect of creating new genetic-breeding technologies to provide plants with nitrogen through the symbiotic complex with nodule bacteria (Campiglia *et al.,* 2010; Mothapo *et al.,* 2013).

Soil degradation is a major environmental problem worldwide and there is strong evidence that the soil degradation processes present an immediate threat to both biomass and economic yields, as well as a long-term hazard to future crop yields. Hairy vetch (*Vicia villosa* Roth.) can be used as a winter annual legume and can grow from 0.6 m to 1.2 m high. It is widely adapted and its high nitrogen production, vigorous growth, tolerance of diverse soil conditions, low fertility needs and diverse climatic conditions make hairy vetch one of the most widely used of winter annual legumes (Chinamo *et al.,* 2010).

Together with genera vetchling (*Lathyrus* L.), lentil (*Lens* Mill.), pea (*Pisum* L.) and vavilovia (*Vavilovia* Fed.), the genus vetch (*Vicia* L.) makes the legume tribe Fabeae (Akopian *et al.,* 2010).

Hungarian vetch (*Vicia pannonica* Crantz), common vetch (*Vicia sativa* L.) and hairy vetch (*Vicia villosa* Roth.) are counted among the economically important crops in many temperate regions worldwide. All of them are multi-purpose crops, used for both, human consumption and animal feeding, in the form of green forage, forage dry matter, forage meal, pods with undeveloped grains, immature grain, mature grain and straw, as well as green manure (Mikic *et al.,* 2013).

As others pasture legumes, *Vicia villosa* is considered by agronomists as an improving physico-chemical soil quality species thanks to its atmospheric nitrogen symbiotic fixation ability and high crop residues return to the soil (Hassen *et al.,* 2012).

Biological nitrogen fixation efficiency depends on the type of Rhizobia strain, crop variety, and interactions between specific strains and crop varieties as well as environmental factors and management practices (Abi-Ghanem *et al.,* 2013).

Worldwide, in the collections of the research centers, a wide range of specimens possessing valuable selection qualities with good phenotypic plasticity and adaptability to changing ecological conditions (Sliesaravi?ius *et al.,* 2004).

The purpose of the study was to assess the biological potential of winter vetch varieties in terms of productivity and productivity components.

MATERIALS AND METHODS

The study was conducted during 2014-16 in the experimental field of the Institute of Forage Crops, Pleven, Bulgaria. Sowing was carried out manually in optimal time according to the technology of the cultivation of vetch. Plant material from aboveground and root mass of 8 winter vetch varieties of different origin, vz. BGE004222, BGE001847, BGE000637, BGE001076, BGE000639, BGE000643, BGE001383 and the Bulgarian variety Asko 1 were analyzed.

The following characteristics have been assessed at the beginning of the flowering stage of the plants: plant height (cm), fresh leaf weight (g), fresh stem weight (g) root length (cm), fresh root mass (g), nodule number and nodule weight (g). The fresh aboveground mass weight/fresh root mass weight ratio was calculated. Biometric measurements are made of 15 plants of each variety.

During the vegetation all observations were done for phenological dates periods of sowing-beginning of flowering and sowing-technical maturity and the degree of earliness by Kuzmova (2002). Criteria for assessing the degree of earliness was adopted 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 1.33, for middle-early ones from 1.34 to 1.66 and for the late varieties was greater than 1.66.

For all taits broad sense heritability (Hbs) was calculated using the formula proposed by Mahmud and Kramer (1951).

The statistical methods were used to process the experimental data: hierarchical cluster analysis by the method of Ward (1963) - for the grouping of genotypes by similarity as a measure for the difference (the genetic distance), the Euclidean distance between them was used, having previously standardization of the data carried out. The relationships between the signs and their variability were established by correlation analysis (Dimova and Marinkov, 1999). For statistical data processing a variance analysis has been applied to the individual signs.

All experimental data were processed statistically with using MS Excel (2003) for Windows XP and the computer software STATGRAPHICS Plus for Windows Version 2.1.

RESULTS

Climatic characterization of the experimental period

The study period covers three consecutive years differing in climatic terms. Table 1 presents the data on average monthly temperatures and the amount of precipitated rainfall by months during vegetation. The vegetation 2014 is the most favorable for the study period with average monthly air temperatures (April 12.3 °C, May 16.7 °C, June 20.6 °C) and rainfall 139.8 mm, 83.0 mm and 54.3 mm, respectively. As a result of the balanced combination of air temperature and optimum rainfall it has been favorable for plant development. The second year (2015) has relatively higher temperatures in May of 18.8 °C and uneven precipitation distribution, characterized by a certain drought in April (43.6 mm) and May (30.6 mm), and a larger quantity in June (95.7 mm). The third year (2016) occupies an intermediate position over the other two years with temperatures in the months of April and May, close to normal (15.3-16.4 °C) and rainfall between 73.1 and 76.5 mm.

Analysis of variance (Table 2) showed significant difference between genotypes only for plant height, indicating genetic variation for studied trait in

TABLE 1
Climatic characterization of the experimental period

Months	2014			2015			2016		
	t °C	rainfall mm	humidity %	T °C	rainfall mm	humidity %	t °C	rainfall mm	humidity %
January	0.8	41.8	82.0	1.9	12.4	80.0	-0.5	98.0	78.0
February	2.3	3.4	82.0	2.3	39.2	80.0	8.7	46.0	75.0
March	9.7	76.9	68.0	6.7	68.4	71.0	8.5	76.6	73.0
April	12.3	139.8	76.0	12.2	43.6	54.0	15.3	73.1	66.0
May	16.7	83.0	70.0	18.8	30.6	66.0	16.4	76.5	71.0
June	20.6	54.3	67.0	20.7	95.7	64.0	23.0	45.8	67.0
July	23.1	71.8	67.0	25.8	21.5	54.0	24.6	7.8	57.0

winter vetch and possibility of selection for improvement this. For almost all the signs the differences were found significant during the years of study. The exception were the fresh leaf weight and the parameter fresh aboveground mass weight/fresh root mass weight ratio.

The vegetation period determines the suitability of a variety for cultivation in a particular region with certain soil and climatic conditions. The length of the vegetation and the inter phenological subperiods constituting it depends both, on the biological characteristics of the variety and the meteorological conditions.

In the BGE004222, BGE000639 and BGE000643 varieties a shorter period of sowing-beginning of flowering (192 days) was established (Table 3). With the longest period to beginning of flowering the BGE001847 and control variety Asko 1 (196 days) were distinguished.

The main characteristic of the variety indicating the possibility of cultivation under certain conditions appears to be the length of the vegetation period and the effectiveness of its cultivation is mainly determined by the seed productivity. The fastest (236 days) for the study period ripen the specimens that intervened at the beginning of flowering stage. With small fluctuations, this pattern also applies to other varieties. For example, BGE000637 started flowering 194 days after sowing and ending vegetation for 234 days, while the beginning of flowering in the BGE000643 was two days earlier (192 days) and ripening for 236 days.

As a result of the studies carried out, the samples can be grouped by earliness in accordance with the climatic conditions in the following order: as ultra early can be determined BGE004222, BGE000639 and BGE000643 with a coefficient of inheritance 1; as early - BGE001076 and BGE001383; as middle-early BGE000637 and late were the varieties BGE001847 and Asko 1.

General information about the variety gives the characteristic of its habit and the assessment of the length of the main stem. With the lowest stem (78.78-88.73 cm) are distinguished varieties of BGE004222 and BGE000639. The length of the stem from 94.93 to 93.58 cm was typical for BGE000637 and BGE001076, and from 101 to 104 cm for BGE000643, BGE001847 and BGE001383. The

TABLE 2
Analysis of variance ANOVA for traits studied in vetch varieties

Source	d. f.	MS							
		Aboveground mass			Root mass		Nodules		Aboveground mass/root mass (fresh weight)
		height cm	fresh leaf weight g	fresh stem weight g	length cm	fresh weight g	number	weight g	
Varieties	7	216.43*	9.21	114.98	4.21	0.12	175.71	0.04	861.42
Years	2	4.284.14**	45.09	851.80*	18.41*	1.51*	2.077.86**	0.33**	2.795.66
Error	14	75.31	15.68	190.27	3.01	0.31	117.07	0.04	1.099.73
Total	23								

*Significant at P<0.05, **Significant at P<0.01.

TABLE 3
Morphological characteristics and phenological development of the vetch varieties

Variety	Sowing- beginning of flowering, days	Vegetation period, days	Earliness coefficient
BGE004222	192	236	1.00
BGE001847	196	241	2.00
BGE000637	194	234	1.50
BGE001076	193	234	1.25
BGE000639	192	236	1.00
BGE000643	192	236	1.00
BGE001383	193	239	1.25
Asko 1	196	241	2.00

Bulgarian variety Asko 1 forms plants, the height of which in the beginning of flowering stage is commensurate with that of the BGE000637 (Table 4).

The forage productivity of varieties is mainly determined by the fresh weight of the leaves and stems of the plant. According to the analysis of the data received, it can be noted that by the fresh weight of the leaves, half of the varieties involved in the study exceed the control variety. In the breeding process they are recommended as sources with an increased leaf weight per plant.

Maximum value by sign fresh stem weight per plant showed the varieties BGE000643 (34.35 g), BGE001847 (28.01 g) and BGE000637 (26.76 g) exceeding the standard with 3 to 9 g.

Some diversity is also found in relation to the signs associated with the root mass. Variety Asko 1 slightly superior to the varieties BGE001076 and BGE000639 along the root length, but inferior to the others, especially the BGE004222 and BGE001847. With the heaviest root mass are found variety BGE000637 (1.23 g), followed by Asko 1 (1.22 g) and BGE000643 (1.07 g). In the case of other specimens, the value of this attribute fluctuates from 0.68 to 0.93 g.

Bezuglova (2015) lends primary importance to legume crops in solving problems to improve nitrogen balance and increase yield. It recommends the widespread use of biological nitrogen obtained by nitrogen fixing bacteria to ensure agricultural production.

Observations on nodulation during the period of study showed that the highest number of nodules (26.47-29.73) formed plants of the varieties BGE001383 and BGE004222, exceeding two to three times the other specimens. The smallest number of nodules was obtained in BGE001076 (8.28) and BGE000643 (10.80).

The examination of the number of nodules per plant is related to the need for analysis of their weight. By nodule weight can be an excellent variety BGE000643 (0.45 g), followed by BGE004222 (0.26 g). The Asko 1 standard occupies a fifth position of 0.14 g nodule weight. For the purposes of symbiotically selection as parent components the BGE004222, BGE000643 and BGE001383 varieties can be used.

In each of the varieties the nodule size is different. Sometimes genotype with a large number of nodules per plant, which can be very small in size, the total weight of the nodule is low. Conversely, the plant may not form many nodules, but in size they are larger and they obtain a higher total mass.

On the basis of the signs and indicators studied, the varieties are classified by the cluster analysis carried out (Fig. 1). It was found that the tested group of specimens was divided into two main clusters. In the first cluster “A” falls only variety BGE004222, which is distinguished from other specimens with lower plants with long roots and with a greater number of nodules. In cluster „B” in subgroup „B1” alone is located a variety Asko 1, which in most of the signs occupies an intermediate position, but formed a relatively heavy aboveground and root mass. In the “B2” subgroup, genotypes which are characterized by similar expressions on the signs studied within the cluster and significant differences with genotypes from the other clusters fall. The cluster analysis of the winter vetch varieties according to the productivity elements

TABLE 4
Distinctive features of the investigated vetch varieties

Variety	Aboveground mass			Root mass		Nodules		Aboveground mass/root mass (fresh weight)
	height	fresh leaf weight	fresh stem weight	length cm	fresh weight	number	weight	
BGE004222	78.78	9.36	18.59	16.33	0.93	29.73	0.26	30.01
BGE001847	103.42	10.66	28.01	16.65	0.92	12.34	0.17	42.12
BGE000637	94.93	11.16	26.76	15.15	1.23	14.99	0.14	30.81
BGE001076	93.58	8.54	19.33	13.38	0.68	8.28	0.08	40.85
BGE000639	88.73	7.05	15.56	13.61	0.82	14.47	0.10	27.60
BGE000643	101.97	12.82	34.35	15.55	1.07	10.80	0.45	43.89
BGE001383	103.97	10.47	19.53	14.33	0.74	26.47	0.22	40.53
Asko 1	94.27	9.40	23.50	14.91	1.22	12.94	0.14	27.07
$LSD_{0.05}$	19.19	6.93	24.15	3.03	0.97	18.94	0.38	58.07
$LSD_{0.01}$	21.09	9.62	33.52	4.21	1.34	26.29	0.53	80.60
$LSD_{0.001}$	29.33	13.38	46.63	5.86	1.87	36.57	0.74	112.11

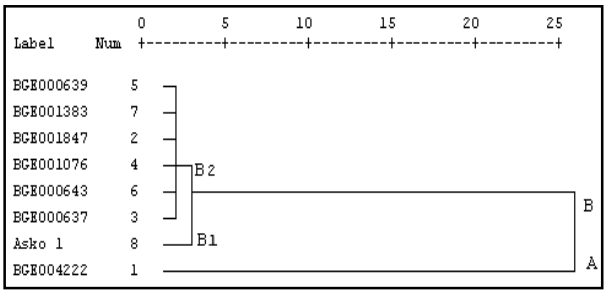

Fig. 1. Dendrograma of winter vetch varieties on the investigated signs.

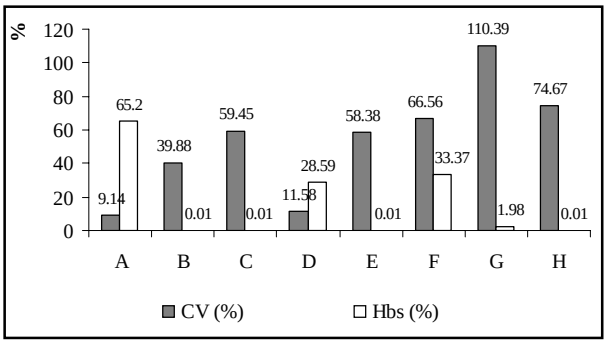

Fig. 2. Variation coefficient and coefficient of inheritance in a broad sense for the quantitative signs studied.
A-plant height (cm), B-fresh leaf weight (g), C-fresh stem weight (g), D-root length (cm), E-fresh root weight (g), F-nodule number per plant, G-nodule weight per plant, H-fresh aboveground mass weight/fresh root mass weight ratio.

of the fresh biomass showed that in the creation of new varieties on the path of combinatorial selection it is necessary to pay more attention to the plants belonging to the more distant clusters as source material. In their selection it is possible to obtain high yielding hybrid forms for forage and a greater number of nodules per plant.

The coefficients of inheritance and the variation (Fig. 2) of the tested signs of the group of winter vetch varieties are defined, which makes it possible to predict the effectiveness of the selection in the breeding process in future hybridization schemes.

When comparing the coefficient of variation for each of the signs studied, it is evident that maximum variability is observed by nodule weight per plant (110.39%). The fresh aboveground mass weight/fresh root mass weight ratio is also quite variable (74.67%) and to a significant extent influenced by environmental factors. The signs nodule number per plant (66.56%), fresh stem weight (59.45%) and fresh root weight (58.38%) also vary considerably. The improvement of growing conditions could lead to an increase in the value of these signs. The analysis of the variability of these major quantitative signs indicates that the level of their genotypic fluctuation is much lower than modificational. The signs stem length and root length are characterised by relatively weak variability (9.14%, 11.58%) to other signs.

High coefficient of inheritance was obtained for the signs of plant height (65.2%), number of nodules per plant (33.37%) and root length (28.59%), which implies that the tested group of vetches is prospective and can be used as an initial material for the selection of varieties with longer stems and roots and with a greater number of nodules per plant. The coefficient of inherience in a broad sense by other signs was found between 0.01 to 1.98%.

It is of particular importance for the selection of new varieties to find correlations between the signs determining productivity and other economic valuable indicators. Success in research can be made easier if there is knowledge of the dependencies between the relevant signs.

The data obtained from the correlation analysis (Table 5) show that there is a strong positive correlation between the stem fresh weight and plant height (r = 0.744) and fresh leaf weight (r = 0.63);

TABLE 5
Correlation coefficients for the investigated signs in vetch varieties

	A	B	C	D	E	F	G
B	0.378						
C	0.744**	0.630**					
D	-0.332	0.046	-0.072				
E	0.099	0.491*	0.508*	0.034			
F	-0.558**	0.135	-0.331	-0.011	0.268		
G	-0.332	0.401	-0.099	0.115	0.338	0.599**	
H	0.245	0.195	0.162	0.036	-0.464*	-0.283	-0.229

**Significant at the 0.01, * at the 0.05 level
A-plant height (cm), B - fresh leaf weight (g), C - fresh stem weight (g), D - root length (cm), E - fresh root weight (g), F - nodule number per plant, G - nodule weight per plant, H- fresh aboveground mass weight/fresh root mass weight ratio.

between fresh root weight and fresh leaf weight (r = 0.491) and stems (r = 0.508); between the nodule weight and number of nodules per plant (r = 0.599).

An average significant reverse relationship between the plant height and number of nodules per plant (r =-0.558) has been observed. The correlation of the plant height signs and fresh stem weight with the root length and with nodule weight per plant was found medium to weak negative.

DISCUSSION

It was found that the length of the fenological stage the beginning of flowering - physiological maturity had the greatest influence on the length of the vegetation period.

Debelyi *et al.* (2011) pointed out that there is currently considerable attention being paid to the evaluation of the individual elements of vetch productivity, determining the yield in changing environmental conditions. The height of the plants most fully reflects the potential vegetative performance in winter vetch varieties and this attribute is characterised by a high coefficient of inheritance in a broad sense. The same authors report the presence of a high positive correlation to the height of the plant with the fresh biomass, the number of petals of the complex leaf and their width.

Sayar (2014) using correlation analysis received results showing, that pod numbers per plant was significantly and positively correlated with seed yield. The remaining yield component traits were highly significantly positively correlated with seed yield. In addition, path coefficients analysis showed that only biological yield and straw yield had the strongest direct effects on seed yield. 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 *et al.*, 2011).

According to Tiurin (2014) the level of seed productivity is not conditioned by the length of flowering-technical maturity period. The absence of a positive relationship of the number of seeds per plant with the length of the period to the beginning of flowering and with the flowering period-ripening shows a real possibility of combining the signs earliness and high seed productivity in one genotype. Increasing the number of pods is possible by developing branches of the stem, and the number of seeds in a pod through the realization of a larger number of seed buds in a pod.

Investigating the initial material in the selection of faba bean Bezuglova (2015) found that the grain yields depend largely on the weight and number of nodules of the plant. According to the author the higher the values of these signs (or at least one of them), the higher the seed yields.

Golparvar (2012) defines the number and weight of nodules, as well as the number and weight of pods per plant as the most important criteria for the selection of genotypes with increased biological nitrogen fixation ability in the annual legumes.

Obuchova *et al.* (2013) in their studies with pea refute the recent opinion that a variety cannot be used simultaneously to increase productivity and at the same time be of increased nitrogen fixing ability. It is considered that the same source of energy is used in these processes - the products of photosynthesis, as the nutrients are consumed, both for the formation of the vegetative mass and for the formation of nodules.

The results of the studies on Kaigorodova (2014) have shown that the nature of the inheritance of selection valuable signs for peas is largely dependent on the genetic basis of plant material studied.

CONCLUSIONS

According to the coefficient of earliness calculation the BGE004222, BGE000639, BGE000643, BGE001076 and BGE001383 vetch varieties were considered as early varieties, however BGE001847 and Asko 1 as late ones. Strong positive correlations were found between the fresh stem weight and plant height (r=0.744), between the fresh stem weight and fresh leaf weight (r=0.63), between the fresh root weight and fresh leaf weight (r=0.491) and between the fresh root weight and fresh stem weight (r=0.508) and between the nodule weight and nodule number per plant (r=0.599). The BGE004222, BGE000643 and BGE001383 varieties could be used as parental forms for the creation of genotypes with an increased both number and weight of nodules per plant.

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