Inheritance of economically important traits in common vetch hybrids (F_1)

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Abstract. The paper presents the results of a study on the true heterosis and the degree of dominance/ depression of traits (the number of pods and seeds per plant, plant height) in F_1 common vetch hybrids. The highest phenotypic dominance and true heterosis of the pod ($H_{tr.}$=151.5 %, h_p=8.7) and seed number ($H_{tr.}$=111.7 %, h_p=6.7) per plant were observed in hybrid accession 13 (Mestnaya x VIR 217). Our correlation analysis revealed a strong direct correlation between seed productivity per plant and the number of seeds (r=0.93) and pods per plant (r=0.92), as well as between the number of seeds and the number of pods per plant (r=0.98).

1 Introduction

The production of animal products is closely linked to the availability of highly nutritious forages. Leguminous crops play an important role in forage production as sources of proteins [1-3]. Common vetch *Vicia sativa* is one of the most valuable forage legumes used for creating highly productive grass seed mixes aimed for the harvest of herbage, haylage, hay, and grain [4-6]. The conditions of Primorsky kray allow farmers to harvest up to 10 t/ha of herbage and 2 t/ha of common vetch seeds [7]. However, there is a need to create new high-yielding varieties of common vetch.

Work on the breeding of new *Vicia sativa* varieties is carried out all around the world [8-10]. The main goal of breeders is to obtain accessions that are able to provide high yet stable yield under local conditions.

Our research goal was to evaluate F1 common vetch hybrids for economically important traits.

The research objectives were:

- To determine the effect of heterosis and the degree of dominance in F_1 hybrid accessions based on the structural analysis.
- To establish correlation between the economically important traits of common vetch.

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2 Materials and methods

The breeding nursery of the first generation (F_1) was organized in the fields of FSBSI "FSC of Agricultural Biotechnology of the Far East" in the steppe zone of Primorsky kray.

The region is characterized by monsoon climate. The positive accumulated temperature (above 10 ^oC) over the growing period of 2022 was 2778 ^oC; the total precipitation over the same period was 657.8 mm.

The conditions were perhumid (the hydro-thermal coefficient of Selyaninov (HTC) = 2.37). The plough layer was 22-25 cm; the content of humus was 3.65±0.51%; the pH of salt extraction was 5.2±0.1; the content of exchangeable potassium was 59±11 mg/kg of soil; the content of mobile phosphorus was 59±10 mg/kg of soil; the content of nitrogen was 60±8 mg/kg of soil.

The research object was F_1 hybrids of common vetch.

Sixteen accessions were studied in our hybrid nursery of the first generation. The following variety accessions were used as paternal and maternal forms: VIR 217 (36345, Russia), Mestnaya (35583, Belgium), Lugovskaya 85 (36371, Russia), Nemchinovskaya yubileinaya (Russia), Omichka (Russia), and Lugovskaya 85 x Belotserkovskaya 222 (local breeding origin).

Common vetch was sown in the last ten days of April. The seeds were harvested at the soft dough stage when the pods began to turn brown.

The setup of the experiment, calculations and phenological observations were performed according to "the Methodology for Studying Collections of Leguminous Crops" (N.I. Miroshnichenko, R.B. Demina, L.V., Moken', 1968) and the methodology for "Common Vetch Breeding" (S.I. Rep'ev, 1991).

The parameters of true heterosis and depression were calculated according to D.S. Omarov (1975). The degree of dominance of traits in the studied hybrids was calculated using the formula of G.L. Brubaker (1966).

The degree of dominance was determined by the formula [(1)]:

$$h_p=(F_1 - M_p) / (P_{max} - M_p) \quad (1)$$

Where h_p – the degree of dominance or depression; F_1 – the arithmetic mean of a trait; M_p – the average of a trait in both parents; P_{max} – the average in the parent with the most developed trait.

The degree of heterosis was calculated by the formula [(2)]:

$$H=(F_1 - P_{max}) / P_{max} \times 100 \quad (2)$$

3 Results and Discussion

The research resulted in the selection of hybrid accessions that significantly exceeded the parental forms in terms of the number of pods and seeds per plant and seed productivity per plant.

The height of F_1 common vetch hybrid plants ranged from 75 to 160 cm depending on the accession (Table 1). The analysis of the inherence of this trait revealed dominance in accessions 7, 8 (Nemchinovskaya yubileinaya x Omichka), and 9 (Nemchinovskaya yubileinaya x Lugovskaya 85) – h_p = 0.4-0.6, and overdominance in accession 3 (Omichka x Lugovskaya 85) – h_p= 1.5. Depression of this trait was observed in all other accessions (Table 2).

Table 1. Some biometric parameters of F_1 common vetch accessions.

No	Accession	Plant height, cm	Number of pods per plant, pcs.	Number of seeds per plant, pcs.	Seed productivity per plant, g
BLOCK 1					
P_1♂	VIR 217 (36345), Russia	150	37	259	8.4
P_2♂	Mestnaya (35583), Belgium	149	21	147	5.5
P_3♂	Lugovskaya 85 (36371), Russia	130	20	120	3.2
P_4♂	Nemchinovskaya yubileinaya, Russia	149	26	181	6.5
P_5♀	Omichka, Russia	154	42	304	12.6
1	Omichka x Lugovskaya 85	115	58	406	13.6
2	Omichka x Mestnaya (35583), Belgium	105	3	18	1.3
3	Omichka x Lugovskaya 85 (36371), Russia	160	55	330	14.0
4	Omichka x Nemchinovskaya yubileinaya	114	24	152	8.6
5	Omichka x Nemchinovskaya yubileinaya	75	15	90	3.3
6	Omichka x VIR 217 (36345)	90	76	532	19.6
BLOCK 2					
P_1♀	Nemchinovskaya yubileinaya, Russia	135	41	307	9.8
P_2♂	(Lugovskaya 85 x Belotserkovskaya 222)	124	65	435	20.1
P_3♂	Lugovskaya 85 (36371), Russia	125	31	217	11.7
P_4♂	Omichka (35456), Russia	100	56	336	17.5
7	Nemchinovskaya yubileinaya x Omichka	125	80	600	34.1
8	Nemchinovskaya yubileinaya x Omichka	125	88	575	28.3
9	Nemchinovskaya yubileinaya x Lugovskaya 85	133	25	144	8.9
10	Nemchinovskaya yubileinaya x Lugovskaya 85	125	73	474	22.1
11	Nemchinovskaya yubileinaya x Lugovskaya 85	118	73	489	25.2
12	Nemchinovskaya yubileinaya x Lugovskaya 85 x Belotserkovskaya 222	78	38	256	13.0
BLOCK 3					
P_1♀	Mestnaya (35583), Belgium	140	33	247	6.2
P_2♂	VIR 217 (36345), Russia	162	20	146	6.5
P_3♀♂	Lugovskaya 85 (36371), Russia	160	57	313	11.8
P_4♂	Nemchinovskaya yubileinaya, Russia	145	57	456	15.3
13	Mestnaya (35583) x VIR 217 (36345)	135	83	523	21.2
14	Mestnaya (35583) x Lugovskaya 85 (36371)	117	20	120	6.3
15	Lugovskaya 85 (36371) x Mestnaya (35583)	120	41	217	10.5
16	Lugovskaya 85 (36371) x Nemchinovskaya yubileinaya	110	53	334	9.9

The following accessions stood out for the number of pods per plant: 1 (Omichka x Lugovskaya 85), 3 (Omichka x Lugovskaya 85), 6 (Omichka x VIR 217), 7 and 8 (Nemchinovskaya yubileinaya x Omichka), 10 and 11 (Nemchinovskaya yubileinaya x Lugov-skaya 85), and 13 (Mestnaya x VIR 217). They exceeded their parental forms by 16-63 pods per plant (Table 1). The highest mid-parent heterosis was found in accessions 6 (Omichka x VIR 217) – 81 %, 10 (Nemchinovskaya yubileinaya x Lugovskaya 85) – 78.1 %, 11 (Nemchinovskaya yubileinaya x Lugovskaya 85) – 78.0 %, and 13 (Mestnaya x VIR 217) – 151 % (Table 2). The degree of dominance varied from 4.9 in accession 6 (Omichka x Nemchinovskaya yubileinaya) to 8.7 in accession 13 (Mestnaya x VIR 217). Significant depression was observed in hybrid accession 2 (Omichka x Mestnaya) – $H_{tr.}$= - 92.9 %.

The number of seeds per plant ranged from 18 (accession 2, Omichka x Mestnaya) to 600 (accession 7, Nemchinovskaya yubileinaya x Omichka).

Significant heterosis in terms of the seed number per plant was discovered in accessions 6 (Omichka x VIR 217) – 75 %, 7 and 8 (Nemchinovskaya yubileinaya x Omichka) – 78.6-71.1 %, and 13 (Mestnaya x VIR 217) – 111.7 %. Negative overdominance was found in accessions 2 (Omichka x Mestnaya), 4 and 5 (Omichka x Nemchinovskaya yubileinaya), 9 (Nemchinovskaya yubileinaya x Lugovskaya 85), 12 (Nemchinovskaya yubileinaya x (Lugovskaya 85 x Belotserkovskaya 222)), and 14 (Mestnaya x Lugovskaya 85) – h_p = -4.8…-1.8 (Table 2).

Table 2. The degree of dominance and heterosis in F_1 common vetch accessions.

No	Accession	Plant height, cm		The number of pods per plant, pcs.		The number of seeds per plant, pcs.	
		H_{tr}, %	h_p	H_{tr},%	h_p	H_{tr}, %	h_p
BLOCK 1							
1	Omichka x Lugovskaya 85	-25.3	-2.3	38.1	2.5	33.6	2.1
2	Omichka x Mestnaya (35583), Belgium	-31.8	-1.9	-92.9	-2.7	-94.1	-2.6
3	Omichka x Lugovskaya 85 (36371), Russia	3.9	1.5	31.0	2.2	8.6	1.3
4	Omichka x Nemchinovskaya yubileinaya	-26.0	-13.4	-42.9	-1.3	-50.0	-1.5
5	Omichka x Nemchinovskaya yubileinaya	-51.3	-27.3	-64.3	-2.4	-70.4	-2.5
6	Omichka x VIR 217 (36345)	-41.6	-31.0	81.0	4.9	75.0	11.1
BLOCK 2							
7	Nemchinovskaya yubileinaya x Omichka	-7.4	0.4	42.9	4.2	78.6	19.2
8	Nemchinovskaya yubileinaya x Omichka	-7.4	0.4	57.1	5.3	71.1	17.5
9	Nemchinovskaya yubileinaya x Lugovskaya 85	-1.5	0.6	-39.0	-2.2	-53.1	-2.6
10	Nemchinovskaya yubileinaya x Lugovskaya 85	-7.4	-1.0	78.1	7.4	54.4	4.7
11	Nemchinovskaya yubileinaya x Lugovskaya 85	-12.6	-2.4	78.0	7.4	59.3	5.0
12	Nemchinovskaya yubileinaya x (Lugovskaya 85 x Belotserkovskaya 222)	-42.2	-9.4	-41.5	-1.3	-41.1	-1.8
BLOCK 3							
13	Mestnaya (35583) x VIR 217 (36345)	-16.7	-1.8	151.5	8.7	111.7	6.5
14	Mestnaya (35583) x Lugovskaya 85 (36371)	-26.9	-3.3	-64.9	-2.1	-61.7	-4.8
15	Lugovskaya 85 (36371) x Mestnaya (35583)	-2.5	-3.0	-28.1	-0.3	-30.7	1.9
16	Lugovskaya 85 (36371) x Nemchinovskaya yubileinaya	-31.3	-5.7	-7.0	-8.0	-26.8	0.7

An important parameter of yield is the productivity of seeds per plant. Among the studied common vetch accessions, this parameter varied from 1.3 (accession 3, Omichka x Lugovskaya 85) to 34.1 g/plant (accession 7, Nemchinovskaya yubileinaya x Omichka) (Table 1). Accessions 6 (Omichka x VIR 217), 7 and 8 (Nemchinovskaya yubileinaya x Omichka), 10 (Nemchinovskaya yubileinaya x Lugovskaya 85), and 13 (Mestnaya (35583) x VIR 217) exceeded their parental forms significantly.

The correlation analysis revealed a weak positive correlation between the number of seeds per plant and the plant height (r=0.01), a weak inverse correlation between the number of pods per plant and the plant height (r=-0.01), and between the seed productivity and the plant height (r=-0.07). It was established that the seed productivity per plant was strongly correlated with the number of pods per plant (r=0.92) and the number of seeds per plant (r=0.93) (Figures 1 and 2).

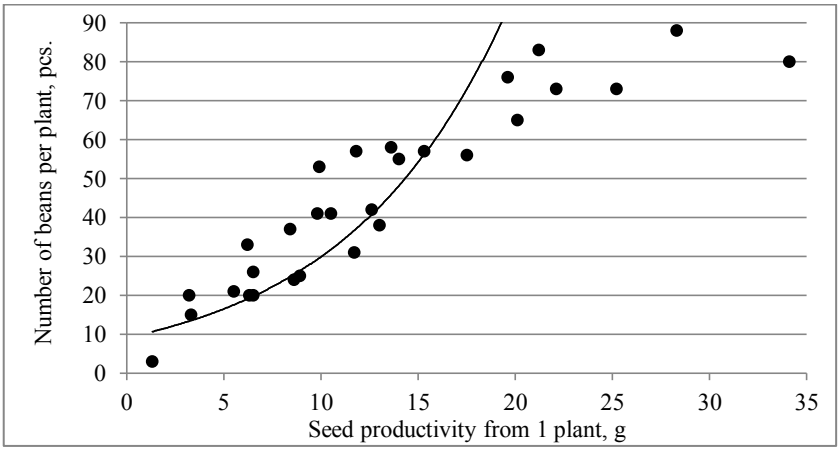

Figure. 1. Seed productivity per plant among F1 common vetch hybrids depending on the number of pods per plant.

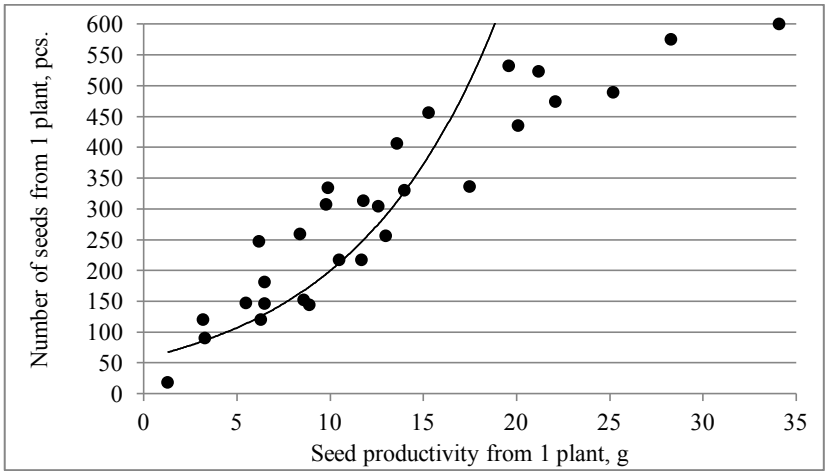

Figure. 2. Seed productivity per plant among F1 common vetch hybrids depending on the number of seeds per plant.

4 Conclusions

The conducted research resulted in the selection of common vetch hybrid accessions with high (above 50 %) true heterosis ($H_{tr.}$) of the following traits:

- The number of pods per plant: accessions 6 (Omichka x VIR 217), 8 (Nemchinovskaya yubileinaya x Omichka), 9 and 10 (Nemchinovskaya yubileinaya x Lugovskaya 85), and 13 (Mestnaya (35583) x VIR 217) – 57.1-151.5 %.
- The number of seeds per plant: accessions 6 (Omichka x VIR 217), 7 and 8 (Nemchinovskaya yubileinaya x Omichka), 10 and 11 (Nemchinovskaya yubileinaya x Lugovskaya 85), and 13 (Mestnaya x VIR 217) – 54.4-111.7 %.

The highest phenotypic dominance and heterosis of the number of pods and seeds per plant were observed in hybrid accession 13 (Mestnaya x VIR 217).

The performed correlation analysis revealed a strong direct correlation between the seed productivity of common vetch and the number of pods and seeds per plant (r=0.92-0.98).

Hybrid accessions 6 (Omichka x VIR 217), 8 (Nemchinovskaya yubileinaya x Omichka), 10 (Nemchinovskaya yubileinaya x Lugovskaya 85), 13 (Mestnaya x VIR 217) generate considerable interest as sources of high seed productivity under the conditions of Primorsky kray.

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