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Genetics and Breeding / Genetika i oplemenjivanje

Ratar. Povrt. / Field Veg. Crop Res. 47 (2010) 499-504
original research article / originalni naučni rad

Adaptability and Stability of Vegetable Common Bean (*Phaseolus vulgaris* L.) Accessions from the VIR Collection in Crimea

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received / primljeno: 22.03.2010. accepted / prihvaćeno: 26.04.2010.

Summary: Adaptability and stable pod per plant productivity of 20 varieties of vegetable common bean from the collection of the Vavilov Institute (VIR) were investigated. The accessions were grown on 8 selective backgrounds: four different patterns and density of planting during two years. The most adaptive accessions, i.e. most tolerant to the different density, having the stable productivity, were identified. The level of affection of accessions with bacterial diseases depending on the density of planting was also determined. The optimal pattern and sowing density had been proposed for breeding nurseries as a selective background for breeding of genotypes with stable productivity.
Key words: adaptability, selective background, stability, vegetable common bean (*Phaseolus vulgaris* L.)

Introduction

The stability in yield with respect to a range of environments is one of the most desired properties of genotypes to fit the crop under available cropping pattern. It is known that genotypes which can adjust their phenotypic state in response to environmental fluctuations in such a way that it gives maximum economic return, can be termed as stable (Allard & Bardshaw 1964). So, searching for high adaptive and stable genotypes is of prime consideration in formulating efficient breeding programs.

Vegetable common bean (*Phaseolus vulgaris* L.), also known as French beans, is a valuable crop produced mainly in the south of Russia. Most varieties of the crop are intensive, i.e. are quite dependent on the environment. Breeding varieties suitable for semi-intensive cropping and forming stable yield in different environments is very interesting for energy-saving technologies.

Plant density ranks are often used as different backgrounds to determine the reaction of genotypes, to reveal the most stable and valuable among them, to select the optimal pattern of cropping and to identify the appropriate selective background for breeding (Kilchevsky & Khotyleva 1989, Zhuchenko 2004).

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Common beans used to be an object of such kinds of assessment in some regions of Russia and Belarus (Skorina et al. 2004, Mazuka et al. 2005).

The aim of our study was to determine the adaptive potential and stability of modern varieties of vegetative common bean at different patterns of sowing and plant density, as well as to assess different options as a selective background for breeding in the Crimea region.

Materials and Methods

The experiments were carried out in the Krasnodar region, at the Crimean experimental breeding station of the Vavilov Institute in 2002-2004. Weather conditions during the growing seasons were quite different in respect to both air temperature and rainfall, which allowed an insight into rather contrasting growing conditions during the three years of experiment.

In 2002 the screening of 100 accessions of vegetable common bean was performed and 20 accessions most adaptive to the local environment were selected for more detailed research. These were modern varieties from the collection of Vavilov Institute. The local variety Dialogue was used as the control (reference variety).

The parameters of genotypes` adaptability and the environmental parameters as the background for selection were calculated using the method of Kilchevsky & Khotyleva (1985). There were four different planting pattern variants and plant

Table 1. Variants of the experiment and selective backgrounds
Tabela 1. Varijante ogleda i selekcione osnove

Variants Varijante	Sowing pattern* Obrazac setve	Sowing density (plants per ha) Gustina setve (biljaka po ha)	Year Godina	Number of selective background Broj selekcione osnove
I (control) kontrola	42 × 10	238,000	2003 2004	1 2
II	40 × 5	500,000	2003 2004	3 4
III	20 × 10	500,000	2003 2004	5 6
IV	20 × 5	1,000,000	2003 2004	7 8

*Row spacing (cm) x spacing between plants in row (cm)
*Razmak između redova (cm) x razmak između biljaka u redu (cm)

densities within two years (2003-2004), in total corresponding to 8 selective backgrounds.

The productivity characteristic, mass of green pods per plant (g) was used as a criterion of the adaptability and the stability of the varieties.

Results and Discussion

Productivity of Varieties Depending on the Density and Planting Patterns

According to the analysis of variance, the highest productivity was revealed in the I variant (pattern 42 cm × 10 cm, control), where the average mass of green pods per plant was 54.25 g and varied among accessions from 24.33 g to 83.13 g (V = 29.7%). The most productive were varieties Vaillant, Empress, Nomad, Slavyanka, Zabava and Sensation with average productivity between 66.2 g and 83.1 g. The rest of the varieties had much poorer productivity than the control variety (Tab. 2).

As the density of sowing increased up to 500,000 plants per hectare (II variant of planting 40 cm x 5 cm), the average productivity of the experimental plot decreased by 22% compared with I variant - coming to 41.15 g and varied from 23.72 g to 69.51 g (V = 25.6%). However, the decrease of productivity was largely dependent on the genotypes. Some varieties reduced

Table 2. Yield of green pods of the common bean varieties depending on planting density
Tabela 2. Prinos zelenih mahuna sorti boranije u zavisnosti od gustine setve

VIR number VIR broj	Accession varieties Naziv sorte	Variants of the experiment Varijante ogleda				
		I (control) *kontrola*	II		IV	
		g per plant g po biljci	g per plant g po biljci	%	g per plant g po biljci	%
14401	Dialog (reference) *standard*	73.7	47.6	65	27.5	37
15281	Nomad	83.1	59.0	71	28.5	34
15356	Zabava	80.3	62.7	78	39.0	49
15231	Slavyanka	77.9	55.5	71	36.4	47
15208	Empress	66.6	49.9	75	27.5	41
14696	Vaillant	66.3	34.7	52	24.0	36
15214	Sensation	66.2	34.4	52	33.5	51
14400	Chaika	59.8	45.1	75	22.3	37
15256	Zagadka	51.6	69.5	135	28.0	54
13535	Trelanel	50.8	50.0	98	27.1	53
15366	Royal Burgundy Purple Pod	50.8	28.7	56	23.3	46
13646	Oltyn	50.4	46.3	92	30.4	60
15359	Brilliant	49.7	32.7	66	17.4	35
15213	Garden Green	42.4	31.3	74	22.3	53
15371	PI-164093	39.6	24.6	62	17.0	43
13542	Doranel	38.9	29.5	76	17.5	45
15175	Vestochka	38.6	43.4	112	24.7	64
15336	Tenderwhite Resistant BCMV	37.5	26.5	71	22.2	59
15245	Oxy	36.7	28.0	76	17.5	48
14393	Apci	24.3	23.7	98	17.1	70
	$\bar{x}$	54.25	41.15	-	25.14	-
	$LSD_{0.05}$	12.3	9.7	-	6.4	-

the productivity slightly - 9-25% compared to the reference variety, others by more than 26-35% and the rest showed similar results in both variants, such as Trelanel, Oltyn and Apci (Tab. 2).

With increasing the density up to 1,000,000 plants per hectare (IV variant of planting 20 cm x 5 cm), all varieties substantially reduced productivity at an average 52% compared to variant I. The average productivity was 25.14 g and varied from 17.02 g to 38.96 g. Some varieties insignificantly reduced productivity, such as Apci, Tenderwhite Resistant BCMV, Vestochka and Oltyn, while others decreased the yield up to 46% -67%. The most productive were Slavyanka and Zabava exceeding the reference variety up to 36.4 g – 39.0 g.

Productivity of Varieties Depending on the Planting Patterns

Average productivity in the experiment with decreasing spacing between rows from 40 cm to 20 cm decreased by 19% - 33.19 g and varied from 18.70 to 45.05 g (V = 19.8%). Most varieties showed weak reaction on the planting patterns (significant difference at 5% level of significance had not been revealed). 13 varieties slightly reduced productivity, the average difference varied from 0.4 to 9.1 g. Nomad, Zabava, Zagadka and Trelanel showed high sensitivity to the compression of the plants in rows (Tab. 3).

Thus, different selective backgrounds resulted in large fluctuations in productivity, i.e. different reactions of genotypes on environment. The most productive varieties are of particular interest, reducing productivity insignificantly in all variants of the experiment. Such was variety Oltyn with moderate and stable productivity in all studied environments.

Relationship Between Productivity and Stability

All studied accessions in all variants of the experiment differed in the properties of adaptability, but all of them decreased productivity at the highest density of the plot (IV variant). The results of variance analysis divided all accessions in two groups in relation to the reference variety: 12 productive varieties and 8 low productive ones. Zabava, Dialog, Nomad, Slavyanka and Zagadka demonstrated the largest effects of general adaptive ability (GAA) among the varieties from the first group. Last three of

Table 3. Yield of green pods of common bean varieties depending on the planting patterns (g per plant)
Tabela 3. Prinos zelenih mahuna sorti boranije u zavisnosti od obrasca setve (g po biljci)

VIR number VIR broj	Accession varieties Naziv sorte	Variants of experiment Varijante ogleda		Difference between the variants Razlika između varijanti
		II	III	
14401	Dialog (reference) *standard*	47.6	42.3	5.3
15281	Nomad	59.0	40.5	18.5
15356	Zabava	62.7	38.3	24.4
15231	Slavyanka	55.5	39.5	16.0
15208	Empress	49.9	38.0	11.9
14696	Vaillant	34.7	34.7	0
15214	Sensation	34.4	37.3	2.9
14400	Chaika	45.1	44.9	0.2
15256	Zagadka	69.5	45.1	24.4
13535	Trelanel	50.0	25.0	25.0
15366	Royal Burgundy Purple Pod	28.7	29.1	0.4
13646	Oltyn	46.3	38.0	8.3
15359	Brilliant	32.7	22.3	10.4
15213	Garden Green	31.3	27.0	4.3
15371	PI-164093	24.6	32.2	7.6
13542	Doranel	29.5	24.3	5.2
15175	Vestochka	43.4	35.4	8.0
15336	Tenderwhite Resistant BCMV	26.5	26.3	0.2
15245	Oxy	28.0	25.0	3.0
14393	Apci	23.7	18.7	5.0
	$\bar{x}$	41.15	33.19	9.1
	$LSD_{0.05}$	9.7	10.3	-

Table 4. The adaptability and stability of common bean varieties
Tabela 4. Adaptabilnost i stabilnost sorti boranije

VIR number VIR broj	Accession varieties Naziv sorte	$\overline{x}$ i	GAAi	SACi	Sgi (%)	*bi*	BVGi i
14401	Dialog (reference) *standard*	47.7	9.3	17.82	37.3	1.24	20.89
15356	Nomad	55.1	16.6	19.6	35.6	1.43	25.55
15281	Zabava	52.8	14.4	22.03	41.4	1.37	19.93
15231	Slavyanka	52.3	13.9	17.44	33.3	1.36	26.07
15208	Empress	45.5	7.0	15.61	34.3	1.18	21.93
15256	Vaillant	45.5	10.1	18.48	38.0	1.26	20.70
14400	Sensation	43.0	4.6	14.63	33.9	1.12	21.01
15214	Chaika	42.9	4.4	16.09	37.5	1.11	18.60
13646	Zagadka	41.3	2.8	8.05	19.5	1.07	31.14
14696	Trelanel	39.9	1.5	20.15	50.3	1.04	19.60
13535	Royal Burgundy Purple Pod	38.2	-0.2	13.32	34.8	0.99	18.19
15175	Oltyn	35.5	-2.9	9.56	26.9	0.92	21.16
15366	Brilliant	32.9	-5.5	10.94	33.2	0.86	16.48
15213	Garden Green	30.8	-7.7	9.57	31.1	0.80	16.35
15359	PI-164093	30.5	-7.9	13.52	44.2	0.79	10.18
15371	Doranel	28.4	-10.1	9.00	31.7	0.73	14.80
15336	Vestochka	28.1	-10.3	6.33	22.4	0.73	18.64
13542	Tenderwhite Resistant BCMV	27.6	-10.9	9.21	33.4	0.71	13.69
15245	Oxy	26.8	-11.7	10.42	38.9	0.70	11.07
14393	Apci	21.0	-17.5	12.40	19.0	0.54	19.13
	$LSD_{0.05}$	12.6	-	-	-	-	-

* $\overline{x}$ i – average for variety (g plant^{-1}); GAAi – general adaptive ability of the variety; SACi - specific adaptive capacity of the variety; Sgi - relative stability of the variety; bi - plasticity or responsiveness (regression coefficient on the environment); BVGi - breeding value of genotypes (varieties)
* $\overline{x}$ i – prosek sorte (g biljka^{-1}); GAAi – opšta adaptabilna sposobnost sorte; SACi – posebna adaptabilna sposobnost sorte; Sgi – relativna stabilnost sorte; bi – plastičnost ili odgovor (regresioni koeficijent sredine); BVGi – oplemenjivačka vrednost genotipa (sorte)

them had an average productivity in all variants (Tab. 4). These accessions are the best in the breeding for the general adaptive capacity, but at the same time, they have a high variance specific adaptive capacity (SAC) that determined the lowest stability. These are intensive varieties which provide a guaranteed high yield only in favourable conditions. They are more suitable for semi-intensive technologies with an average level of energy consumption and at the same time are very responsive to the improvement of growth conditions.

The best accessions, combining high productivity and its stability, were Oltyn, Slavyanka and Zabava. The last two of them had maximum GAA. Consequently, despite the lack of a close link between productivity and stability, as a result of individual selection from these varieties plants with maximum productivity and high stability can be obtained. Moreover, variety Zabava took the third meaning of BVG (breeding value of the genotype) in the sample and revealed the highest productivity - 55.1 g per plant. It also had the highest regression coefficient (*bi* = 1.43) and more than others responsive on the improvement of cropping conditions.

The lowest relative stability (Sg = 33.3%) is typical for Slavyanka, which combines productivity with environmental sustainability and has the second meaning of BVG. Variety Oltyn has high productivity and relative stability and the highest rate BVG.

The highest adaptive capacity was identified in variety Apci. Very close to it were varieties Tenderwhite Resistant BCMV, PI-164093 and Oxy, but all of them had low productivity in all variants of the experiment and regression coefficient below 1.0 and were poorly responsive to improvement of cropping conditions. Breeding value of these accessions (BVG) had a low meaning – 11.07 – 18.64.

Table 5. Parameters of the environment as a background for the selection
Tabela 5. Parametri sredine kao selekcione osnove

Selective background Selekciona osnova		u+D*	D	σDCC	Se	Ke	Tk	P
1	2003-42×10	55.9	17.4	21.09	38.6	9.12	0.893	0,345
2	2004-42×10	52.6	14.1	15.38	29.5	4.85	0.756	0,223
Average Prosek		54,3	15.8	18.24	34.1	6.99	0.825	0.284
3	2003-40×5	40.3	1.8	17.22	43.7	6.08	0.876	0,374
4	2004-40×5	42.0	3.5	11.62	27.7	2.77	0.785	0,217
Average Prosek		41,1	2.7	14.42	35.7	4.43	0.831	0.296
5	2003-20×10	32.0	-6.5	9.14	28.6	1.71	0.896	0,256
6	2004-20×10	34.4	-4.1	6.62	19.2	0.90	0.669	0,128
Average Prosek		33,2	-5.3	7.88	23.9	1.31	0.783	0.192
7	2003-20×5	24.5	-14.0	8.01	32.7	1.31	0.852	0,279
8	2004-20×5	25.8	-12.7	5.11	19.8	1.32	0.779	0,154
Average Prosek		25,2	-13.5	6.56	26.3	1.32	0.816	0.217

*u+D - the average productivity (g plant^{-1}), D - the productivity of the environment, σDCC - variance differentiating ability of the environment, T – coefficient of typicality of environment, Se - the relative differentiating ability of the environment, P - coefficient predictable environment, Ke – coefficient of compensation environment
*u+D – prosečna produktivnost (g biljka^{-1}), D – produktivnost sredine, σDCC – varijansa izdvajajuća sposobnost sredine, T – koeficijent osobenosti sredine, Se – relativna izdvajajuća sposobnost sredine, P – koeficijent predvidivosti sredine, Ke – koeficijent kompenzacije sredine

Comprehensive Assessment of Planting Density as a Background for the Selection

Analyses of the productivity were performed in four environments (pattern and density of planting) during two years, i.e. on 8 selective backgrounds (Tab. 1). The highest productivity (D) was provided on the backgrounds 1, 2, 3, 4, while the lowest was on 7 and 8 (Tab. 5).

The highest differentiating ability of the environment and its typicality was observed at backgrounds 1, 2, 3, 4. The rate of their destabilizing effect Ke > 1 corresponded to analyzing background Se > 20%. Backgrounds 5 and 7 are stabilizing, 6 and 8 had a leveling effect (Tab. 6). Typicality of environment (T) in the experiment was quite high, but varied from year to year. The backgrounds 1, 3, 5, 7 had the highest typicality.

According to the preliminary analysis, the pattern 40 cm × 5 cm with analyzing ability of the background (Se3;4 = 35.7%) was the most suitable for the selection. It is the best as the combination of typical environment and high productivity of accessions. The pattern 20 cm × 10 cm also suits the requirements for selective backgrounds, but only on the parameters Se, which corresponded to stabilizing background during two years of the experiment. Typicality (T5;6) and productivity (D5;6) of this variant were comparatively low – 0.783 and 33.2 respectively.

The scheme of 20 cm × 5 cm suited least of all for the selection of genotypes, especially in unfavourable weather conditions. This environment had a weak effect of destabilization (Se7;8 = 26.3%), low typicality (T7;8 = 0,816), the minimum standards of productivity (D7;8 =- 13.5) and weak polymorphism (DCC7,8 = 6, 56). This background may be leveling in unfavourable weather conditions, able to oppress the viability of strains and to smooth the differences between them.

Effect of Planting Density on Defeat with Bacterial Diseases

The affectation of the accessions with bacteria diseases increases with increasing density of sowing. At the same time, the degree of damage depends on the susceptibility of plant varieties. The varieties slightly affected with bacteriosis (less than 15%), regardless of the pattern and the density of sowing were Zabava, Oltyn, Zagadka, Nomad and Sen-

Table 6. Characteristics of the selective backgrounds
Tabela 6. Karakteristike selekcionih osnova

Selective background Selekciona osnova		(Dk) productivity Produktivnost	(Sek) background Osnova	(Tk) typicality Osobenost
1	03-42×10	high visoka	analyzing analizirajuća	high visoka
2	04-42×10	high visoka	analyzing analizirajuća	middle srednja
3	03-40×5	high visoka	analyzing analizirajuća	high visoka
4	04-40×5	high visoka	analyzing analizirajuća	middle srednja
5	03-20×10	middle srednja	stabilizing stabilizirajuća	high visoka
6	04-20×10	high visoka	middle srednja	low niska
7	03-20×5	low niska	stabilizing stabilizirajuća	high visoka
8	04-20×5	low niska	middle srednja	middle srednja

sation. The varieties Dialogue, Trelanel, Doranel, Vestochka, Empress, Garden Green and Slavyanka were ranked as moderately affected (35%). Strong reaction on the density of sowing was characteristic for cultivars Vaillant, Brilliant, Chaika, Oxy, Tenderwhite Resistant BCMV, Royal Burgundy Purple Pod, PI-164093 and Apci, increasing infected plants from 36% to 80% with increased sowing density.

Conclusions

The significant differences between vegetative common bean varieties in adaptability and stability in different environment were revealed. The varieties that showed the greatest adaptive capacity (tolerance to density of sowing) were identified, as well as the accessions with better ability to combine high productivity and stability. The research on planting patterns as selective background showed that the scheme of 40 cm × 5 cm with a density of 500,000 plants per hectare is the most suitable for breeding and selection of vegetable common bean genotypes: it is the best in providing a more accurate and reliable identification of varieties with high productivity in the Crimea region of Russia.

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Adaptabilnost i stabilnost populacija boranije (*Phaseolus vulgaris* L.) iz kolekcije VIR na Krimu

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Izvod: Adaptabilnost i stabilnost produktivnosti mahuna po biljci su ispitivane na uzorku od 20 populacija pasulja iz zbirke Instituta Vavilova (VIR). Populacije su gajene u skladu sa 8 različitih selekcionih osnova: četiri različita sklopa, odnosno, razmaka između i unutar redova i gustine setve, tokom dve godine. Identifikovane su populacije sa najvećom adaptabilnošću, odnosno sa najmanjim uticajem različitog sklopa i stabilnom produktivnošću. Takođe je utvrđen nivo osetljivosti populacija na bakterioze u zavisnosti od sklopa. Predloženi su optimalni obrazac i gustina setve za oplemenjivačke oglede kao selekciona osnova za oplemenjivanje na stabilnu produktivnost.

Ključne reči: adaptabilnost, boranija, selekciona osnova, stabilnost