

Phenotypic variation of common bush bean (*Phaseolus vulgaris* L. var. *nanus* (L.) Aschers) genotypes based on qualitative and quantitative traits.

Tsvetelina STOILOVA ^{1, 2}, Petar CHAVDAROV ¹, Hristina RANGELOVA ¹

Received September 22, 2025, accepted October 20, 2025.
Delo je prispelo 22 september 2025, sprejeto 20. oktober 2025

Phenotypic variation of common bush bean (*Phaseolus vulgaris* L. var. *nanus* (L.) Aschers) genotypes based on qualitative and quantitative traits.

Abstract: The study was carried out during 2022-2023 with 20 accessions of common bean (*Ph. vulgaris* var. *nanus* (L.) Aschers). The variation of fourteen quantitative characters was studied. The objectives of this study were to characterize a small subset of *Phaseolus* germplasm from the National collection for qualitative and quantitative traits and to group genotypes based on their similarities and correlation coefficients. The results showed that number and mass of pods per plant was positively correlated with total mass of seeds per plant. Results of studied genotypes offers to select early, medium or late maturity, with bigger number of pods per plant, consequently bigger number of seeds per pod, total mass of seeds per plant, bigger size of seeds based on 100 seed mass to get high grain yield per genotype and preferences of farmers. The accessions with high mass of seeds per plant were with local origin, A9E1121, B0E0048 and B9E0002 and use these results as a source of future breeding activities for breeding improvement or for new cultivars with desirable traits, as earliness, high number of pods per plant, mass of seeds per plant, organoleptic taste, etc. **Key-words:** morphological characterization, evaluation, bean germplasm, agronomical traits

Key words: morphological characterization, evaluation, bean germplasm, agronomical traits

Fenotipska variabilnost genotipov navadnega fižola (*Phaseolus vulgaris* L.) na podlagi kakovostnih in količinskih lastnosti.

Izvleček: Raziskava je bila izvedena v letih 2022–2023 z 20 akcijami navadnega fižola (*Ph. vulgaris* L.). Proučevane so bile spremenljivosti štirinajstih kvantitativnih znakov. Cilji te raziskave so bili opredeliti majhno podmnožico genotipov navadnega fižola iz nacionalne zbirke za kvalitativne in kvantitativne lastnosti ter združiti genotipe v skupine na podlagi njihovih podobnosti in korelacijskih koeficientov. Rezultati so pokazali, da sta število in masa strokov na rastlino v pozitivni korelaciji s skupno maso semen na rastlino. Rezultati proučevanih genotipov ponujajo izbiro zgodnje, srednje ali pozne zrelosti, z večjim številom strokov na rastlino, posledično večjim številom semen na strok, skupno maso semen na rastlino, večjo velikostjo semen glede na maso 100 semen, da dobimo velik pridelek zrnja na genotip in preferenco kmetov. Akcesije z veliko maso semen na rastlino so bile lokalnega izvora, A9E1121, B0E0048 in B9E0002, in jih lahko uporabimo kot vir prihodnjih žlahtniteljskih dejavnosti za izboljšanje in vzgojo novih sort z zaželenimi lastnostmi, kot so zgodnost, veliko število strokov na rastlino, masa semen na rastlino, organoleptični okus itd.

Ključne besede: morfološka opredelitev, ovrednotenje, genski viri fižola, agronomске lastnosti

¹ Agricultural Academy, Institute of Plant Genetic Resources, Plant Genetic Resources Department, 2 Druzhba str., 4122 Sadovo, Bulgaria

² Corresponding author: e-mail: tz_st@abv.bg

1 INTRODUCTION

Common bush bean (*Phaseolus vulgaris* var. *nanus* (L.) Aschers) is annual crop from Fabaceae family. It originates from South America, and it is the most important grain legume for direct consumption in the world (Kaplan, 1981; CIAT, 1993). Common bean is valuable crop, which is one of the traditional pulses for Bulgarian nation (Stoilova *et al.*, 2014). The main use of beans is for dry seeds and immature pods. Common bean is the main source of protein, essential amino acids, carbohydrate, essential minerals, fibers and vitamins (Los Basso *et al.*, 2018). There are many old varieties and populations of common bush bean still grown and maintained in different regions of the country by elderly people. The common bean seeds were preserved from one generation to another, however nowadays the old seeds are at risk of extinction (Krasteva *et al.*, 2009). Depopulation of the villages leads to the process of losing our treasure as plant genetic resources. Landraces were developed by farmers' preferences through individual selection with focus on taste, color, size of fruits or seeds, resistance to diseases and yield over many years (Oh *et al.*, 2012). The common bush bean landraces are usually grown in home gardens or in small farms by people from rural and marginal areas (Scarano *et al.*, 2014; Savić *et al.*, 2020). Landraces are described as genetically diverse material with specific traits for growing region. Traditionally, they are grown in low input farming systems very well adapted to local agro-climatic conditions and show high level of phenotypic diversity. According to the FAO definition "A landrace of a seed-propagated crop can be defined as a variable population, which is identifiable and usually has a local name. It lacks "formal" crop improvement, it is characterized by a specific adaptation to the environmental conditions of the cultivation area (tolerant to biotic and abiotic stresses of that area) and it is closely associated with

the traditional uses, knowledge, habits, dialects, and celebrations of the people who developed and continue to grow it." The wide genetic base of landraces makes them interesting and important for conservation, breeding and research activities (Gioia *et al.*, 2019). The production is directed mainly for family subsistence use and abundant is sold in the nearest local market (Maxted *et al.*, 2013). Many authors studied diversity of common bean landraces in many countries in the world (Raggi *et al.*, 2013; Mallor *et al.*, 2018; Debouck, 2014). National *Phaseolus* collection is conserved at the genebank of the Institute of plant genetic resources (IPGR), Sadovo and contained more than 2700 accessions with local and foreign origin, at about 750 accessions were landraces and old varieties. The scientific work on local *Phaseolus* germplasm in Sadovo started from beginning of last century and continues till today (Gradinarov, 1939; Stoilova, 2007).

The objectives of this study were: 1) to characterize a small subset of *Phaseolus vulgaris* var. *nanus* (L.) Aschers germplasm from the National collection for qualitative and quantitative traits; 2) to group genotypes according to their similarities and correlation coefficients. The information will be useful both for more efficient germplasm utilization and as a helpful criterion for common bush bean breeders and researchers.

2 MATERIAL AND METHODS

Twenty genotypes of common bean (*Phaseolus vulgaris* var. *nanus* (L.) Aschers) with local and foreign origin were included in this study. Landraces were collected from southern part of the country, as follows: in district of Blagoevgrad -1, Burgas -2, Gabrovo -1, Plovdiv -2, Ruse -2, Stara Zagora - 4. Genotypes with foreign origin were from USA 3, Germany 3 and Holland 2. All genotypes were multiplied, characterized and evalu-

Table 1: Characters used for *Phaseolus* spp. L. characterization

No	Characters	No	Characters
1	H of plant (cm) (H/pl)	9	Pod width (cm) (PW)
2	Total mass of plant (g) (TMPL)	10	Pod thickness (cm) (PT)
3	Numbers of branches (Nr/br)	11	Number of seeds/pod (NS/P)
4	Mass of plant without pods (g) (Mpl/wP)	12	Seed length (cm)(SL)
5	Height of 1st pod (cm) (H/1stp)	13	Seed width (cm) (SW)
6	Number of pods/pl (NP/pl)	14	Seed thickness (cm) (ST)
7	Mass of pods/pl (g) (MP/pl)	15	Total seed mass/pl (g)(TSM/pl)
8	Pod length (cm) (PL)	16	Mass of 100 seeds (g) (M100S)

ated according to the International *Phaseolus* descriptor (Bioversity Int. / IBPGR, 1982) (Table 1).

Phenological observations, as beginning of flowering, mass flowering (50 % flowering), duration of flowering and maturation were done on the whole plot of each genotype. The research study was conducted in a period of two years (2022-2023), at the experimental field of the Institute of plant genetic resources (IPGR), Sadovo. The IPGR is situated in the Thracian plane (Central Southern Bulgaria) on cinnamon-forest soil with a neutral pH. The grains were sown manually in 2 row plots, with 2 m length and 0.7 m between rows. Biometrical measurements were performed in the field and in the laboratory, concerning those related to total plant mass, number and mass of pods, number and mass of seeds per plant were taken from 10 randomized chosen plants after harvesting. Although, the water content of pods and seeds varied, the mass was measured at 10 % water content of all samples. Mean, the minimum and maximum values, range of variation and coefficient of variation (CV %) were determined for all characters (Lidanski, 1988). The results of the clustering are presented graphically by a dendrogram. The studied genotypes are divided into groups, depending on the behavior of their characterizing traits relative to the average values. To determine the similarity and proximity of the studied accessions of *Phaseolus vulgaris*, hierarchical cluster analysis was applied (Ward, 1963). All collected data were analyzed statistically using computer software SPSS 19 for Windows Version 19.0 (IBM Corp. 2009).

3 RESULTS

3.1 WEATHER CONDITIONS

A wide range in maximum and minimum air temperature (°C) was observed during March and April. There were differences in average temperatures during March in 2022 and 2023, as T °C was higher during 2023 compared with the first experimental year. In May and June the average T °C was higher in 2022 compared with the second year with 2 °C and 1.5 °C, respectively (Figure 1, 2). During the reproductive phase a high temperature prevailed. During flowering stage at the end of May and June the maximum decade's T °C was 25 °C and above, while the minimum T °C was with average value of 15.3 and 14.2 °C (Figure 1, 2). The decade cumulative rainfall during the crop cycle in 2022 with 100.7 l m⁻² and 2023 with 107.9 l m⁻² showed water scarcity during pod setting and grain filling. The scarcity of rainfall and high daily temperatures during the reproductive stages

of common bean affected yield and yield components, considered the most sensitive period related to yield production (Reichert et al., 2015).

3.2 PHENOLOGICAL OBSERVATIONS

The results of phenological observations are presented in Table 2 and Figure 3. The genotypes No1 (A7E0279), No7 (A9E0182) and No18 (BOE0048) started flowering 28 days after emergency. They were the earliest among all plant materials (Figure 3). Different accessions continued flowering differently with range from 20 to 36 days with mean value of 28 days. Among four phenological phases duration of flowering showed higher variation, with CV %-16.1 % compared with days to beginning of flowering (12.4 %), days to 50 % flowering (10.9 %) and days to maturity (6.2 %) (Table 2). Variability of phenological phases allowed accessions to develop reproductive organs under different environmental conditions during the vegetation cycle. The largest yield was generally obtained when

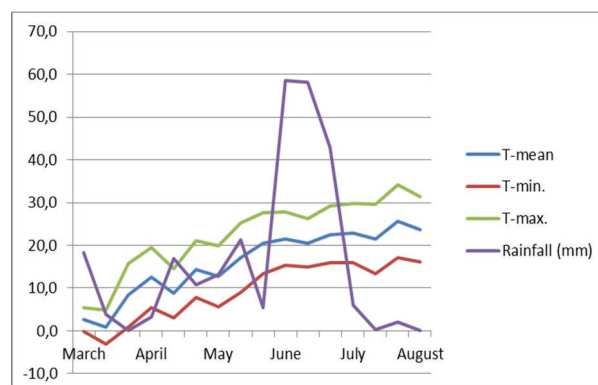


Figure 1: T°C and rainfall during 2023

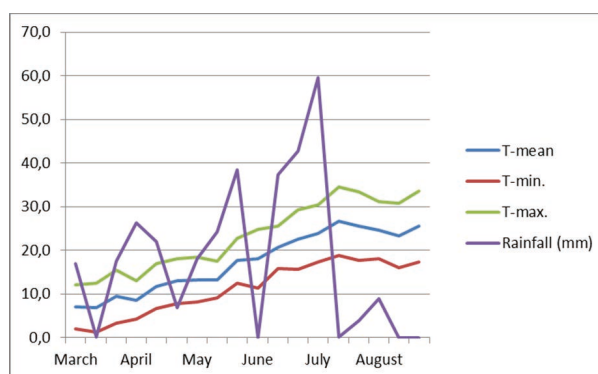
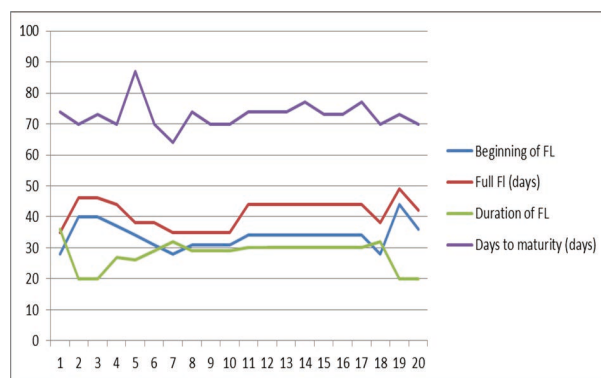


Figure 2: T°C and rainfall during 2023

Table 2: Statistical values of phenological phases

Statistical values	Days to beginning of flowering	Days to 50 % flowering	Duration of flowering	Days to maturity (95 %)
Min.	28	35	20	64
Max.	44	49	36	87
Mean	33.9	41.2	28.0	72.9
St. Error	0.9	1.0	1.0	1.0
CV %	12.4	10.9	16.1	6.2

**Figure 2:** T°C and rainfall during 2023

seeds were sown at the end of March or early in April, with minimum soil temperature of 8-10°C and above. Delayed seed sowing was one of the major factors decreasing average seed yield, as consequence of reducing number of flowers, number of pods and seeds per plant.

3.3 MORPHOLOGICAL TRAITS

Morphological traits of vegetative and reproductive organs are presented in Table 3 and Table 4. The plant height of studied genotypes was registered with mean value of 31.9 cm, whereas 55 % of them were shorter and the rest of genotypes (45 %) were taller than average. The total mass of plant ranged from 11.3 to 61.2 g with coefficient of variation (CV %) of 35.4 %. The mass of plant depended from plant height, number of primary branches, mass of pods and mass of seeds per plant. The genotypes with the highest mass of plant originated from Germany (84201018), following by local genotype grown in Dimitrovgrad (B0E0054) with total mass of plant 61.2 g and 53.5 g, respectively. The plants of common bean usually formed 2-3 and rare 4 branches. In current case the

mean value of this trait was 2.5 with range from 1 to 3.6 branches. Only 35 % of genotypes showed more than average number of branches. The highest mass of plant without pods was measured in the same genotypes with the highest value of total mass of plant. This quantitative trait showed the highest variation with CV %-47.8 % compared with other morphological traits (Table 3, 4). Number of pods per plant was trait with the second highest coefficient of variation, CV %-41 %. The mean number of pods per plant was 7.8; 65 % of genotypes were with less than average number of pods per plant, while 35 % of studied genotypes were with bigger number of pods per plant than average. Genotypes with the biggest mass of pods per plant were with local origin, as follows: B0E0048, B9E0002 and A9E1121. Size of pods is important from the consumer's point of view. The longest pods were registered with genotype 84201011 (Germany) 17.6 cm, followed by the local accessions A4E0001 (Cheshnegirovo) 15.4 cm and A8E0355 (Obzor) 12.9 cm. The coefficient of variation of pod length was the highest among the three pod sizes with value of CV % 19.5 cm, followed by the pod width varied with similar value of coefficient of variation CV % 18.2 %, while the least variation was registered by the pod thickness with CV % 11.1 cm (Table 3).

Among the quantitative seeds' traits with higher variation was found total mass of seeds per plant (CV %-37.0 %) followed by the mass of 100 seeds (CV %-30.6 %). Different genotypes produced different number of pods per plant with different mass of pods. The biggest mass of seeds per plant was measured in two genotypes B0E0048 (12.2 g) and B9E0002 (11.9 g) with local origin. The mean value of mass of seeds per plant was 7.3 g with ranged from 2.8 to 12.2 g. Higher yield potential of studied genotypes with mass of seeds per plant more than average for the group 7.3 g. The biggest size of seeds related to 100 seed mass was observed in local genotype A9E1121 with value of 43.6 g, followed by 91201180 (USA) with 42.0 g of 100 seed mass. There were two accessions from Holland with the smallest seeds No 82201201 16.8 g and No 84201015 17.5 g. The mean value of this character was 26.8 g. Genotypes' seeds of this study were very diverse in terms of color and shape (Figure 4, 5, 6). The predominant seed color was white with kidney shape, followed by beige color, beige with lilac or beige with brown spots. One genotype possessed white seed color with black spots on it (Figure 4). In terms of seed shape, the second more frequent was cuboid and oval shape. Few genotypes were with round shape (Figure 5, 6).

Table 3: Morphological characters of 20 common bean genotypes

Nº	cat.No	Origin	H/ (cm)	pl TMPL (g)	Nr/br	Mpl/ (g)	wPH (cm)	1st/p NP/pl	MP/pl (g)	PL (cm)	PW (cm)	PT (cm)
1	A7E0270	Blagoevgrad	24.8	24.5	1.2	16.8	11.2	6.0	7.2	9.7	1.4	0.9
2	A8E0271	Geravna	33.6	45.0	2.0	31.0	26.0	16.9	9.6	11.3	1.1	0.8
3	A8E0634	Sozopol	49.4	36.3	2.0	22.7	14.6	7.6	12.8	11.9	1.0	0.8
4	A8E0641	Zetiovo	59.2	41.7	3.0	28.9	12.6	8.2	12.1	11.6	1.1	0.8
5	A8E0355	Obzor	28.0	34.0	2.4	29.3	10.7	4.4	4.8	12.9	1.2	0.9
6	A9E0430	Obretenuk	34.4	23.7	2.0	13.9	11.2	6.2	8.8	10.2	1.1	0.9
7	A9E0182	Kmetovtsi	28.6	11.3	1.0	4.1	13.0	5.0	7.3	11.8	1.2	1.0
8	A9E1121	Oryahovo	31.0	30.2	2.6	15.2	13.6	6.4	14.9	10.3	1.6	1.1
9	91201180	USA	28.8	24.6	3.4	13.6	11.4	5.6	10.7	12.7	1.5	1.2
10	A4E0001	Cheshnegirovo	23.6	18.6	2.6	10.4	13.0	4.8	7.2	15.4	1.1	0.9
11	84201011	Germany	33.0	47.7	3.6	35.4	14.2	7.2	11.8	17.6	0.9	1.0
12	84201015	Germany	31.6	29.8	3.2	15.9	12.4	10.2	13.5	11.9	0.9	0.9
13	84201018	Germany	28.4	61.2	3.6	49.7	11.6	7.8	11.5	12.6	0.9	1.0
14	82201201	Netherland	19.8	26.2	2.0	18.5	6.0	7.2	7.5	8.5	0.9	0.8
15	82201002	Nederland	22.2	25.6	2.0	16.1	7.2	7.0	9.3	10.7	0.9	0.8
16	84201025	USA	35.6	31.9	3.6	25.6	15.8	5.8	6.1	14.0	1.0	1.1
17	B0E0054	Dimitrovgrad	25.8	53.5	2.0	41.1	10.0	6.4	11.9	13.5	1.6	0.9
18	B0E0048	Dimitrovgrad	32.0	39.6	2.6	22.2	13.0	14.2	16.9	9.0	1.1	0.9
19	B9E0002	Cheshnegirovo	32.0	34.5	2.0	19.3	8.8	11.4	16.0	8.7	1.0	0.8
20	88201008	USA	35.2	37.6	3.0	26.8	9.6	8.4	12.4	11.5	1.3	0.8
Min.			19.8	11.3	1	4.1	6	4.4	4.8	8.5	0.9	0.8
Max.			59.2	61.2	3.6	49.7	26	16.9	16.9	17.6	1.6	1.2
Mean			31.9	33.9	2.5	22.8	12.3	7.8	10.6	11.8	1.1	0.9
St. Error			2.0	2.7	0.2	2.4	0.9	0.7	0.7	0.5	0.05	0.03
CV %			28.2	35.4	32	47.8	32.5	41	32.0	19.5	18.2	11.1

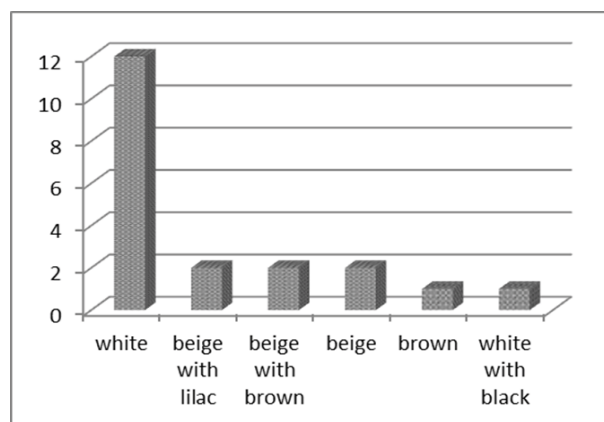
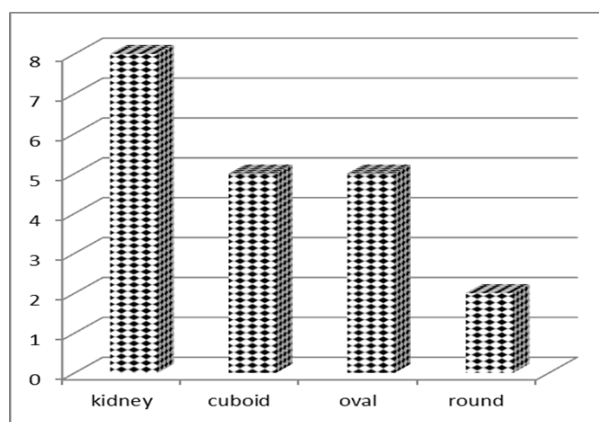
**Figure 4:** Distribution of seeds according seed color**Figure 5:** Distribution of seeds according to the seed shape

Table 4: Biometrical measurements of common bean' seeds

Nº	Cat. No	NS/P	SL (cm)	SW (cm)	ST (cm)	TSM/pl (g)	M100S (g)
1	A7E0270	3.2	1.3	0.8	0.7	5.3	37.4
2	A8E0271	4.8	1.1	0.6	0.5	8.8	21.1
3	A8E0634	5.4	1.4	0.8	0.5	9.2	35.8
4	A8E0641	4.4	1.2	0.6	0.5	7.3	27.0
5	A8E0355	4.2	1.2	0.6	0.5	2.9	28.1
6	A9E0430	4.6	1.1	0.6	0.5	5.4	27.0
7	A9E0182	4.6	1.2	0.8	0.5	5.8	31.0
8	A9E1121	3.4	1.2	0.8	0.7	1.0	43.6
9	91201180	4.8	1.7	0.9	0.6	7.8	42.0
10	A4E0001	5.2	1.5	0.7	0.5	4.9	31.7
11	84201011	5.6	1.4	0.6	0.5	8.0	23.2
12	84201015	5.0	1.1	0.5	0.5	9.0	17.5
13	84201018	4.6	1.2	0.6	0.5	6.5	21.3
14	82201201	4.2	1.0	0.6	0.5	4.2	16.8
15	82201202	4.4	1.1	0.5	0.5	6.0	18.2
16	84201025	5.4	1.2	0.5	0.4	2.8	18.6
17	B0E0054	4.6	1.1	0.7	0.6	7.5	31.1
18	B0E0048	3.6	0.8	0.6	0.5	12.2	19.3
19	B9E0002	3.8	0.9	0.7	0.5	11.9	19.5
20	88201008	3.6	1.1	0.8	0.5	8.8	26.2
Min.		3.2	0.8	0.5	0.4	2.8	16.8
Max.		5.6	1.7	0.9	0.7	12.2	43.6
Mean		4.5	1.2	0.7	0.5	7.3	26.8
St. Error		0.2	0.04	0.03	0.02	0.6	1.8
CV %		15.6	16.7	14.3	20	37.0	30.6

3.4 PHENOTYPIC CORRELATIONS OF DIFFERENT CHARACTERS OF COMMON BEAN.

The positive and negative correlations between different morphological characters are listed in Table 5. Yield and yield components showed strong positive correlations. Number of branches showed medium positive correlation with total mass of plant and pod length. Mass of plant without pods was in a strong correlation with total mass of plant, mass of pods per plant and number of pods per plant, seed length and number of pods per plant, as well as total seed mass per plant depended from number of pods per plant and mass of pods per plant. Number of pods per plant had a medium correlation with height of the 1st pod. Number of seeds per pod and seed length was in a strong positive correlation with pod

**Figure 6:** Common bean genotypes' seeds

length, while seed width and seed thickness showed a strong positive correlation with pod width. Mass of 100 seeds was in a strong correlation with pod width, seed length, seed width and seed thickness and in a medium negative one with number of pods per plant.

It is shown that mass of seeds per plant varied in linear dependence from number and mass of pods per plant. Significant correlations among these traits are demonstrated by the linear equation 1.

$$(1) Y = -1,182 + 0,150 \cdot NP/pl + 0,685 \cdot WP/pl$$

3.5 CLUSTER ANALYSIS

Grouping *Phaseolus vulgaris* var. *nanus* (L.) accessions based on morphological characters showed four clusters with different number of accessions. Cluster one was the biggest and includes eight accessions, among them cat. No 82201201 and 82201202, cat. No B0E0048 and B9E0002, are genetically narrow based accessions (Table 6) (Figure 7). The first two accessions originated from Netherland, while the second two have local origin. Accessions 82201201 and 82201202 are differed from the other accessions by the low average values for the traits height of the first pod, length of pod, width of pod and pod thickness. B0E0048 and B9E0002 have a greater mass of pods per plant and mass of seeds per plant. The accessions A7E0270, 91201180, A9E1121, A9E0182, A4E0001 and A9E0430 are included in the second cluster. All accessions have high average value for mass of the 100 grains. Next two accessions, A8E0634 and A8E0641 grouped together in one cluster (Figure 7). The last two accessions originated from two locations of one region. They are very similar in morphological characters con-

Table 5: Correlations among different characters in common bean.

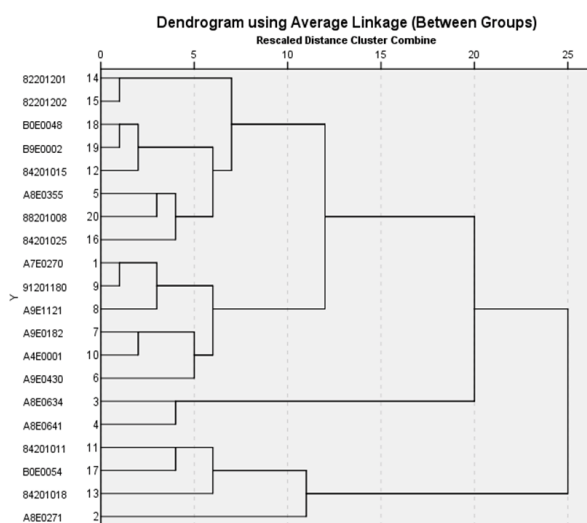
	H/pl	TMP/l	Nr/br	Mpl/wP	H/1 st p	NP/pl	MP/pl	PL	PM	PT	NS/P	SL	SM	ST	TSM/pl	M100S
H/pl	1	.258	.233	.174	.326	.194	.323	.055	-.105	-.185	.196	.063	.012	-.234	.269	.085
TMP/l		1	0.449*	.961**	.213	.389	.405	.229	-.083	-.112	.092	-.196	-.250	-.084	.286	-.254
Nr/br			1	.440	.088	.008	.224	.512*	-.200	.426	.371	.257	-.277	-.292	.058	-.182
Mpl/wP				1	.156	.211	.153	.323	-.101	-.082	.144	-.120	-.291	-.141	.024	-.267
H/1 st p					1	0.506*	-.009	.265	-.001	.112	.350	.146	-.058	-.114	.161	.047
NP/pl						1	0.545**	-.362	-.257	-.407	-.138	-.548**	-.262	-.189	.641**	-.469*
MP/pl							1	-.262	.056	-.091	-.250	-.337	.126	.167	.949**	-.027
PL								1	-.050	.379	.727**	.622**	-.075	-.220	-.301	.108
PM									1	.383	-.437	.246	.692**	.766**	.140	.787**
PT										1	.181	0.513*	.266	.264	-.111	.438
NS/P											1	0.474*	-.292	.550**	-.293	-.165
SL												1	0.469*	.236	-.294	.645**
SM													1	.606**	.259	.831**
ST														1	.239	.737**
TSM/pl															1	.066
M100S																1

** Correlation is significant at the 0.01 (2- tailed), *Correlation is significant at the 0.05 (2- tailed). Significant correlations are in bold. Abbreviations are given in Table 1.

cerned number of pods, mass of pods per plant, pod length, pod width and pod thickness. The fourth cluster included accessions 84201011, BOE0054, 84201018 and A8E0271. Among them there are some with highest values of the studied traits. For example, accession A8E0271 has height of the 1st pod 26 cm and number of pods per plant 16.9, accession 84201018 has mass of plant 61.2 g,

number of branches 3.6 and mass of plant without pods 49.7 g, while the accession 84201011 has length of pod 17.6 cm and number of seeds per pod 5.6. Accessions with maximum genetic distance were No 7 (A9E0182) with local origin and No 13 (84201018) from Germany, No13 (84201018) and No 10 (A4E0001) with local origin (Table 7).

To understand better diversity among the studied accessions and to be more in use for breeders Principal Component analysis was applied. The results showed that the first (PC1) explained 27.4 % of the total variation, the

**Figure 7:** Dendrogram of 20 common bean accessions.**Table 6:** Genetically narrow based accessions.

Stage	Genotypes		Coefficients
1	14	15	26.7
2	18	19	61.37
3	1	9	82.79

Table 7: Genetically distanced accessions.

Genotypes	Coefficients	
7	13	4698.96
13	10	3531.81

Table 8. Total Variaton among components.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.4	27.4	27.4
2	3.6	22.4	49.8
3	2.9	17.9	67.7
4	1.5	9.4	77.1
5	1.1	7.0	84.1

Table 9. Explained significant components by traits

TRAITS	Component				
	PC1	PC2	PC3	PC4	PC5
H/pl	-0.265	-0.014	0.446	0.461	0.033
TMP1	-0.556	-0.025	0.629	-0.453	0.254
Nr/Br	-0.331	0.455	0.532	-0.211	-0.463
Mpl/wP	-0.509	0.156	0.504	-0.557	0.347
H/1st pod	-0.208	0.143	0.438	0.553	0.490
NP/pl	-0.634	-0.536	0.228	0.287	0.156
MP/pl	-0.263	-0.626	0.564	0.046	-0.421
PL	-0.002	0.821	0.385	-0.027	0.024
PM	0.752	-0.264	0.356	-0.186	0.213
PT	0.474	0.404	0.366	-0.116	-0.331
NS/P	-0.271	0.795	0.148	0.341	-0.039
SL	0.569	0.631	0.331	0.193	-0.025
SM	0.780	-0.246	0.319	0.147	0.025
ST	0.722	-0.413	0.272	-0.244	0.141
TSM/pl	-0.163	-0.698	0.549	0.219	-0.283
M100S	0.883	-0.025	0.386	0.113	0.110

second (PC2) explained 22.4 %, the third (PC3) 17.9 %, the fourth (PC4) 9.4 % and the fifth (PC5) 7.0. The five components together explained 84.1 % of the total variation (Table 8).

The relative weight of each character and its belonging to the significant factors is shown on table 9.

Morphological traits responsible for the separation in the first component were number of pods per plant, pod width, pod thickness, seed width, seed thickness and mass of 100 seeds (Table 9). For the second component is strongly, positively associated with three traits, pod length, number of seeds per pod and seed length, and

Table 10. Explained significant components by accessions.

Accessions	Component				
	1	2	3	4	5
A7E0270	1.864	-1.253	-1.153	-0.153	-0.399
A8E0271	-0.138	-1.542	-0.355	0.873	2.947
A8E0634	0.236	0.239	0.433	-0.629	1.818
A8E0641	-0.297	0.041	0.531	0.338	0.945
A8E0355	0.030	-0.155	-1.706	0.665	-0.508
A9E0430	-0.372	-0.356	-0.469	-0.847	-0.092
A9E0182	0.362	-0.255	-0.874	-1.852	0.378
A9E1121	2.106	0.229	1.274	-0.212	-0.508
91201180	1.550	2.050	0.509	-0.884	-0.255
A4E0001	-0.083	1.003	-1.033	-1.101	0.317
84201011	-0.642	1.831	0.178	0.969	0.406
84201015	-1.287	0.423	1.017	-0.585	-0.154
84201018	-0.469	0.713	0.033	2.224	-0.740
82201201	-0.959	-1.065	-0.805	-0.400	-1.491
82201202	-1.088	-0.596	-0.457	-0.552	-1.129
84201025	-1.317	1.318	-0.944	0.067	0.240
B0E0054	1.225	-0.303	-0.509	2.007	-0.473
B0E0048	-0.521	-0.971	1.987	0.128	-0.270
B9E0002	-0.505	-1.067	1.655	-0.440	-0.573
88201008	0.306	-0.283	0.689	0.383	-0.458

negatively with mass of pods per plant and total mass of seeds per pant. Two traits are associated positively with the third component, total mass of plant and number of branches. The fourth component is positively associated with two traits, height of plant and height of the 1st pod, and negatively with mass of plant without pods (Table 9).

The studied accessions relate differently to the five principal components. Accessions A7E0270 (1.864) and A9E1121 (2.106) are located in the positive values of the first main component, while accession 84201015 (-1.287) is in the negative values of the PC1 (Table 10). The smallest number of the studied accessions is related to PC2. Two of them are located in the positive values of the PC2, accession 92201180 (2.050) and 84201025 (1.3180), and 82201201 (-1.065) fall into the negative values. The accessions BOE0054 (1.987), B9E0002 (1.655) and 88201008 (0.689) are positively connected with PC3, and accession A8E0355 (-1.706) is in the negative values of the component. The fourth main component is represented by the seven accessions, four of them 84201018 (2.224), BOE0054 (2.007), 84201011 (0.969) and A8E0355 (0.665) are in the positive values of the component and

other three accessions are with negative values. Three accessions are positively connected to the fifth principal component, accession A8E0271 (2.947), A8E0634 (1.818) and A8E0641 (0.945) and one accession is in the negative values 82201202 (-1.129) (Table 10). Accessions A9E0271 (2.947), 84201018 (2.224), A9E1121 (2.106) and 91201180 (2.050) showed the high variability and can be use as donor of the certain trait in breeding programme or directly in the production process.

4 DISCUSSION

Legume crops are grown across the world but yield and yield – related traits are affected by the climatic conditions, particularly drought and heat indicating the treat of water scarcity for legumes in the future (Gayacharan et al., 2023). The specific climate mainly the high temperature and humidity are important for the development of flowers, pods and seeds of common bean local populations and cultivars (Muasya et al., 2008). Analysis of variance showed that genotypes differed significantly for days to flowering and maturity. Genotype A9E0182 flowered early (28 days) and matured in 64 days, compared to the other accessions. In contrast, genotype A8E0355 flowered later (38 days) than the earliest accession and had the longest maturation cycle (87 days). Considerable variability was observed among genotypes for both traits. Similar significant differences in flowering and maturity of common bean genotypes were also reported by Shahid and Kamaluddin (2013), Fahad et al. (2014), and Yohannes et al. (2020). Variations in plant height and number of primary branches among common bean accessions were significantly influenced by inherent genetic variability (Loha et al., 2023). The tallest plants were recorded by the accession A8E0641 (59.2 cm), while the accessions with the greatest number of primary branches were 84201011, 84201018 and 84201025 (with 3.6). All accessions produced different number of primary branches. Number of branches was strongly influenced by the environmental conditions (Panayotov et al., 2009). Quantitative characteristics related to grain yield of common beans, as pods per plant and seeds per plant, showed similar variation of 41 and 37%. Hobdari et al. (2023) found almost the same level of variability as results of their study on 40 farmers' varieties. They reported values of minimum and average number of pods per plant, with 4.0 and 9.7 against 4.8 and 10.6 in our study. Kebede et al. (2014) reported that number of pods per plant was significantly affected by the sites and environments. This is in agreement with the conclusions done by Panayotov et al. (2009) shared that morphological characters: mass of pods per plant, size and number of pods were controlled by the genotype and

environmental conditions. The study described by Ilić et al. (2023) showed phenotypic and genotypic variability of the selected set of Serbian landraces with results similar to our results with average seed yield per plant of 7.9 g against to 7.3 g obtained from this experiment, with bigger seeds of 42.5 g, related to mass of 100 seeds against to 26.8 g in our study (2023).

5 CONCLUSIONS

Based on the obtained results several genotypes were selected with extreme values of studied characters.

Genotypes A7E0279, A9E0182 and BOE0048 showed earlier maturity with 64 to 74 days after emergence. These accessions will avoid high daily temperature during flowering and pod filling stages, which lead to more stable yield production.

The selected genotypes with highest mass of plant were 84201018 and B0E0054. They showed higher number of pods per plant and mass of pods per plant compared with average value of the group, which may be the prerequisite to increase yield production.

The biggest seed mass per plant was measured in genotypes B0E0048 (12.2 g) and B9E0002 (11.9 g). This plant material could be useful to obtain new lines and varieties with high seed production.

The biggest size of seeds was registered in genotypes A9E1121 and 91201180. Two accessions 82201201 and 84201015 produced the smallest seeds. The mean value of this character was 26.8 g. The big seed size is of special interest for consumers and producers, the smallest seeds are of interest for harvest mechanization.

The predominant seed color of the included genotypes was white with kidney shape, followed by beige color, beige with lilac or brown spots. Consumer's preferences are predominantly for white seeds, however there are many regions with local preferences to brown color with stripes, spots etc.

Yield and yield components showed strong positive correlations. Results from correlation and cluster analyses will be of use to select quantitative traits showed positive connection with yield, accessions with maximum genetic distance from the main group could be used as a donor of particular trait in breeding process and for research.

With climatic changes the main aim of the breeding process is to achieve new varieties more tolerant to abiotic stress factors with sustainable yield production.

6 STATEMENTS AND DECKLARATION

6.1 FUNDING

The research leading to these results has received funding from the National Science Fund, Bulgaria by the Grant KII-06-H56/13 / 21.11.2021.

This research work was presented at the VI International, Agricultural, Biological & Life Science Conference (AGBIOL), 18-20 September, 2024 Edirne, Turkey with support of the same Grant.

6.2 DATA AVAILABILITY STATEMENT

The original contributions presented in this study are available in the Mendeley Data published on 11/12/2025 (<http://datacite.org/schema/kernel-4>). Further inquiries can be directed to the corresponding author.

6.3 COMPLIANCE OF ETHICAL STANDARDS (CONFLICT INTEREST)

The authors declare that they have no conflict of interest.

7 REFERENCES

- Bioversity International/ International Board for Plant Genetic Resources (IBPGR) (1982). *Descriptors for Phaseolus vulgaris*. IBPGR, International Plant Genetic Resources Institute, Rome, Italy.
- Celmeli, T., Sari, I.D.H., Canci, H., Sari, D., ID, A.A., Eker, T., Toker, G. (2018). The nutritional content of common bean (*Phaseolus vulgaris* L.) landraces in comparison to modern varieties. *Agronomy*, 8, 166. <https://doi.org/10.3390/agronomy8090166>
- CIAT, (1993). *Trends in CIAT commodities*. Working document No 128. CIAT, Cali, Colombia.
- Debouck, G.D. (2014). *Conservation of Phaseolus beans genetic resources. A strategy*. Rome, Italy, Global Crop Trust Diversity, p. 79. www.croptrust.org
- Fahad, A., Muhammad, K., Obaid, A., Mukhtar, A., Arshad, C. (2014). Agromorphological evaluation of some exotic common bean (*Phaseolus vulgaris* L.) genotypes under rain fed conditions of Islamabad. *Pakistan Journal of Botany*, 46(1), 259–264.
- Gayacharan, Parida S.K., Mondal, N., Yadav, R., Vishwakarma, H., Rana, J.C. (2023). Mining legume germplasm for genetic gains: An Indian perspective. *Frontiers in Genetics*, 14, 996828. <https://doi.org/10.3389/fgene.2023.996828>
- Gioia, T., Logozzo, G., Marzario, S., Zeuli, S.P., Gepts, P. (2019). *Plos One*, 14(1), e0211342. <https://doi.org/10.1371/journal.pone.0211342>
- Gradinarov, L. (1939). *Morphological and agro-botanical study on variety list of field and garden beans available at that time in Bulgaria*. Bulgarian Academy of Science (BASc), Sofia, p. 241.
- Hobdari, V., Jani, S., Elezi, F. (2023). Characterization and evaluation of common bean (*Phaseolus vulgaris* L.) accessions stored in the Albanian genetic bank. *International Scientific Journal „Mechanization in agriculture & conserving of the resources“ Year LXIX*, 2, 71-75. Print ISSN 2603-3704
- IBM Corp. (2009). *IBM SPSS Statistics for Windows, Version 19.0*; IBM Corp: Armonk, NY, USA.
- Ilić, D.A., Zorić, Z.M., Zivanov, B.D., Medic-Pap, S.S., Vasić, A.M. (2023). Productivity assessment of common bean (*Phaseolus vulgaris*) germplasm from Serbia. *Crop and Pasture Science*, 74(5), 470-482. <https://doi.org/10.11071/CP22275>
- Kaplan, L. (1981). What is the origin of the common bean? *Economic Botany*, 35(2), 240–54. JSTOR, <http://www.jstor.org/stable/4254281>. Accessed 15 Oct. 2025.
- Krasteva, L., Stoilova, T., Varbanova, K., Neikov, S. (2009). Bulgarian landrace inventory-significance and use. In: European landraces on-farm conservation, management and use. Eds.: Veteläinen M., Negri V., Maxted N. *Bioversity Technical Bulletin*, 15, 53-69.
- Lidanski, T. (1988). *Statistical Methods in Biology and Agriculture*; Zemizdat: Sofia, Bulgaria, 160p. (In Bulgarian)
- Loha, G., Silas, M., Gidago, G. (2023). Effect of common bean (*Phaseolus vulgaris* L.) varieties and variable rates of potassium fertilizer on yield and yield-related traits in Ethiopia. *Applied and Environmental Soil Science*, <https://doi.org/10.1155/2023/5996945>
- Los Basso, G.F., Zielinski, F.A.A., Wojeicchowski, P.J., Nogueira, A., Demiate, M.I. (2018). Beans (*Phaseolus vulgaris* L.): whole seeds with complex chemical composition. *Current Opinion in Food Science*, 19, 63. www.sciencedirect.com
- Mallor, K., Barberan, M., Aibar, J. (2018). Recovery of a common bean landrace (*Phaseolus vulgaris* L.) for commercial purposes. *Frontiers of Plant Science*, 9, 1440. <https://doi.org/10.3389/fpls.2018.01440>
- Maxted, N., Magos, B.J., Kell, S. (2013). *Resource book for preparation of national conservation plans for crop wild relatives and landraces. Section B. Landraces*, pp. 263-423. University of Birmingham, United Kingdom.
- Mendeley Data published on 11.12.2025 (<http://datacite.org/schema/kernel-4>).
- Muasya, M.R., Lommen, M.J.W., Muui, W.C., Struik, C.P. (2008). How weather during development of common bean (*Phaseolus vulgaris* L.) affects the crop's maximum attainable seed quality. *NJAS-Wageningen Journal of Life Sciences*, 56(1/2), 85-100. <https://library.wur.nl/ojs/index.php/njas/article/view/1604>
- Oh, Se-Jong, S., Jae-Young, J.L., Gi-An, L., Ho-Cheol, K., Stoilova, T., Krasteva, L., Kim, Yeon-Gyu, Rhee Ju-Hee, Gwag, Ro Jae-Gyun, Hur Na-Young, Lee, On-Sook, Myung-Chul (2012). Evaluation of genetic diversity of red pepper landraces (*Capsicum annuum* L.) from Bulgaria using SSR markers. *Journal of the Korean Society of the International Agriculture*, 24(5), 547-556. <http://dx.doi.org/10.12719/KSIA.2012.24.5.547>

- Panayotov, N., Apostolova, E., Dimova, D., Svetleva, D. (2009). Inheritance of some common bean (*Phaseolus vulgaris* L.) traits in the cross A 195 x Kristal 137. *Acta Horticulturae*, 830, 221-228. <https://doi.org/10.17660/ActaHortic.2009.830.30>
- Raggi, L., Tiranti, B., Negri, V. (2013). Italian common bean landraces: Diversity and population structure. *Genetic Resources and Crop Evolution*, 60, 1515-1530. <https://doi.org/10.1007/s10722-012-9939-y>
- Reichert, M.J., Rodrigues, F.M., Awe, O.G., Riquelme, B.F.U., Kaiser, R.D., Reinert, J.D. (2015). Common bean in highly variable weather conditions, on sandy soils, and food security in a subtropical environment. *Food and Energy Security*, 4(3), 219-237. <https://doi.org/10.1002/fes3.65>
- Scarano, D., Rubio, F., Ruiz, J.J., Rao, R., Corrado, G. (2014). Morphological and genetic diversity among and within common bean (*Phaseolus vulgaris* L.) landraces from the Campania region (Southern Italy). *Scientia Horticulturae*, 180, 72-78. <https://doi.org/10.1016/j.scienta.2014.10.013>
- Shahid, A., Kamaluddin, C. (2013). Correlation and path analysis for agro - morphological traits in Rajmash bean under Baramulla-Kashmir. *African Journal of Agricultural Research*, 8(18), 2027-2032. <https://doi.org/10.5897/AJAR2012.0014>
- Stoilova, T. (2007). The collection of dry beans as initial material for breeding. In *Proceedings of International Scientific Conference - Plant Genetic Stocks - The Basis for Agriculture of today. 13-14 June 2007*, 1: 53-58. <https://ipgrbg.com/wp-content/uploads/2017/01/VsichkiStatii-Za-CD-ISBNNoF-NI.pdf>
- Stoilova, T., Berova, M., Kouzмова, K., Stamatov, S. (2014). Study on diversity of *Phaseolus* spp. landraces with reference to global climate change. *African Journal of Agricultural Research*, 9(39), 2925-2935. <https://doi.org/10.5897/AJAR2013.8135>
- Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, 58, 236-244.
- Yohannes, S., Loha, G., Kebede, M.G. (2020). Performance evaluation of common bean (*Phaseolus vulgaris* L.) genotypes for yield and related traits at areka, Southern Ethiopia. Hindawi, *Advances in Agriculture*, ID 1497530, pp. 8. <https://doi.org/10.1155/2020/1497530>