Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2019, 9(2), 156-169

ORIGINAL ARTICLE

The inheritance of economically valuable features in the intraspecific hybridization of bean (*Phaseolus* L)

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Received: 27.04.2019. Accepted: 24.05.2019

The detailed study of the variability range of the productivity components will allow conducting the effective selection of the perspective hybrid plants at earlier stages of their study and using them for the further breeding work, especially under the conditions of biosystems adaptation to the climate changes. It is known that the success of hybridization depends on the well-chosen parental forms. 8 samples of bean were involved into the intraspecific hybridization. The selection of the samples was performed on the basis of morphological, isoenzyme and RAPD analyses. According to the research methods the samples are genetically remote and differ morphologically. As the result of the conducted research and on the basis of the statistical analysis of the data concerning the inheritance of the productivity elements, the following combinations of the cross-breeding were identified: Dokuchaievska/Holberg, Dokuchaievska/UDO501722, Pervomaiska/UDO501722 and Pervomaiska/UDO501709 (most of the studied features in the hybrid populations are genetically determined and they have a positive heterosis effect). In most cases, we found a high degree of the transgressive forms, which were combined with their high frequency on the basis of "the number of beans per plant", "the number of seeds from the plant" and "the mass of seeds from the plant". The simultaneous combination of the high degree and frequency of the transgressions depends on the well-chosen parental components for the cross-breeding. It was established that the degree and frequency of the transgressive forms appearance were higher when the high level of the heterosis was observed. When conducting the heterosis selection (especially concerning the productivity), first of all, the attention should be paid to those combinations that exhibit a high heterosis effect by the number of beans per plant, the number of seeds from the plant and the mass of seeds from the plant. However, there are some cases when in the first generation of the hybrids there is a depression of the economically valuable signs, and in the subsequent generations, on the contrary, we observe an increase in the degree of these signs manifestation. It is precisely these cases we observed in the further study of the hybrid populations. The comparative estimation of the received data showed that between the various signs of the hybrids and parenalt forms, the most common is the correlative dependence of the low force. The analysis of the degree of the correlative relations between F_1, F_2 hybbrids and their parental forms of *Ph. vulgaris* species showed that both parental forms have strong, medium and weak correlative relations with the prevalence of the latter. In the first generation we have noted the dominance of weak correlative forces of relations; in addition there was a small number of strong relations between the investigated signs. In the next generation, the spectrum of the correlative relations level extends as a result of splitting, we observe three degrees of manifestation of the correlative relations tightness. In our case, the F_2 hybrids are characterized by the presence of strong, medium and weak links with the prevalence of the latter.
Keywords: Heterosis; prevalence; gene; hybrid; cross-breeding; *Phaseolus vulgaris L.*

Introduction

The breeding is a continuous process, the result of which is the continual creation of new varieties and plant hybrids. One of the most effective methods for enhancing the breeding is the methods of selection and hybridization (Konovalov et al., 2008). The cross-breeding of varieties of different ecological and geographical origin is an effective way to expand the genetic basis of the bean in order to improve the existing species and create new varieties (Guy et al., 1988). The manifestation of the heterosis in the first-generation hybrids (F_1) is one of the criteria for the cross-breeding efficiency. Despite a large number of forms with different characteristics, the creation of most varieties involves a small number of samples. It is necessary to involve more widely into the cross-breeding the varieties with the adaptive properties, as well as the wild-growing forms and various species of the bean. The attention should be paid to the directions of their usage (grain, vegetable, universal), the ways of cultivating (pure or mixed crops, greenhouse crops, irrigation, etc.) and to the needs of the population (habits, taste, etc.). But in all cases the variety must be productive (Malyshev et al., 2005; Katalog mirovoj kollekcii VIR 2004; Kozhuhova et al., 2006).

The species *Phaseolus vulgaris* (*L.*) is represented by a wide botanical diversity of forms and varieties with a wide polymorphism of morphological and biological characteristics, which contributes to the creation of fundamentally new varieties of the bean. The results of the hybridization experiments carried out within the bounds of the commom bean (*Ph. vulgaris*), involving a number of varieties geographically distant from the place of their formation, indicate the effectiveness of this method, which allows to influence the plants in order to expand their forming boundaries and to diversify the initial material when selected this crop (Illieva-Staneva, 1978; Kochieva et al., 2002).

At the example of varieties with different morphological features and their place of breeding, the contrast is established in the behavior of the hybrid offspring, which depends on the components of the cross-breeding. In the selection of the common bean, the hybridization within the species of *Ph. vulgaris* is one of the valid methods for creating a new phenotypically altered and valuable material for the selection.

The productivity of the crop and its increase are the actual task of the breeding process. This feature has a polygenic character, which makes it difficult to selective changes. Quite often the productivity is subdivided into separate structural elements, which, in turn, will give the opportunity to study separately the inheritance and variability of each element and their impact in general (Konarev et al., 2000).

In the literary sources there are data based on which it becomes clear that not only the biological peculiarities of the parental components, but also the conditions of cultivation affect the manifestation of the heterosis (Goncharenko et al., 1993). The genotypes taken for the selection had qualitative and quantitative differences as for the selected signs; and they were geographically and environmentally distant, which gave the perspectives for obtaining the new forms with valuable properties.

To accelerate the selection process, it is very important to choose the high-yield genotypes from the obtained hybrid populations, but this process is complicated due to the significant influence of the environmental factors on the elements that determine the efficiency of the sample (Bezugla, 1999; Golovan et al., 2011). The character of the quantitative signs inheritance is specific for each crop, and this fact is pointed out in many literary sources (Gostimskij et al., 1999; Baudoin, 1988; Jones et al., 1997). As quantitative characteristics are less subjected to the strict genetic control, one can observe a strong manifestation of heterosis (Gostimskij et al., 1999).

But at the present time, due to the wide involvement of the local initial material and different varieties of foreign selection into the breeding work and due to the climate changes, there was a question of the necessity to deepen the scientific knowledge as for the peculiarities of the manifestation of morphological and biological characteristics and properties; and the following researches are devoted to this very problem.

Methods

It is well known that the success of the hybridization depends on the well-chosen parental forms. 8 samples of the bean are involved into the intraspecific hybridization. The sampling was performed on the basis of the conducted morphological, isoenzyme and RAPD analyses. Thus, the samples that were genetically distant by the methods of the research and differed morphologically, and the samples that were genetically close had been selected.

In the process of the genetically distant forms cross-breeding, it is possible to limit the breeding by 20-30 flowers in order to obtain a sufficient variety of forms. The practice shows that under the optimal conditions for growing the hybrids of the first generation, 20-30 hybrid seeds are sufficient to produce the genetic diversity in the second generation (Guy et al., 1988; Golovan et al., 2011; Golovan et al., 2011).

The field experiments were carried out on the experimental field of Kharkiv National Agrarian University named after V.V. Dokuchaiev in 2007 - 2017. The experimental field is located in the northeastern part of the Kharkiv region within the limits of the land use of the educational and research farm of Kharkiv National Agrarian University named after V.V. Dokuchaiev.

The sowing was carried out by hand in the optimal time for the eastern part of the Forest-Steppe of Ukraine (May 1-10), with the norm of sowing 15 seeds per 1 linear metre. The predecessor is a bare fallow. The placement of the plots is standard. The method of sowing is a broad row with the space between the rows of 45 cm. The field experiments were laid out and executed according to the methods of the research work by B.A. Dospekhov (Dospehov, 1985). The bean cultivation technology is commonly used in the Forest-Steppe zone.

The observation and registration on the experimental plots were carried out in accordance with the "The Methods for Studying the Collection of Leguminous Crops" (Ivanova, 1968) and with the methods of the state sort testing of the agricultural crops (Volkodav, 2000). The morphological characteristics corresponded to "The Methodical Guidelines for the Study of the World Bean Collection Samples" (Chekalina, 1987), "The Method for Studying the Collection of Leguminous Crops" (Ivanova, 1968) and "The Wide Unified Classification of Ukraine of the *Phaseolus L* Genus" (Shirokyi unifakovanyi klasyfikator Ukrainy rodu Phaseolus L., 2004). As an initial material, 8 samples of the bean from the collection of Kharkiv National Agrarian University named after V.V. Dokuchaiev (KhNAU) and the National Center of Plant Genetic Resources of Ukraine (NCPGRU) were used (Table 1). The samples were introduced from various ecological and geographical regions (Ukraine, Bulgaria, Turkey, France, and USA) and they belonged to the species of *Phaseolus vulgaris*.

The cross-breeding plan was compiled according to the degree of the genetic proximity between the genotypes from the collection and the positive results from obtaining the fertile hybrid material, and this is described in the literary sources

(Illieva-Staneva, 1978; Mitranov, 1997; Molhova et al., 1986). The intraspecies cross-breeding was conducted during the period of the plants mass flowering.

The contrast parental forms with the high manifestation of economically valuable features (the high seed yield and resistance to damage by the pathogenic organisms) were selected for the cross-breeding.The cross-breeding was carried out according to the Fridental's method (Fridental, 1953). 50 flowers were pollinated for each combination. After the hybridization the pollinated flowers were marked with the coloured threads. The obtained hybrid material was collected separately for each combination and it was analyzed in the laboratory by hand. The percentage of the ovary was determined by counting the number of the beans that had become ovarian.

Table 1. Characteristics of bean collection samples by country of origin and national catalog numbers.

№	National Catalog of Ukraine	Sample name	Country Origin
		Ph. Vulgaris	
1	UD0300775	Dokuchaievska	Ukraine
2	UD0300025	Pervomaiska	Ukraine
3	UD0501709	-	Ukraine
4	UD0501722	-	Ukraine
5	UD0503341	-	Ukraine
6	UD0503256	-	Ukraine
7	UD0500223	Isex	France
8	UD0500227	Holberg	USA

In the hybrid hotbed F_1 the parenalt forms were sown next to the hybrid combinations. During the vegetation period the phenological observations of the hybrids and their parental forms were carried out. All the selected hybrids and 30 plants of the parental forms were collected by hand and the structural analysis was conducted under the laboratory conditions.

To characterise the hybrid material, such index as the variability of the quantitative characteristics was determined by the indicator of the arithmetical mean and its absolute error (Golovan et al., 2011). The value of the hybrid combination in the selection as for the true and hypothetical heteroses according to separetely studied features was calculated based on the formula (Abramova, 1992). The depression of the true heterosis in F_2 was calculated according to the formula (Zamotailov et al., 1987). The patterns of the sign inheritance in the first generation and the nature of the genes action were determined depending on the obtained index of the phenotype dominance degree, which was calculated according to the formula by B. Griffing (Abramova, 1992; Griffing, 1950). The degree of dominance may reach the values from $-\infty$ to $+\infty$. The grouping of the obtained data was carried out in accordance with the classification by G.M. Beil., R.E. Atkins (Boudet, 1977).

The proportion of the genotype-determined variability of the studied characteristics was determined depending on the obtained value of the heredity coefficient in its broad sense and on the indicator of the relative diversity (Abramova, 1992). The effect of the total action of the polymeric genes, which manifested itself in a steady increase (T_c positive) or a decrease (T_c negative) of the quantitative manifestation of any feature in some plants in F_2 was characterised by the degree and frequency. The degree and frequency of the transgression were calculated using the formula of Voskressenska and Shpota (Voskressenska et al., 1967).

Results

On the whole, 600 flowers were pollinated as the result of 12 hybrid combinations, and 204 hybrid beans and 442 hybrid seeds with an average ovary value of 34.0% have been obtained (Table 2). The percentage of the ovary fluctuated within a small range – from 26.0% (combination ♀ Dokuchaievska/♂Isex) to 44.0% (♀ Pervomaiska/♂UDO501709). The percentage of the ovary depended on the combination of the cross-breeding, thus more seeds were obtained by breeding the genetically distant samples rather than genetically close ones. It has been established that the signs that determine the productivity are quite unsteady in both the parental forms and in the derived hybrid populations. The most changeable signs were: "the number of beans per plant" (the coefficient of variation was 16.3-58.3% for the parents, and 19.8-81.2% for F_1 - F_2 respectively), "the number of seeds from the plant" (the coefficient of variation was 23.6-76.6% for the parents and 30.3-84.6% for F_1 - F_2 respectively) and "the seed mass from the plant" (the coefficient of variation was 19.6-76.1% for the parents and 24.1-90.3% for F_1 - F_2 respectively).

Table 2. The binding of hybrid beans at intraspecific hybridization.

Combination of crosses	Isoenzyme/RAPD analysis	Pollinated flowers, pcs	Received		Fastener, %
			hybrid beans, pcs	hybrid seeds, pcs	
♀Dokuchaievska/♂Holberg	genetically distant	50	19	34	38
♀Dokuchaievska/♂Isex	distant/close	50	13	29	26
♀Dokuchaievska/♂UDO503341	distant/close	50	15	31	30
♀Dokuchaievska/♂UDO501709	close/distant	50	20	38	40
♀Dokuchaievska/♂UDO503256	distant/distant	50	14	32	28
♀Dokuchaievska/♂UDO501722	close/distant	50	17	36	34
♀Pervomaiska/♂Holberg	genetically close	50	16	42	32

♀Pervomaiska/♂Isex	distant/close	50	17	39	34
♀Pervomaiska/♂UDO503256	distant/close	50	14	34	28
♀Pervomaiska/♂UDO503341	genetically distant	50	18	36	36
♀Pervomaiska/♂UDO501722	genetically distant	50	19	40	38
♀Pervomaiska/♂UDO501709	distant /distant	50	22	51	44
Total	-	600	204	442	34

The signs "the plant height" and "the height of the lower bean fastening" in the conducted studies had an average coefficient of variation. Thus, the coefficient of variation for the parents was 16.9-32.4%, and for F_1 - F_2 it was 13.2-49.3%. The coefficient concerning the height of plants and the height of the bean fastening was 13.2-34.2% for the parents and 17.3-48.2% for F_1 – F_2 respectively. The least changeable signs among the studied ones that determine the level of the bean productivity are the "number of seeds in the bean" and "the mass of 1000 seeds". Accordingly, the coefficient of variation in the number of seeds in the bean of the parental forms ranged from 8.3% to 14.3%, while in the hybrids F_1- F_2 it was 6.2-19.4%. While the coefficient of variation of 1000 seeds mass in the parental forms was V=4.2-12.6%, in the hybrids it was 3.2-13.4%, respectively. This will give an opportunity to carry out the selections in the earlier generations based on these signs.

Table 3. Heterosis and inheritance of some quantitative characteristics in hybrid populations F_1, F_2 *Ph. vulgaris.*

Signs	Statistical Indexes	Hybrids											
		♀1/♂2* F_1	♀1/♂2 F_2	♀1/♂3 F_1	♀1/♂3 F_2	♀1/♂4 F_1	♀1/♂4 F_2	♀1/♂5 F_1	♀1/♂5 F_2	♀1/♂6 F_1	♀1/♂6 F_2	1/♂7 F_1	♀1/♂7 F_2
Plant height	hp**	+0.7	-	-1.0	-	+0.7	-	+0.2	-	+0.7	-	+0.1	-
	H_{true}, %	-5.9	-	-5.2	-	-5.0	-	-10.9	-	-3.6	-	-6.3	-
	H_{hyp}, %	13.7	-	2.7	-	12.6	-	3.2	-	11.6	-	0.84	-
	Depr., %	-	11.4	-	14.5	-	13.2	-	14.3	-	20.8	-	11.7
	H^2, %	+32.8	+40.1	+31.5	-31.5	-10.9	+2.2	-7.1	+3.5	-15.0	-3.8	+10.7	-22.9
	IRD	0.09	0.10	0.08	0.08	0.06	0.07	0.12	0.13	0.10	0.11	0.08	0.06
The height of the lower bean fastening	hp	+2.0	-	+2.3	-	+3.0	-	+3.0	-	+5.0	-	+5.0	-
	H_{true}, %	+9.1	-	+14.3	-	+8.3	-	+15.4	-	+16.7	-	+18.2	-
	H_{hyp}, %	20.0	-	28.0	-	13.0	-	25.0	-	21.7	-	23.8	-
	Depr., %	-	-8.3	-	25.0	-	23.1	-	0.0	-	35.7	-	-15.4
	H^2, %	+29.5	+24.7	+25.3	+25.6	+10.6	-17.7	+31.7	+44.8	+32.5	-50.5	+60.0	+68.7
	IRD	0.45	0.42	0.41	0.41	0.31	0.20	0.6	0.68	0.47	0.21	1.1	1.5
The number of beans per plant	hp	+15.6	-	+1.6	-	+9.0	-	+1.8	-	+8.5	-	+9.3	-
	H_{true}, %	+88.0	-	+9.4	-	+17.4	-	+9.1	-	+57.7	-	+110.0	-
	H_{hyp}, %	100.0	-	29.6	-	20.0	-	23.1	-	70.8	-	142.3	-
	Depr., %	-	-13.0	-	28.6	-	25.9	-	-41.7	-	26.8	-	-14.3
	H^2, %	+76.3	+82.1	+36.1	-6.8	+34.6	-3.9	+52.4	+69.6	+49.1	+16.1	+75.7	+81.0
	IRD	0.9	1.19	0.19	0.11	0.19	0.12	0.29	0.45	0.24	0.14	0.58	0.74
The number of seeds from the plant	hp	+6.0	-	+0.46	-	+3.2	-	+3.0	-	+4.3	-	+7.3	-
	H_{true}, %	+67.3	-	-15.3	-	+13.5	-	+24.3	-	+50.5	-	+120.8	-
	H_{hyp}, %	93.1	-	18.0	-	20.9	-	41.5	-	77.9	-	173.2	-
	Depr., %	-	-24.3	-	30.6	-	16.7	-	-55.4	-	19.3	-	-0.38
	H^2, %	+66.4	+76.2	+28.6	-8.4	+49.3	+23.5	+63.3	+73.7	+55.3	+39.9	+77.7	+76.2
	IRD	0.14	0.20	0.04	0.03	0.07	0.05	0.10	0.14	0.07	0.05	0.15	0.14
The seed mass from the plant	hp	+8.5	-	+3.9	-	+4.5	-	+16.6	-	+2.4	-	+7.7	-
	H_{true}, %	+261.5	-	+111.8	-	+77.7	-	+260.0	-	+46.1	-	+231.0	-
	H_{hyp}, %	452.9	-	242.9	-	128.6	-	332.0	-	117.1	-	405.3	-
	Depr., %	-	-54.3	-	5.6	-	25.0	-	-25.9	-	36.8	-	-3.1
	H^2, %	+93.2	+96.5	+79.4	+80.4	+65.0	+47.3	+90.0	+91.5	+67.8	+30.5	+91.2	+91.2
	IRD	3.6	7.0	0.91	0.95	0.6	0.40	2.5	2.9	0.64	0.30	1.6	1.6
Number of seeds in the bean	hp	+0.3	-	-0.2	-	+0.5	-	+7.0	-	+0.8	-	+1.9	-
	H_{true}, %	-5.3	-	-22.6	-	-3.1	-	+18.8	-	-2.5	-	+7.7	-
	H_{hyp}, %	2.9	-	-3.5	-	3.3	-	22.6	-	8.3	-	18.3	-
	Depr., %	-	-5.6	-	-4.9	-	-3.2	-	-5.3	-	-5.1	-	-2.4
	H^2, %	+24.1	+9.6	+3.8	+3.8	-27.8	+2.0	+45.0	+49.4	+31.2	+22.2	+36.5	+35.6
	IRD	3.5	2.9	2.9	2.8	2.7	3.5	7.2	7.8	4.1	3.6	3.6	3.5
The mass of 1000 seeds	hp	+3.9	-	+0.33	-	+0.44	-	+3.63	-	+0.29	-	+4.39	-
	H_{true}, %	+35.3	-	-6.03	-	-10.8	-	+45.2	-	-10.0	-	+56.1	-
	H_{hyp}, %	64.9	-	3.31	-	10.5	-	75.4	-	4.44	-	86.9	-
	Depr., %	-	-34.4	-	3.7	-	-2.6	-	-34.9	-	-15.0	-	36.7
	H^2, %	+50.0	+60.8	-78.6	-1.8	-60.4	-45.2	+60.0	+69.6	-14.5	-25.7	+67.5	+74.7
	IRD	0.12	0.16	0.03	0.06	0.03	0.04	0.14	0.18	0.06	0.06	0.19	0.24

Note: *1 – Dokuchaievska, 2 – Holberg, 3 – Isex, 4 – UDO503341, 5 – UDO501709, 6 – UDO503256, 7 – UDO501722;
*** hp is the degree of the phenotype dominance, H true is the true heterosis, H hyp is the hypothetical heterosis, Depr. is the depression of the true heterosis, H^2 is a coefficient of inheritance, IRD is an indicator of the relative diversity.*

An estimate in order to define the character of the inherited quantitative signs was made in the obtained hybrid populations F_1 and F_2. It has been established that by the nature of growth the hybrids F_1 inherited the height of plants according to the following types: the partial positive prevalence (the combinations of Dokuchaievska/Holberg, Dokuchaeivska/UDO503341 and Dokuchaievska/UDO503256), the intermediate inheritance (Dokuchaievska/UDO501709, Dokuchaievska/UDO501722, Pervomaiska/Isex, Pervomaiska/UDO503341, Pervomaiska/UDO501709 and Pervomaiska/UDO501722 combinations) and partial negative prevalence (Dokuchaievska/Isex, Pervomaiska/Holberg and Pervomaiska/UDO503256 combinations). In the studied combinations the negative heterosis effect was observed in relation to a better parental form. According to the given sign, the depression of the heterosis, which was observed in the second generation in all hybrid combibations, was insignificant and varied from 7.7% to 32 (Tables 3 and 4).

The analysis of F_2 hybrids revealed the presence of a low inheritance coefficient (H^2) by this feature (the index varies from 2.2% to 48.6%), which indicates a significant dependence of this feature on the environmental conditions. The indicator of the relative diversity (IRD) on the basis of the plant height varied from 0.05 to 0.14.

The inheritance of the height of the lower beans tier fastening over the level of soil in the first generation occurs by the types of the intermediate inheritance (Pervomaiska/Isex and Pervomaiska/UDO503256) and positive overdomination (all the others). The best hybrid combinations of F_1 were Pervomaiska/UDO501709 and Dokuchaievska/UDO501722. They had the values of the true heterosis of 23.1 and 18.2%, and the degree of the phenotype domination of 7.0 and 5.0 (Tables 3 & 4). The hybrid combinations Dokuchaievska/UDO503256, Pervomaiska/Holberg and Pervomaiska/Isex showed a sharp decrease in the heterosis at 21.2-35.7%.

The coefficient of inheritance on this basis was at a rather low level for almost all hybrid combinations, which indicates the phenotype variability of this feature, with the exception of the Dokuchaievska/UDO501722 combination (H^2=68.7%). The relative diversity index in F_2 varied within the range of 0.20-1.5%.

The inheritance of the number of beans per plant in the first generation of the hybrids in all combinations takes place according to the type of the positive overdomination. On this basis the best hybrid combinations of F_1 were Dokuchaievska/UDO501722 and Pervomaiska/UDO501709, with the true heterosis indices of 110 and 105% and with the degree of the phenotype dominance of 9.3 and 15. On the basis of this sign the hybrid combinations of Dokuchievska/Holberg and Pervomaiska/UDO501722 were also singled out, they had the high positive heterosis of F_1 that amounted to 96.7 and 88%. Their degrees of domination reached the values of 15.6 and 6.8. The obtained data show that the quantitatively investigated sign in the second generation decreases by 13.1-28.6%.

The coefficient of inheritance of the number of beans per plant in the F_2 fluctuated within the range of 9.3-80.7%, depending on the combination of the cross-breeding; the obtained data indicate a different contribution of the genotype and environment in the formation of this feature in the researched hybrid combinations. The relative diversity index in all hybrid combinations was at a rather low level, indicating a low variation of the sign within each combination (Tables 5.3 & 5.4). The exception was the combination of Dokuchiaevska/Holberg, which IRD was 1.19.

The inheritance of the number of seeds from the plant in the first generation of the hybrids occurs by the following types: the positive overdomination (8 combinations), the partial positive domination (3 combinations) and the intermediate inheritance (1 combination). The sign "the number of seeds from the plant" was quite pronounced in the hybrids F_1 of the Dokuchaievska/UDO501722, Dokuchaievska/Holberg and Pervomaiska/UDO501722 combinations; the true heterosis according to the given sign was 120.8, 67.3 and 55.8% respectively. In the hybrids F_1 of the Dokuchaievska/Isex combination, the number of seeds from the plant is significantly reduced compared to the parental form, and the negative heterosis reached the value of 15.3%. In the latter combinations the heterosis varied from 13.5% to 5.5%. In 6 combinations from the next generation there was a decrease in the heterosis effect by 5.1-30.6%. The analysis of the heritability coefficient of F_2 plants shows that it varied within the range of 1.4-77.5% depending on the combination of the cross-breeding; the obtained data indicate a different contribution of the genotype and the environment in the formation of this sign in the researched hybrid combinations. On this basis the indicator of the relative diversity in F_2 was absent.

The inheritance of the seeds mass from the plant in the hybrids of the first generation for all hybrid combinations takes place according to the type of the positive overdomination, the exception was the combination of Pervomaiska/UDO503341 (the intermediate inheritance). The high level of the true positive heterosis was shown by the F_1 hybrid plants of Dokuchaievska/Holberg, Dokuchaievska/UDO501709 and Dokuchaievska/UDO501722 combinations, it was 261.5%, 260.0% and 231.0% respectively (Tables 3 and 4).

The hybrid combinations of Pervomaiska/UDO501709 and Pervomaiska/UDO501722 with the high positive heterosis degrees of 162.5 and 123.1% for F_1 were also singled out. Their domination degrees reached the value of 18.3 and 7.4. The obtained data show that the quantitatively investigated feature in the second generation of 5 hybrid combinations is reduced by 5.6 – 36.8%. On this basis, the coefficient of inheritance in the F_2 hybrid combinations was 30.5-96.5% respectively, and it depended on the combination of the cross-breeding. The obtained data indicate a different contribution of the genotype and environment to the formation of this sign in the researched hybrid combinations.

The inheritance of the seeds number in the bean of the first generation hybrids took place according to the following types: the positive overdomination (5 combinations), the partial positive domination (2 combinations), the intermediate inheritance (4 combinations) and the partial negative domination (1 combination). It has been established that on this basis the majority of hybrid combinations showed a negative heterosis (Tables 3 & 4), which fluctuated from 2.5% to 22.6%, depending on the variant of the experiment. Only in the combinations in which the overdomination has been observed, the positive true heterosis that fluctuates within the range of 7.7-18.8% has been obtained. In all combinations of F_2 there was an increase in the sign by 2.4% - 11.8% in comparission with the first generation. The exception was the combination of

Pervomaiska/UDO503256 in which the depression at the level of 3.2% was observed. As the data of the coefficient of inheritance show, to a greater extent for most combinations the variability of the sign is due to the environmental impact.
On the basis of "the mass of 1000 seeds" the inheritance takes place by the following types: the positive overdomination (7 combinations) and the intermediate inheritance (5 combinations). The heterosis in the positive form was observed in those combinations where the inheritance of this sign took place on the basis of the positive overdomination, and it fluctuated within 3.1-64.5% respectively. As it has been established on the basis of the inheritance coefficient, the changeability of the sign fluctuates within 4.3-74.7% depending on the cross-breeding combination. The obtained data show various contributions of the genotype and the environment to the formation of this feature in the researched hybrid combinations.

Table 4. Heterosis and inheritance of some quantitative characteristics in hybrid populations F_1, F_2 *Ph. vulgaris*.

Signs	Statistical Indexes	Hybrids											
		♀1/♂2*	♀1/♂2	♀1/♂3	♀1/♂3	♀1/♂4	♀1/♂4	♀1/♂5	♀1/♂5	♀1/♂6	♀1/♂6	1/♂7	♀1/♂7
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Plant height	hp**	-0.4	-	0.0	-	+0.4	-	+0.5	-	-0.2	-	0.0	-
	H_{true}, %	-15.5	-	-6.1	-	-5.0	-	-10.6	-	-22.7	-	-1.5	-
	H_{hyp}, %	-5.3	-	0.0	-	4.1	-	11.3	-	-3.8	-	0.0	-
	Depr., %	-	15.1		11.5	-	8.5	-	32.0	-	11.6	-	7.7
	H^2, %	+12.8	-8.1	+6.4	-24.1	+46.3	+48.6	+56.6	+24.4	+11.2	+12.8	+33.0	+11.0
	IRD	0.06	0.05	0.09	0.07	0.11	0.11	0.25	0.14	0.11	0.11	0.09	0.07
The height of the lower bean fastening	hp	+2.3	-	0.0	-	+2.0	-	+7.0	-	0.0	-	+3.0	-
	H_{true}, %	+16.7	-	0.0	-	+14.3	-	+23.1	-	-15.4	-	+16.7	-
	H_{hyp}, %	33.3	-	7.1	-	33.3	-	4.0	-	-8.3	-	27.3	-
	Depr., %	-	21.2		26.6	-	8.9	-	8.3	-	-9.9	-	5.7
	H^2, %	+41.9	+35.3	+2.2	-23.5	+59.1	+39.6	+54.8	+34.5	+16.1	+9.7	+49.3	+34.1
	IRD	0.76	0.68	0.44	0.34	0.94	0.64	1.16	0.80	0.53	0.49	1.2	0.96
The number of beans per plant	hp	+3.0	-	+2.5	-	+12.3	-	+15.0	-	+4.3	-	+6.8	-
	H_{true}, %	+20.0	-	+28.1	-	+73.9	-	+105.0	-	+38.5	-	+96.7	-
	H_{hyp}, %	33.3	-	57.7	-	86.0	-	121.6	-	56.5	-	136.0	-
	Depr., %	-	13.1	-	26.0	-	-0.11	-	-19.9	-	-8.3	-	5.1
	H^2, %	+33.9	+9.3	+47.9	+11.4	+71.8	+77.7	+74.9	+80.7	+34.4	+32.2	+76.7	+78.5
	IRD	0.33	0.24	0.23	0.14	0.44	0.56	0.55	0.72	0.19	0.18	0.10	0.66
The number of seeds from the plant	hp	+0.7	-	+0.7	-	+7.7	-	+3.7	-	+0.7	-	+3.6	-
	H_{true}, %	-5.0	-	-8.3	-	+14.7	-	+23.5	-	-5.6	-	+55.8	-
	H_{hyp}, %	13.6	-	31.1	-	17.3	-	35.5	-	15.4	-	98.9	-
	Depr., %	-	5.1	-	23.1	-	-14.2	-	-16.9	-	10.9	-	-3.7
	H^2, %	+30.3	+18.4	+35.9	-7.6	+47.7	+54.7	+52.0	+60.3	+13.6	+1.4	+72.1	+77.5
	IRD	0.06	0.05	0.04	0.02	0.06	0.06	0.06	0.08	0.03	0.03	0.10	0.12
The seed mass from the plant	hp	+6.3	-	+2.6	-	0.0	-	+18.3	-	+5.9	-	+7.4	-
	H_{true}, %	+72.2	-	+36.7	-	+106.3	-	+162.5	-	+73.9	-	+123.1	-
	H_{hyp}, %	100.0	-	78.3	-	106.3	-	189.7	-	105.1	-	176.2	-
	Depr., %	-	20.3	-	11.6	-	-22.3	-	-34.5	-	-1.3	-	-4.7
	H^2, %	+53.2	+56.4	+46.0	+41.8	+59.1	+84.2	+86.1	+88.8	+61.3	+56.2	+84.8	+85.7
	IRD	0.48	0.51	0.31	0.29	0.94	1.16	1.60	1.98	0.48	0.43	0.84	0.89
Number of seeds in the bean	hp	-0.3	-	0.05	-	+2.5	-	+5.0	-	-0.3	-	+2.4	-
	H_{true}, %	-10.5	-	-18.9	-	+9.4	-	+12.5	-	-22.5	-	+12.8	-
	H_{hyp}, %	-2.9	-	1.2	-	12.9	-	16.1	-	-13.8	-	23.9	-
	Depr., %	-	-11.8	-	-7.0	-	-2.9	-	-8.3	-	3.2	-	-4.5
	H^2, %	-12.4	+0.2	-27.7	-1.5	+30.8	+27.0	+29.6	+41.9	+0.4	+8.7	+52.6	+14.4
	IRD	2.5	2.9	2.3	2.9	5.4	5.1	6.1	7.4	3.1	3.3	5.2	2.9
The mass of 1000 seeds	hp	-0.4	-	+1.9	-	+2.6	-	+3.2	-	+0.2	-	+7.0	-
	H_{true}, %	-12.7	-	+3.1	-	+23.0	-	+28.5	-	-6.0	-	+64.5	-
	H_{hyp}, %	-4.2	-	6.7	-	43.2	-	48.0	-	2.0	-	84.5	-
	Depr., %	-	11.1	-	20.5	-	-22.7	-	-7.3	-	4.5	-	-3.4
	H^2, %	-3.6	+12.6	+12.7	-95.1	+39.7	+31.7	+30.5	+15.2	-64.8	+4.3	+74.4	+71.1
	IRD	0.08	0.09	0.07	0.04	0.12	0.17	0.10	0.09	0.06	0.11	0.32	0.28

Note: *1– Pervomaiska, 2 – Holberg, 3 – Isex, 4 – UDO503341, 5 – UDO501709, 6 – UDO503256, 7 – UDO501722;
*** hp is the degree of the phenotype dominance, H true is the true heterosis, H hyp is the hypothetical heterosis, Depr. is the depression of the true heterosis, H^2 is a coefficient of inheritance, IRD is an indicator of the relative diversity.*

Thus, according to the conducted statistic analysis of the data relating to the productive elements inheritance, it is possible to name the following cross-breeding combinations: Dokuchaievska/Holberg, Dokuchaievska/UDO501722, Pervomaiska/UDO501722 and Pervomaiska/UDO501709 (most researched features in the hybrid populations are genetically determined and they have the positive heterosis effect).
The manifestation of the transgressive variability in F_2 hybrids of Ph. vulgaris. The analysis of the quantitative signs inheritance in the hybrids contributed to the revealing of the transgressive forms. The revealed plants differed in stronger expressions of certain features in contrast to both parental forms. The numerical values of the polymerically inherited quantitative signs changed in the bean both, positively and negatively. The positive transgressions were noted for most of the studied signs: the

number of beans per plant, the number and mass of seeds from the plant, the mass of 1000 seeds, and the height of the lower bean fastening (Tables 5 and 6).

It has been established that the degree of the positive transgressions in the hybrid combinations on the basis of "the plant height" varied from 0.14 to 9.7% (Tables 5.6), while the degree of the negative transgressions varied from -0.8 to -15.7 %. On the basis of "the height of the lower bean fastening" the positive transgressions ranged from 4.4 to 36.8%, while the negative transgressions varied from -13.1 to -29.1% respectively. On the basis of "the number of beans per plant" the positive transgressions ranged from 4.1 to 27.8% respectively, the negative transgressions were -7.8%. On the basis of the "the number of seeds from the plant", the range of the positive transgressions was from 5.3 to 46.7%, the negative transgressions varied in the range from -2.6 to -18.6% respectively; on the basis of "the mass of the seeds from the plant" the positive transgressions varied from 14.3 to 86.0%, and the negative transgressions were revealed in only one hybrid combination and they reached the value of -1.9%. By "the number of seeds in the bean" the variation boundaries of the positive transgressions ranged from 2.4 to 26.0%, while the negative transgressions were within the range of -3.8 to -7.7% respectively; and on the basis of "the mass of 1000 seeds" the degree of the positive transgressions ranged from 0.4 to 53.4%, while the degree of the negative ones varied from -2.1 to -22.9% respectively.

On the average, in all combinations the degree of the positive transgressions concerning the plant height was 3.1% (negative - 2.2%), as for "the height of the lower bean fastening" the positive transgressions were 16.3%, and the negative ones were - 19.6%, by "the number of beans per the plant" the degree of the positive transgressions was 16.5% and the degree of the negative ones was -7.8%, by "the number of seeds from the plant" the positive transgressions reached the value of 24.3% and the negative ones were -7.1%. On the basis of "the mass of the plant seeds" the positive transgressions amounted to 41.9% and the negative ones reached the value of -1.9%; by "the number of seeds in the bean" the positive transgressions were 12.1% and the negative ones – -5.8%; and by "the mass of 1000 seeds" the positive transgressions were 20.1% and the negative ones – -10.9%. For most of the studied economically valuable signs, the degree of the positive transgression exceeded the degree of the negative ones, with the exception of the sign of the height of the lower bean fastening on the plant (Tables 5 and 6).

Table 5. Degree and Frequency of the transgressive variability in F_2 hybrids of *Ph. vulgaris*, %.

Combination of crosses	The height of the lower bean fastening				The number of beans per plant				The number of seeds from the plant			
	T_d. pos.	T_d. neg.	T_f. pos.	T_f. neg.	T_d. pos.	T_d. neg.	T_f. pos.	T_f. neg.	T_d. pos.	T_d. neg.	T_f. pos.	T_f. neg.
Dokuchaievska/Holberg	17.6	-	9.6	-	25.9	-	31.6	-	38.9	-	23.1	-
Dokuchaievska/Isex	-	-17.3	-	1.2	7.0	-	5.2	-	-	-2.6	-	3.6
Dokuchaievska/UDO503341	6.9	-21.0	4.3	1.4	4.9	-	4.1	-	12.2	-3.1	9.6	2.7
Dokuchaievska/UDO501709	7.1	-	6.7	-	18.4	-	21.3	-	35.7	-	24.6	-
Dokuchaievska/UDO503256	-	-29.1	-	0.7	6.7	-	33.4	-	6.7	-	20.9	-
Dokuchaievska/UDO501722	41.9	-13.1	3.6	2.1	27.8	-	8.7	-	37.9	-	7.3	-
Pervomaiska/Holberg	4.4	-	2.7	-	-	-	-	-	-	-	-	-
Pervomaiska/Isex	-	-17.6	-	2.4	4.1	-7.8	2.3	2.4	-	-4.1	-	5.9
Pervomaiska/UDO503256	18.4	-	5.7	-	4.8	-	2.6	-	5.3	-18.6	4.8	14.3
Pervomaiska/UDO503341	5.7	-	4.9	-	43.7	-	51.6	-	16.7	-	30.7	-
Pervomaiska/UDO501722	36.8	-	5.3	-	15.3	-	19.7	-	18.2	-	15.9	-
Pervomaiska/UDO501709	6.5	-	6.8	-	23.0	-	42.7	-	46.7	-7.3	21.4	1.7
Average	16.3	-19.6	5.5	1.6	16.5	-7.8	20.3	2.4	24.3	-7.1	17.6	5.6

Note: * T_d. pos. – the degree of positive transgressions, T_d. neg. – the degree of negative transgressions, T_f. pos. – the frequency of positive transgressions, T_f. neg. – the frequency of negative transgressions.

The conducted statistical processing of the obtained data showed that the frequency of the positive transgressive forms appearance as for the plant height varied within the range of 0.7-5.7%, as for the height of the lower bean fastening it varied from 2.7 to 9.6%, for the number of beans per plant it fluctuated within the limits of 2.3-5.6%, by the number of seeds from the plant it varied from 4.8 to 30.7%, by the mass of the seeds from the plant – from 4.3 to 4.3%, by the number of the seeds in the bean the frequency of the positive transgressive forms appearance varied from 1.6 to 17.6% and by the mass of 1000 seeds it varied from 4.3 to 25.3%, depending on the combination of the cross-breeding.

Table 6. Degree and Frequency of the transgressive variability in F_2 hybrids of *Ph. vulgaris*, %.

Combination of crosses	The seed mass from the plant				Number of seeds in the bean				The mass of 1000 seeds			
	T_d. pos.	T_d. neg.	T_f. pos.	T_f. neg.	T_d. pos.	T_d. neg.	T_f. pos.	T_f. neg.	T_d. pos.	T_d. neg.	T_f. pos.	T_f. neg.
Dokuchaievska/Holberg	75.0	-	4.3	-	9.5	-	4.3	-	32.4	-	5.6	-
Dokuchaievska/Isex	26.6	-	19.6	-	-	-	-	-	0.4	-14.3	4.3	1.7
Dokuchaievska/UDO503341	22.4	-	24.6	-	2.4	-3.8	1.6	5.3	3.8	-2.1	6.7	4.5
Dokuchaievska/UDO501709	22.4	-	21.9	-	26.0	-	8.3	-	18.6	-	10.3	-
Dokuchaievska/UDO503256	14.3	-1.9	40.3	2.3	8.3	-	17.6	-	8.3	-	4.9	-

Dokuchaievska/UDO501722	86.0	-	7.6	-	21.7	-	3.2	-	25.6	-	11.6	-
Pervomaiska/Holberg	-	-	-	-	9.5	-	2.7	-	-	-13.0	-	4.9
Pervomaiska/Isex	-	-	-	-	-	-	-	-	-	-22.9	-	5.7
Pervomaiska/UDO503256	54.8	-	20.6	-	-	-7.7	-	4.4	16.7	-2.2	10.7	6.9
Pervomaiska/UDO503341	77.6	-	10.2	-	9.5	-	4.3	-	53.4	-	24.6	-
Pervomaiska/UDO501722	17.4	-	19.4	-	15.2	-	10.6	-	21.3	-	25.3	-
Pervomaiska/UDO501709	22.4	-	21.8	-	6.5	-	4.5	-	-	-	-	-
Average	41.9	-1.9	19.0	2.3	12.1	-5.8	6.3	4.9	20.1	-10.9	11.6	4.7

Note:* T_d. pos. – the degree of positive transgressions, T_d. neg. – the degree of negative transgressions, T_f. pos. – the frequency of positive transgressions, T_f. neg. – the frequency of negative transgressions.

The frequency of the negative transgressive forms appearance as for the plant height varied from 1.6 to 3.1%, as for the height of the lower bean fastening it varied from 0.7 to 2.4%, by the number of beans per plant it was 2.4%, by the number of seeds from the plant it was in the range of 1.7-14.3%, by the mass of the seeds from the plant – 2.3%, by the number of seeds in the bean the frequency was 4.4-5.3% and the mass of 1000 seeds varied within the limits of 1.7-6.9%, depending on the combination of the cross-breeding. On the average, for all the studied combinations, the transgression frequency as for the plant height was 3.8% (positive) and 2.3% (negative), by the height of the lower bean fastening it was 5.5% (positive) and 1.6% (negative) , by the number of beans per plant it was 20.3% (positive) and 2.4% (negative), by the number of seeds from the plant the frequency reached the value of 17.6% (positive) and 5.6% (negative), by the mass of the seeds from the plant it was 19.0% (positive) and 2.3% (negative), by the number of seeds in the bean it was 6.3% (positive) and 4.95 (negative) and by the mass of 1000 seeds it ranged within the limits of 11.6% (positive) and 4.7% (negative).

The following hybrid combinations were distinguished by the degree of the transgressive forms manifestation: Dokuchaeivska/Holberg, Dokuchaievska/UDO501709, Dokuchaievska/UDO501722, Pervomaiska/UDO503341, Pervomaiska/UDO501722 and Pervomaiska/UDO501709. Thus, from the obtained results it is clear that the highest degree of the transgression was observed in the number of beans and seeds from the plant and in the mass of the seeds from the plant. According to the other researched signs, the degree of transgression is negligible. The following hybrid combinations were identified in the sum of the highest frequency of the transgressive forms in F_2: Pervomaiska/UDO503341 (4 signs), Dokuchaievska/Holberg, Dokuchaievska/UDO501709, Dokuchaievska/UDO503256, Pervomaiska/UDO501722 and Pervomaiska/UDO501709 (3 signs).

Thus, according to the obtained data it is observed that in most cases the high degree of the transgressive forms was combined with their high frequency on the bases of "the number of beans per plant", "the number of seeds from the plant" and "the mass of the seeds from the plant". The simultaneous combination of the high degree and the transgression frequency is quite rare and especially it depends on the well-chosen parental components for the cross-breeding. In our studies it has been found that the degree and frequency of the transgressive forms were higher when there was the high level of the heterosis (that is, it depended on the cross-breeding combination). Thus, on the basis of the conducted researches it can be concluded that when conducting the heterosis selection (especially concerning the productivity), first of all the attention should be paid to those combinations that exhibit the high heterosis effect by the number of beans per plant, the number of seeds from the plant and the mass of the seeds from the plant. However, there are cases when in the first generation of the hybrids there is depression of economically valuable signs, and in the subsequent generations, on the contrary, we observe an increase in the degree of the sign manifestation. It is precisely such cases we observed in the further study of the hybrid populations.

The correlative relations between economically valuable features in the system of "parents and descendants" of the type Ph. Vulgaris.

The combined variability of two or more features is widely used in breeding to predict the effect of the artificial selection. The study of the manifestation of the correlative coefficient of the separate features and environmental conditions is very important in practice.

The statistical processing of the obtained results allowed to reveal a reliable correlative dependence as for the signs of "the plant height", "the number of beans per plant", "the number of seeds from the plant", "the seed mass from the plant", "the number of seeds in the bean" and "the mass of 1000 seeds" in the system "parents – descendants". The strong positive correlation was noted for the "plant height" between F_1 and the parental forms of Dokuchaievska/Isex: Isex (r=0.65), Pervomaiska/UDO503256: Pervomaiska (r=0.52) and Pervomaiska/UDO501709: UDO501709 (r=0.86) (Table 7). The influence of parents on the formation of the indicated feature reached 42.3%, 27.0% and 74.0%. The adverse parents of the above-mentioned combinations had little effect on the development of the plant length sign in F_1, which is confirmed by the determination coefficient (3.2, 0.4 and 7.8%). The average negative correlation dependence was revealed between the F_1 hybrid combination Dokuchaievska/UDO503256 and its maternal form r=-0.42 (Table 7). Accordingly the determination coefficient was 17.6%. The relations between the other hybrid combinations and the corresponding parental forms were at a quite low level.

On the basis of "the number of beans per plant", a strong positive correlative dependence was observed in the system of the F_1 hybrid Dokuchaievska/UDO503341 and the maternal form of Dokuchaievska (r=0.62) with a determination coefficient of 38.4% and in the system of the hybrid of F_1 Pervomaiska/UDO501709 and its maternal form Pervomaiska (r=0.71) with a determination coefficient of 50.4%, respectively. The correlative dependence of the average force was observed between the Dokuchaievska/Isex hybrid and its parental form Isex r=0.40 with a determination coefficient of 16.0% and between the Pervomaiska/Holberg hybrid and its maternal form r=0.51 with the determination coefficient of 26.0%.

On the basis of the "the number of seeds from the plant", the positive high correlative relation was observed between the hybrid combination Pervomaiska/UDO501722 and its parental form (r=0.67) with a tightness of connection of 44.9% (Table 7). The same relation was also observed between the hybrid Dokuchaievska/UDO501722 and the parental form (r=0.45) with the determination coefficient of 20.3%. The correlative dependence of the average strength was negative by the value between the hybrid of Pervomaiska/(UDO503256) and its maternal form (r=-0.50) with a force of influence of 25.0%.

The strong positive correlation was noted on the basis of "the mass of seeds from the plant" between F_1 and the parental form of Dokuchiaevska/Holberg: Holberg (r=0.71) (Table 8). The force of influence on the formation of this sign reached 50.4%. The average positive correlative dependence was found between F_1 of the hybrid combination of Dokuchaievska/UDO503341 and its parental form: r=-0.42, between the hybrid Dokuchaievska/UDO501722 and its parental form (r=0.41) and between the Pervomaiska/Isex hybrid and its parental form (r=0.45). The determination coefficients were 31.4%, 16.8% and 20.3% respectively. The correlative dependence of the average strength was negative as for the values between the Pervomaiska/UDO501722 hybrid and the maternal form (r=-0.61) with the force of influence of 37.2%. The relations between the other hybrid combinations and the corresponding parental forms were at a quite low level.

Table 7. Correlation dependence of economic-valuable features between hybrids F_1 and parent genotypes of the species *Ph. vulgaris.*

Hybrids and parental forms	Plant height		The height of the lower bean fastening		The number of beans per plant		The number of seeds from the plant	
	r ± Sr*	D_{xy}, %	r ± Sr	D_{xy}, %	r ± Sr	D_{xy}, %	r ± Sr	D_{xy}, %
Dokuchaievska/Holberg: ♀	-0.25 ± 0.18	6.3	-0.34 ± 0.18	11.6	0.37 ± 0.18	13.7	-0.11 ± 0.19	1.2
Dokuchaievska/Holberg:♂	0.21 ± 0.18	4.4	0.03 ± 0.19	0.09	-0.31 ± 0.18	9.6	-0.15 ± 0.19	2.3
Dokuchaievska/Isex:♀	-0.18 ± 0.19	3.2	0.04 ± 0.19	0.2	0.20 ± 0.19	4.0	-0.03 ± 0.19	0.09
Dokuchaievska/Isex:♂	***0.65 ± 0.14***	***42.3***	-0.15 ± 0.19	2.3	***0.40 ± 0.17***	***16.0***	0.31 ± 0.18	9.6
Dokuchaievska/UDO503341:♀	0.03 ± 0.19	0.09	-0.12 ± 0.19	1.4	***0.62 ± 0.15***	***38.4***	0.06 ± 0.19	0.4
Dokuchaievska/UDO503341:♂	0.17 ± 0.19	2.9	-0.37 ± 0.18	13.7	-0.14 ± 0.19	2.0	0.03 ± 0.19	0.09
Dokuchaievska/UDO501709:♀	-0.04 ± 0.19	0.2	-0.15 ± 0.19	2.3	-0.18 ± 0.19	3.2	0.03 ± 0.19	0.09
Dokuchaievska/UDO501709:♂	0.17 ± 0.19	2.9	0.15 ± 0.19	2.3	0.36 ± 0.18	13.0	0.24 ± 0.18	5.8
Dokuchaievska/UDO503256:♀	***-0.42 ± 0.18***	***17.6***	-0.03 ± 0.19	0.09	-0.32 ± 0.18	10.2	0.16 ± 0.19	2.6
Dokuchaievska/UDO503256:♂	0.03 ± 0.19	0.09	-0.22 ± 0.18	4.8	-0.25 ± 0.18	6.3	0.12 ± 0.19	1.4
Dokuchaievska/UDO501722:♀	0.06 ± 0.19	0.4	0.03 ± 0.19	0.09	0.18 ± 0.19	3.2	-0.04 ± 0.19	0.2
Dokuchaievska/UDO501722:♂	-0.12 ± 0.19	1.4	-0.10 ± 0.19	1.0	0.24 ± 0.18	5.8	***0.45 ± 0.17***	***20.3***
Pervomaiska/Holberg:♀	0.17 ± 0.19	2.9	-0.21 ± 0.18	4.4	***0.51 ± 0.16***	***26.0***	-0.22 ± 0.18	4.8
Pervomaiska/Holberg:♂	-0.21 ± 0.18	4.4	0.05 ± 0.19	0.3	-0.14 ± 0.19	2.0	0.03 ± 0.19	0.09
Pervomaiska/Isex:♀	0.16 ± 0.16	2.6	0.10 ± 0.19	1.0	-0.18 ± 0.19	3.2	0.10 ± 0.19	1.0
Pervomaiska/Isex:♂	0.37 ± 0.18	13.7	-0.17 ± 0.19	2.9	0.17 ± 0.19	2.9	-0.11 ± 0.19	1.2
Pervomaiska/UDO503256:♀	***0.52 ± 0.16***	***27.0***	-0.12 ± 0.19	1.4	0.37 ± 0.18	13.7	***-0.50 ± 0.16***	***25.0***
Pervomaiska/UDO503256:♂	0.06 ± 0.19	0.4	-0.22 ± 0.18	4.8	-0.04 ± 0.19	0.2	0.03 ± 0.19	0.09
Pervomaiska/UDO503341:♀	-0.04 ± 0.19	0.2	-0.14 ± 0.19	2.0	-0.25 ± 0.18	6.3	0.17 ± 0.19	2.9
Pervomaiska/UDO503341:♂	0.21 ± 0.18	4.4	-0.36 ± 0.18	13.0	-0.04 ± 0.19	0.2	-0.11 ± 0.19	1.2
Pervomaiska/UDO501722:♀	-0.04 ± 0.19	0.2	0.03 ± 0.19	0.09	0.16 ± 0.19	2.6	0.03 ± 0.19	0.09
Pervomaiska/UDO501722:♂	-0.22 ± 0.18	4.8	0.21 ± 0.18	4.4	0.10 ± 0.19	1.0	***0.67 ± 0.15***	***44.9***
Pervomaiska/UDO501709:♀	0.28 ± 0.18	7.8	0.08 ± 0.19	0.6	***0.71 ± 0.15***	***50.4***	0.08 ± 0.19	0.6
Pervomaiska/UDO501709:♂	***0.86 ± 0.11***	***74.0***	-0.16 ± 0.16	2.6	-0.02 ± 0.19	0.04	-0.22 ± 0.18	4.8

Note: * r – the correlation coefficient, Sr – absolute error, D_{xy} – the determination coefficient

The average correlation based on "the number of seeds in the bean" was observed between the hybrid combination F_1 Dokuchaievska/UDO501722 and its parental form (r=0.45) and between the hybrid of Pervomaiska/UDO501709 and its parental form (r=0.44) (Table 8). The determination coefficients were 20.3% and 19.4% respectively. The correlative dependence of the average strength, negative in the value, was observed between the Dokuchaievska/Isex hybrid and the parental form r=-0.53 with the determination coefficient of 28.1%; it was also observed between the Dokuchaievska/UDO503341 hybrid and the maternal form r=-0.49 and between the Pervomaiska/UDO503341 hybrid and the maternal form (r=-0.56) with the force of influence of 28.1%, 24.0% and 31.4%.

The correlation on the basis of "the mass of 1000 seeds" between the hybrid combination Dokuchaievska/Holberg and the parental form had the positive average force, in which only 19.4% of the sign variation was determined by the parental form (Table 8). Also the positive correlative relation of the average force was established between the hybrid combination Dokuchaievska/UDO501709 and the parental form with the determination coefficient of 20.3%. The correlative dependence of the average force, negative in value, was observed between the Dokuchaievska/UDO503341 hybrid and its parental form r=-0.49 with the determination coefficient of 24.0% and between the Pervomaiska/UDO503256 hybrid and the maternal form (r=-0.53) with the force of influence of 28.1%.

It has been established that on the basis of "the height of the lower bean fastening" the correlative relation in all the studied hybrid combinations is completely absent (Table 8). Besides the correlative dependence between the economically valuable features of the parental genotypes and their hybrid combinations of the *Ph. vulgaris* species, the correlative relations between the economically valuable features of the F_1 and F_2 hybrids and their parental genotypes were found. In this connection the weak, medium and strong positive or negative correlative relations were revealed between all the researched features in the hybrid collection and in the initial parental forms of the *Ph. vulgaris* species.

The average positive correlative dependence was found between the "number of seeds from the plant" and "the number of seeds in the bean" (r=0.40-0.61) and between the "number of seeds from the plant" and "the mass of 1000 seeds" (r=0.23-0.42) (Table 9).

Table 8. Correlation dependence of economic-valuable features between hybrids F_1 and parent genotypes of the species *Ph. vulgaris.*

Hybrids and parental forms	The seed mass from the plant		Number of seeds in the bean		The mass of 1000 seeds	
	r ± Sr	D_{xy}, %	r ± Sr	D_{xy}, %	r ± Sr	D_{xy}, %
Dokuchaievska/Holberg: ♀	-0.29 ± 0.18	8.4	-0.34 ± 0.18	11.6	-0.17 ± 0.19	2.9
Dokuchaievska/Holberg:♂	***0.71 ± 0.13***	***50.4***	-0.18 ± 0.19	3.2	***0.44 ± 0.17***	***19.4***
Dokuchaievska/Isex:♀	-0.17 ± 0.19	2.9	0.16 ± 0.19	2.6	0.14 ± 0.19	2.0
Dokuchaievska/Isex:♂	0.29 ± 0.18	8.4	***-0.53 ± 0.16***	***28.1***	-0.08 ± 0.19	0.6
Dokuchaievska/UDO503341:♀	0.25 ± 0.18	6.3	-0.15 ± 0.19	2.3	0.12 ± 0.19	1.4
Dokuchaievska/UDO503341:♂	***0.56 ± 0.16***	***31.4***	0.13 ± 0.19	1.7	***-0.49 ± 0.16***	***24.0***
Dokuchaievska/UDO501709:♀	-0.18 ± 0.19	3.2	-0.25 ± 0.18	6.3	0.20 ± 0.19	4.0
Dokuchaievska/UDO501709:♂	0.32 ± 0.18	10.2	0.18 ± 0.19	3.2	***0.45 ± 0.17***	***20.3***
Dokuchaievska/UDO503256:♀	0.13 ± 0.19	1.7	***-0.49 ± 0.16***	***24.0***	-0.11 ± 0.19	1.2
Dokuchaievska/UDO503256:♂	***-0.55 ± 0.16***	***30.3***	-0.26 ± 0.18	6.8	-0.08 ± 0.19	0.6
Dokuchaievska/UDO501722:♀	0.08 ± 0.19	0.6	0.09 ± 0.19	0.8	-0.17 ± 0.19	2.9
Dokuchaievska/UDO501722:♂	***0.41 ± 0.17***	***16.8***	***0.45 ± 0.17***	***20.3***	0.30 ± 0.18	9.0
Pervomaiska/Holberg:♀	0.19 ± 0.19	3.6	-0.18 ± 0.19	3.2	-0.15 ± 0.19	2.3
Pervomaiska/Holberg:♂	0.27 ± 0.18	7.3	0.32 ± 0.18	10.2	-0.08 ± 0.19	0.6
Pervomaiska/Isex:♀	0.14 ± 0.19	2.0	-0.15 ± 0.19	2.3	0.16 ± 0.19	2.6
Pervomaiska/Isex:♂	***0.45 ± 0.17***	***20.3***	0.13 ± 0.19	1.7	-0.17 ± 0.19	2.9
Pervomaiska/UDO503256:♀	-0.21 ± 0.18	4.4	-0.25 ± 0.18	6.3	***-0.53 ± 0.16***	***28.1***
Pervomaiska/UDO503256:♂	-0.16 ± 0.19	2.6	0.19 ± 0.19	3.6	0.14 ± 0.19	2.0
Pervomaiska/UDO503341:♀	0.32 ± 0.18	10.2	***-0.56 ± 0.16***	***31.4***	-0.15 ± 0.19	2.3
Pervomaiska/UDO503341:♂	-0.17 ± 0.19	2.9	-0.17 ± 0.19	2.9	0.14 ± 0.19	2.0
Pervomaiska/UDO501722:♀	***-0.61 ± 0.15***	***37.2***	-0.34 ± 0.18	11.6	-0.18 ± 0.19	3.2
Pervomaiska/UDO501722: ♂	0.29 ± 0.18	8.4	0.13 ± 0.19	1.7	0.12 ± 0.19	1.4
Pervomaiska/UDO501709:♀	0.08 ± 0.19	0.6	-0.25 ± 0.18	6.3	-0.18 ± 0.19	3.2
Pervomaiska/UDO501709:♂	-0.18 ± 0.19	3.2	***0.44 ± 0.17***	***19.4***	0.32 ± 0.18	10.2

Note: * r – the correlation coefficient, Sr – absolute error, D_{xy} – the determination coefficient

The determination coefficient was within the range of 16.0-33.6% and 5.3-18.5%. The positive and negative weak correlative relations were found between "the height of the plant" and "the height of the lower bean fastening" (r=0.01-0.18 and r=- 0.02-0.21); between "the height of the plant" and "the number of seeds in the bean" (r=0.02-0.20 and r=- 0.06-0.21); between "the height of the plant" and "the mass of 1000 seeds" (r=-0.10-0.24); between "the height of the lower bean fastening" and "the number of beans" (r=0.02-0.13 and r=-0.03-0.05). The same relations were also found between "the height of the lower bean stening" and "the number of seeds" (r=0.02-0.13 and r=-0.02-0.13); between "the height of the lower bean fastening" and "the number of seeds in the bean" (r=0.02-0.15 and r=-0.02-0.07), between "the height of the lower bean fastening" and "the mass of the seeds from the plant" (r=0.02-0.15 and r=-0.02 -0.09), between "the height of the lower bean fastening" and "the mass of 1000 seeds" (r=0.01-0.04 and r=-0.01-0.08), between "the number of beans from the plant" and "the mass of 1000 seeds" (r=0.01-0.06 and r=-0.03-0.26), between "the number of seeds in the bean" and "the mass of the seeds from the plant" (r=0.01-0.14 and r=-0.06-0.16) and between "the mass of seeds from the plant" and the "the mass of 1000 seeds" (r=-0.01-0.14) (Table 9). The determination coefficient was quite low. At the same time the positive close connections were found. They reached the level of the strong correlations between "the plant height and the number of beans per plant" (r=0.64-0.86), between "the plant height and the number of seeds from the plant" (r=0.68-0.93), betewen "the plant height" and "the mass of seeds from the plant" (r=0.60-0.81), between "the number of beans from the plant" and "the number of seeds from the plant" (r=0.70-0.93), between "the number of beans from the plant" and "the mass of the seeds from the plant" (r=0.65-0.86), and between "the number of seeds from the plant" and "the mass of seeds from the plant" (r=0.66-0.89) (Table 9). The determination coefficient was in the range of 41.0-74.0%, 46.2-86.5%, 36.0-65.6%, 49.0-86.5%, 39.7-74.0%, and 43.6-79.2% respectively. The negative weak correlative relations reached the average level between "the number of seeds in the bean" and "the mass of 1000 seeds" r=-0.03-0.37% respectively.

The comparative estimation of the received data showed that between the various signs of the hybrids and parental forms, the most widespread is the correlative dependence of the low force. The analysis of the manifestation degree of the correlative relations between the F_1 and F_2 hybrids and their parental forms of *Ph. vulgaris* species showed that both parental forms have strong, medium and weak correlative relations with the prevalence of the latter.

In the first generation we have noted the dominance of the correlative relations of weak forces, in addition there is a small number of strong connections between the investigated features. In the next generation, the level spectrum of the correlative relations extends as a result of splitting; we observe three degrees of the correlative relations tightness manifestation. In our case the F_2 hybrids are characterised by the presence of strong, medium and weak relations with the prevalence of the latter.

Table 9. Degree of manifestation of correlations in hybrids F_1, F_2 and their parent forms of the form *Ph. vulgaris.*

Signs		The correlation coefficient			
		F_1	F_2	♀	♂
PH: HLB*	Positive	0.03-0.18	0.01-0.16	0.06-0.17	0.08-0.13
	Negative	0.08-0.21	0.02-0.11	-	0.11-0.12
PH: NB	Positive	0.64-0.84	0.67-0.86	0.73-0.76	0.69-0.85
	Negative	-	-	-	-
PH: NS	Positive	0.70-0.88	0.68-0.86	0.83-0.93	0.73-0.89
	Negative	-	-	-	-
PH: NSB	Positive	0.05-0.13	0.02-0.20	0.10-0.12	0.11-0.20
	Negative	0.07-0.18	0.06-0.16	-	0.09-0.21
PH: SM	Positive	0.60-0.80	0.63-0.79	0.66-0.69	0.62-0.81
	Negative	-	-	-	-
PH:M1000	Positive	-	-	-	-
	Negative	0.13-0.28	0.10-0.24	0.12-0.22	0.12-0.19
HLB: NB	Positive	0.02-0.13	0.02-0.13	0.03-0.08	0.05-0.12
	Negative	0.03-0.05	0.03-0.05	-	-
HLB: NS	Positive	0.04-0.13	0.02-0.10	0.10-0.12	0.11-0.16
	Negative	0.08-0.12	0.02-0.13	-	0.08-0.11
HLB: NSB	Positive	0.02-0.10	0.02-0.07	0.08-0.15	0.02-0.08
	Negative	0.05	0.02-0.07	-	-
HLB: SM	Positive	0.02-0.13	0.03-0.11	0.09-0.12	0.02-0.15
	Negative	0.04-0.09	0.02-0.06	-	-
HLB:M1000	Positive	0.01-0.04	0.01-0.02	0.01-0.03	0.01-0.02
	Negative	0.01-0.08	0.02-0.03	-	0.01-0.03
NB: NS	Positive	0.75-0.90	0.72-0.90	0.82-0.90	0.70-0.93
	Negative	-	-	-	-
NB: SM	Positive	0.69-0.86	0.65-0.86	0.79-0.82	0.63-0.85
	Negative	-	-	-	-
NB:M1000	Positive	0.02-0.06	0.01	-	-
	Negative	0.06-0.19	0.03-0.17	0.23-0.26	0.09-0.21
NS: NSB	Positive	0.40-0.61	0.40-0.58	0.40-0.52	0.47-0.58
	Negative	-	-	-	-
NS: SM	Positive	0.72-0.89	0.66-0.87	0.78-0.85	0.72-0.83
	Negative	-	-	-	-
NS:M1000	Positive	-	-	-	-
	Negative	0.23-0.42	0.26-0.43	0.30-0.39	0.27-0.37
NSB: SM	Positive	0.05-0.11	0.01-0.14	0.08-0.10	0.07-0.12
	Negative	0.06-0.16	0.07-0.16	-	0.10-0.11

NSB:M1000	Positive	-	-	-	-
	Negative	0.03-0.31	0.04-0.37	0.08-0.10	0.07-0.37
SM:M1000	Positive	-	-	-	-
	Negative	0.01-0.14	0.01-0.13	0.10-0.11	0.03-0.14

Note: * PH – Plant height, HLB – The height of the lower bean fastening, NB – The number of beans per plant, NS – The number of seeds from the plant, NSB – Number of seeds in the bean, SM – The seed mass from the plant, M1000 – The mass of 1000 seeds.

Discussion

The detailed study of the variability range of the proguctivity component elements will make it possible to conduct the effective selections of the perspective hybrid plants at earlier stages of their study and use them for the further breeding work (Nerinéia Dalfollo et al., 2014), especially when conducting the breeding relating the resistance to the main harmful organisms (Valérie et al. 2000; Geovani, 2007). The effective use of such resources will be the main condition for the biosystems adaptation to the climate change (Stephen et al., 2007; Phillip et al., 2011; Kwabena et al., 2016). The conducted researches clearly show the specificity of changes in the basic elements of the productivity of the bean intraspecies hybrids.

The cyclic changes that occur in the environment are often accompanied by the reorganization in the state of populations. In the middle of the nineteenth century two theoretical concepts of the population dynamics were formulated simultaneously. They are "the moving equilibrium" concept and the trophoclimatic one, formulated by K.F. Rouille (1814-1858). Their essence and conceptual foundations are described in the review of I.Ya Poliakov (1912-1992), who showed the formation of the basic theoretical ideas about the dynamics of the populations in the historical aspect (Stankevych et al., 2019).

With the thorough study of the crop, the knowledge of the varieties genotypes and their donor properties, there was a necessity to improve the existing varieties and to obtain the new ones by the hybridization method (Myounghai et al., 2009; Corrêa et al., 2016).

Almost at every cross-breeding the selectionist pays attention to the transgressive forms which allow him to conduct the selections successfully. Very often the transgressions occur with the convergent cross-breeding, that is, while breeding the forms that are separated geographically or they are very different phenotypically or genotypically (Singh et al., 1995). As many researchers think, it is quite effective to conduct a preliminary top-crossing or a diallel cross-breeding in the local conditions in order to detect the donor qualities of the source material (Jai et al., 2012). Under modern conditions the genetic selection with the use of the microsatellite locus and the genes identification with the help of the QTL alazil are used for phenotyping and determining the agronomically important characteristics of the source material, which, in its turn, facilitates the selection strategy (Taislene et al., 2006; Elliot et al., 2009; Monik et al. al, 2011).

Conclusions

As the result of the conducted intraspecific hybridization it has been established that the percentage of the hybrid beans ovary depends on the combination of the cross-breeding (the well-chosen parental pairs).

The ovary rate varied from 26.0 to 44.0%. While conducting the intraspecific hybridization, we managed to obtain the hybrid beans when crossing the common bean with the multiflora bean. The ovary rate varied within the range of 10.0-20.0%, depending on the combination of the cross-breeding.

It has been established that the component elements of the yield are quite variable in the parental forms, as well as in the first and second generations' hybrids. The most changeable signs turned to be "the number of beans per plant", "the number of seeds from the plant" and "the mass of seeds from the plant"; and the least changeable were "the number of seeds in the bean" and "the mass of 1000 seeds". The signs of "the plant height" and "the height of the lower bean fastening" had an average coefficient of variation.

It has been found that the hybrids inherited the plant height in three types: the partial positive dominance, the intermediate inheritance and the partial negative dominance.

The inheritance of the height of the lower beans tier fastening above the level of soil occurs by the types of the positive overdomination and the intermediate inheritance. The number of beans per plant is inherited in all combinations by the type of the positive overdomination. The inheritance of the number of seeds from the plant occurs by the types of the positive overdomination, the positive domination and the intermediate inheritance.

The mass of seeds from the plant in the first-generation hybrids is inherited by the types of the positive overdomination and the intermediate inheritance. The inheritance of the number of seeds in the bean occurs by the types of the positive overdomination, the partial positive domination, the intermediate inheritance and the partial negative domination. The mass of 1000 seeds is inherited by the types of the positive domination and the intermediate inheritance.

On the basis of the statistical analysis of the data concerning the inheritance of the elements of productivity, the following combinations of the cross-breeding are selected: Dokuchaievska/Holberg, Dokuchaievska/UDO501722, Pervomaiska/UDO501722 and Pervomaiska/UDO501709 (most of the studied features in the hybrid populations are genetically determined and their positive heterosis effect is found).

For most of the studied economically valuable signs, the degree and frequency of the positive transgressions exceeded the degree of the negative ones, with the exception of the sign of the height of the lower bean fastening on the plant.

The highest degree of the transgression was observed in the number of beans and seeds from the plant and the mass of the seeds from the plant. According to the other researched signs the degree of the transgression was negligible.

By the degree of the manifestation and frequency of the transgressive forms appearance, the following hybrid combinations are distinguished: Dokuchaievska/Holberg, Dokuchaievska/UDO501709, Dokuchaievska/UDO501722, Pervomaiska/UDO503341, Pervomaiska/UDO501722 and Pervomaiska/UDO501709.

In order to secure the economically valuable characteristics of the parental forms in the variety, it is necessary to take into account the existence of correlative relations between the signs in the system of "parent-descendants". In some cases there is the dependence between the signs of the parental forms and their hybrids, which proves the importance of the proper selection of pairs for the hybridization in order to create the perspective hybrids.

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Citation: Golovan, L.V., Klymenko, I.V., Stankevych, S.V., Vasylieva, Yu.V., Chupryna, Yu.Yu., Zabrodina, I.V., Zhukova, L.V., Nazarenko, V.V., Belay, Yu.M. (2019). The inheritance of economically valuable features in the intraspecific hybridization of bean (Phaseolus L). Ukrainian Journal of Ecology, 9(2), 156-169.