Studies of the genetic resources of common beans (Phaseolus vulgaris L.) in Armenia

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Abstract. The research was conducted at the experimental station of the Scientific Center of Vegetable and Technical Crops of RA from 2021 to 2023. Over 15 determinant and semi-determinant varieties belonging to the *Phaseolus vulgaris* species, including climbing, semi-climbing, and vegetable cultivars, were studied. Among them, eight samples (Contender, Blue Lake, Tendergreen, Dragon Tang, SP-1, FL-2, SM-3, and SH-5) exhibited the highest complex positive indicators. The local Masisi banjarayin variety served as the control. Most of the studied bean cultivars can serve as raw materials for creating new breeding varieties, enriching the existing genetic base, and promoting cultivation based on biological, phenological, and economic factors. Notably, the Contender and SM-3 cultivars stood out for their high yield of green beans, providing an 18.8–19.5% yield increase compared to the control variety.

1 Introduction

The common bean, also known by its scientific name, Phaseolus vulgaris, is a member of the Leguminosae family. Its roots trace back to Central and South America [1].

In the global area of legume crops, the common bean crop holds the second position after soybean. According to data from the Food and Agriculture Organization [2], the annual area under bean cultivation ranges from 25 to 26.7 million hectares. The largest cultivated areas for bean crops are in Brazil (4.7 million hectares), Mexico (1.9 million hectares), and the USA (695 thousand hectares). India and China are considered the largest grain and green bean producing countries [3-4].

Information about beans in Armenia has been documented since the 15th century. However, historical details regarding their appearance and distribution remain elusive [5-6].

Both globally and within the Republic of Armenia, common bean cultivation is on the rise [7].

Figure 1 shows the area of bean cultivation in the Republic of Armenia (measured in hectares) by region, for the year 2020. This upward trend can be attributed to the multifaceted socio-economic benefits of beans [8].

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Primarily, beans serve as an invaluable source of alternative proteins, microelements, anti-oxidants, and vitamins, contributing significantly to food security in the state [9-10].

Furthermore, beans are an essential crop, acting as a precursor and a means of enriching the soil with nitrogen naturally. For this reason, beans have been referred to as the "bean of hope" in world literature because they can alleviate global food shortages, thereby contributing to food security [11-12]. Considering the above, it becomes both necessary and interesting to study new bean genotypes, localize them, create new varieties, and grow these to enrich the existing base.

Fig. 1. The area of bean cultivation in the Republic of Armenia (ha) by regions, in 2020.

2 Materials and methods

Scientific research was conducted at the Darakert experimental station of the Scientific Center for Vegetable and Industrial Crops, under the Ministry of Economy of the Republic of Armenia, in open ground conditions from 2021 to 2023. The subject of the research was the common bean (Phaseolus vulgaris L.), a crop that is currently in high demand and widespread globally. More than 15 determinate and semi-determinate varieties of Phaseolus vulgaris were studied, including climbing, semi-climbing, and bush types. Among them, eight cultivars (Contender, Blue Lake, Tendergreen, Dragon Tang, SP-1, FL-2, SM-3, and Sh-5) (Figures 2-5) were selected based on their superior performance across multiple indicators. The local variety, Masisi banjarayin, served as the standard for comparison.

Fig. 2. Contender, Blue Lake, Tendergreen, Dragon Tang, SP-1, FL-2, SM-3, and Sh-5 common bean.

The experiments were conducted in three repetitions on experimental plots measuring 20 sq.m each. The planting pattern was 90+70/2x15cm. Seeds were sown by hand, 3-5 cm deep, during the first ten days of May, adhering to agrotechnical requirements. The orientation of the experimental plots was from north to south, and the preceding crop in the open ground was winter wheat. The variety testing was conducted in accordance with the methods of state variety testing for agricultural crops and international bean variety testing [13-14].

All agrotechnical activities, including care work, were conducted in accordance with the specific zone and characteristics of the crop. The results of agrochemical analysis of soil samples taken from the experimental plots served as the basis for determining the appropriate fertilizer doses. During the course of the scientific research, economic and biological studies were conducted on both local and imported varieties, as well as breeding lines. These studies included the examination of phenological phase transitions, duration of vegetation, stem shape, foliage, branching, yield, yield dynamics, shape of green pods, color, weight, and more. During scientific research, the following observations, calculations and analyzes were made:

- Morphological Characteristics: During the growing season, the morphological characteristics of plants were described. Each replicate included 10 plants from each sample. The plants were characterized by bush shape, degree of branching and foliage, flower color, pod color, length, width, shape, weight, seed content, height of the first pod, weight of 1000 seeds, color, shape, etc.

- Phenological Observations: The stages of plant growth and development were determined, including germination, germination-flowering, germination-technical ripening, flowering-technical ripening, and the dates of the first and last harvests.
- Crop Counts: Counts of green bean pods and bean crops were conducted by weighing the yield from each plot.
- Statistical Analysis: Yield data was subjected to statistical processing. Data were analyzed using two-way statistical analysis of variance (ANOVA, DMRT). Graphs were created in Excel [14].

3 Results and Discussion

The objective was to study and evaluate the biological and economic characteristics of both local and imported new bean varieties, with the aim of selecting the best ones for production investment and identifying varieties with valuable traits that could serve as breeding material. The growth and development of a plant proceed with the formation of new organs, which, during individual development, have different structures depending on their location on the plant, thereby determining biological characteristics .A number of biological features were identified in the studied bean varieties. The most pronounced differences include varying degrees of plant foliage, green bean pods, as well as grain size, shape, color, and flower coloration . The smallest biological variations were noted in the degree of stem branching, growth, the nature of the parchment layer, and seam. For cultivation in open ground, it is more advisable to introduce varieties with deterministic stem growth. These varieties, which have the shape of a gathering bush, occupy less space in the field, simplify inter-row maintenance work, and ultimately, make it easier to organize mechanization of work on large areas. The determinate and grape-shaped bush, as well as the height of the lower stem above the soil surface, are the main indicators of suitability for mechanized harvesting. The criteria used include determinant growth of the stem 45-55 cm high, the height of the lower stem 12-14 cm, and uniform ripening of the stems. Almost all the studied bush varieties met the above criteria and are suitable for mechanized harvesting. In our studies, the stems of determinate growth forms were predominantly medium-sized, measuring 45-65 cm in length. The varieties Contender and FL-2 stood out due to their comparatively high growth, with stem heights of 75 and 72 cm, respectively. The height of the lower green bean pods from the soil surface ranged from 11.3-14.4 cm, which is an acceptable indicator for the use of mechanized harvesting operations. Research has shown that most varieties have strong branching. Of the eight shrub forms studied, only two - Tendergreen and SH-5 - had weak branching. For determinate forms, a direct correlation was observed between the degree of branching and yield indicators. Varieties with weak branching had relatively low yields. According to the literature, there is also a direct correlation between the degree of foliage of bean plants and yield. The same pattern was observed in our studies. The denser the degree of foliage, the higher the plant productivity, and vice versa (Figure 3).

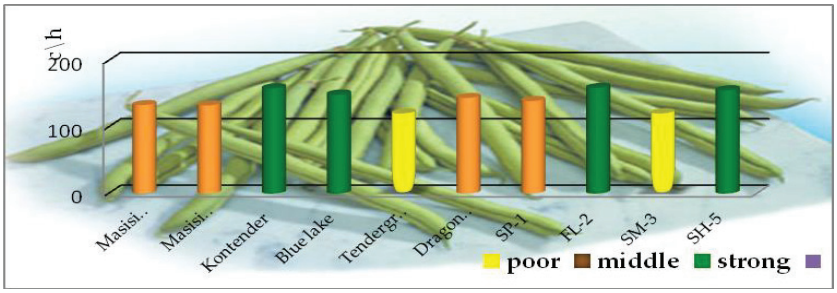

Fig. 3. Relationship between leafiness and yield (2021-2023).

In beans, there is a direct correlation between the color of the flowers and the color of the seed coat. The genes that determine seed color also simultaneously control the color of other organs. Plants with white flowers usually produce white seeds. The darker the seed color, the brighter the flower color. This is due to the pleiotropic effect of the dominant R and B1 genes.The bright red color of the flowers results from the interaction of four dominant genes - Am, Sal, Beg, and No - in the presence of the P and T genes. All these genes are recessive in Phaseolus vulgaris cultivars . During our studies, the absence of red flowers can be attributed to the recessive nature of these genes (Figure 4).

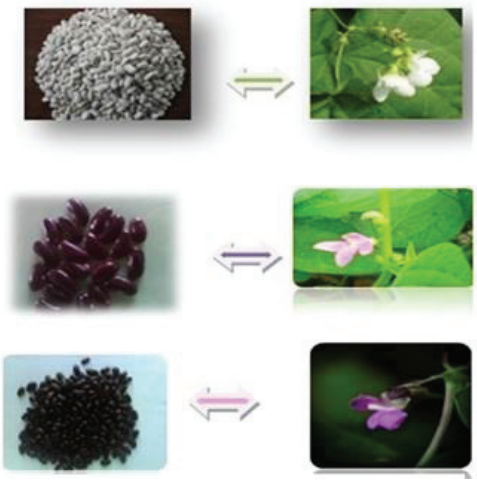

Fig. 4. The relationship between the color of flowers and seed coats of a beans plant.

Among the varieties we examined, pink and purple flowers were predominant. The color of the seed coat ranged from light brown to black. Bean seeds exhibited the greatest color diversity. Seed color is a varietal trait that significantly influences the timing of biological maturity and several morphological characteristics. In our research, seven varieties displayed dark-colored seeds: Masisi banjarayin St., Contender, Tendergreen, Dragon Tang, FL-2, SM-3, and Sh-5. On the other hand, two samples, namely Blue Lake and SP-1, had light-colored seeds.

According to several researchers, the shape of green bean pods determines their practical use. For instance, round green bean pods are more suitable for technological purposes, as they retain firmness during heat treatment. Conversely, flatter-shaped pods are better suited for fresh consumption, as they harden more slowly during technical maturation.

Among the researched cultivars, Contender, Blue Lake, SP-1, FL-2, and SH-5 exhibit a rounded shape, while the others have a flat shape. The rounded shape of the green bean pods is determined by the recessive genes ea, eb, ia, and ib, whereas the flat shape is influenced by the genes Ea, Eb, la, and Ib. Common bean green bean pods vary significantly in length and width. Studies have demonstrated that the length of the green bean pods is dominant over their shortness, and this inheritance pattern is polygenic. This phenomenon is controlled by the Te and te allele genes.

It is interesting that the length of green bean pods, which is a varietal characteristic, determines the commodity quality of the crop and the suitability for canning. In our studies, the length of green bean pods ranged from 10.2 to 11.9 centimeters. Based on the results we obtained, green bean pods can be conditionally divided into three groups:

- Short green bean pods, measuring up to 11 centimeters.
- Medium-length pods, ranging from 11 to 20 centimeters.
- Long pods, measuring 20 centimeters or more.

From our findings, it became clear that short and medium-length green bean pods were predominant in our studies. Additionally, the presence of a parchment layer on the pods and the nature of the seam are also important qualitative indicators. The seam's characteristics and the presence of a thread within it are determined by the st recessive gene. Poorly developed threads in the seams are barely noticeable, while medium development results in a fine thread that can be felt. Well-developed threads are typically found in green bean pod varieties intended for grain production. In contrast, in varieties with a sugar or vegetable orientation, these threads are either weakly expressed or absent not felt in the seams.

In varieties with a sugar or vegetable orientation, these traits are either weakly expressed or absent in the seams. However, in varieties intended for grain, they are quite developed and can disqualify the green stem. Heat is considered a crucial factor for the development of threads in the seams, as higher temperatures lead to rapid thread growth. Scientists have identified the Ts gene that regulates the growth of filaments in response to air temperature .

In all the studied cultivars, the nature of the seed coat did not undergo significant changes, as there were no substantial air temperature fluctuations during the study years. In our research, the parchment layer was weakly expressed in two cultivars: Tendergreen and SM-3 (Table 1).

For the proper selection of vegetable crop cultivation, in addition to the total harvest yield, the timing of the harvest is also crucial.

The short duration of vegetation and the possibility of early harvest are among the main problems in selection and horticulture. Studying the duration of the growing season of legumes allows for the introduction of varieties into corresponding zones. Additionally, understanding the duration of interphase transitions—such as seed mass, germination, germination-flowering, and flowering-technical ripeness—facilitates general adaptation and inclusion in breeding work. Based on the duration of green bean pod ripening, the studied cultivars were divided into three groups: early (up to 50 days), middle (51-60 days), and late (61 days or more).

The longer the period from sowing to germination, the greater the likelihood of plant disease and pest infestation. Several researchers agree with the statement and link the length of this stage mainly to ambient temperature and soil moisture . In the years under study, the mass germination of cultivars ranged from 5 to 10 days, primarily determined by the climatic conditions in different years. The study results indicated that this germination period was superior to the control by one day. According to the literature, the early maturity of leguminous crops is particularly influenced by the duration of the germination and flowering phase.

Table 1. The biomorphological characteristics of the researched common bean cultivars (average for 2021-2023).

Variety	Degree of branching	The leaves	Color of flowers	Lower green pods height, cm	characteristic of green bean pods					Seed characteristics		
					form/color	length, cm	width, mm	the parchment-layer	the nature of the stitch	color	Avg No of seeds in a green pod pcs	mass of 1000 seeds, g
Masisi banjarayin, st	strong	green, weakly plump, broad oval	light purple	11.3	flat, straight, pointed, green	11.4	9.5	is absent	soft, thread-less	black	6.3	400.1
Contender	strong	green, pointed, elongated rhomboidal	white yellow	14.4	Arcuat,round, green	11.4	9.0	is absent	with a soft, fine thread	Brown	6.1	401.3
Blue Lake	strong	dark green, weakly pubescent, narrowly ovate spike	white	13.8	round, cylindrical, green	11.6	7.8	is absent	soft, threadless	whitish-yellow	6.4	356.3
Tendergreen	weak	green, pointed, elongated rhomboidal	white-grey	12.5	straight, flat, pointed, dark green	10.4	9.1	weakly expressed	soft, loose thread	maroon with cream patterns	5.9	361.4
Dragon Tang	strong	broad round, green with faint anthocyanin hues	light purple	11.8	flat-yellow slightly curved, green with manu-shaka-color spots	11.9	9.4	is absent	soft, threadless	cream with purple spots	5.4	407.6
SP-1	strong	green, elongated rhomboidal	white	12.1	round, straight pointed, light yellow	10.4	6.2	is absent	with a soft, fine thread	white with brown eyes	5.8	396.3
FL-2	strong	green, pointed, elongated	light purple	13.1	roundish saucer-shaped, green	10.2	7.0	is absent	soft, thread-less	dark purple	6.4	402.5
SM-3	weak	green, pointed, elongated	white-grey	12.4	arcuate, round, green	10.3	7.1	weakly expressed	soft, loose thread	purple with white patterns	6.1	401.6
SH-5	weak	green, broadly oval	light yellowish brown	11.6	round, slightly arcuate, green	9.8	7.2	is absent	soft, thread-less	brownish	5.7	387.8

Observations in this direction documented that the duration of the germination-flowering phase for the investigated cultivars varied between 27 and 32 days for early-ripening varieties and 33 to 37 days for middle-ripening ones.

The duration of the budding-flowering phase was shortest in the Contender variety (27 days), which exceeded the control Masisi banjarayin variety (33 days) by six days. The longest period was recorded in the SP-1 variety (37 days), which was inferior to the above control, for four days. Among the studied shrub varieties, the shortest flowering and technical ripening period, compared to the control Masisi banjarayin (24 days), was observed in the Dragon Tan variety (21 days). Conversely, the SP-1 variety had the longest period (28 days), trailing the control by four days.

For green beans, the duration of the germination-technical ripening period is particularly important as it guarantees an early harvest. At this stage, the Contender variety stood out for its early maturity (50 days), surpassing the corresponding control variety by seven days and the SM-3 and SP-1 varieties exhibited late maturity (62 and 65 days, respectively), which were inferior to the control by five and eight days, respectively (Figure 5).

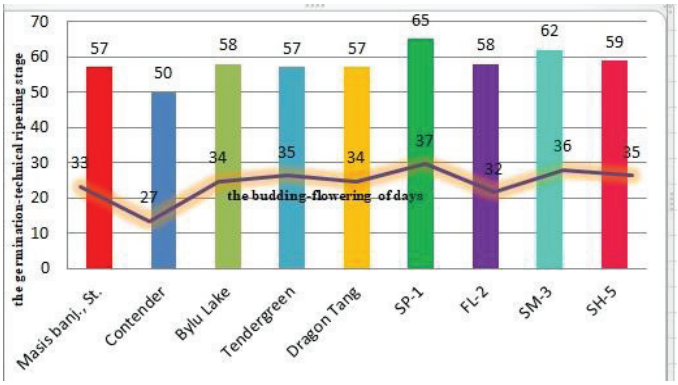

Fig. 5. The duration of the germination-technical ripening, and the budding- flowering stage of the studied bean varieties (2021-2023).

As for the Blue Lake, Tendergreen, Dragon Tang, and SM-3 bush forms, they were mid-adults when green bean pods matured at the same time as the control.

During the years of study under the conditions of open field cultivation, the researched varieties did not exhibit significant fluctuations in yield (Table 2).

Table 2. Yield indicators of studied varieties (average for 2021-2023).

Varieties	The yield of green beans, c/ha			The addition of the harvest		in total	Average, c/ha	Dispersion
	2021	2022	2023	c/ha	%			
Masisi banjarayin, st	132.0	132.8	133. 0	-	-	397.8	132.6	0.08
Contender	158.0	157.7	159.35	25.7	19. 3	475.05	158.35	0.845
Blue Lake	149.6	149.0	148.7	16.5	12. 4	447.3	149.1	0.32
Tendergreen	120.25	121.1	120.0	-12.2	-9.2	361.35	120.45	0.845
Dragon Tang	144.0	143.0	144.7	11. 3	8. 5	431.7	143.9	0.32
SP-1	138.85	139.6	139.0	6. 5	4.9	417.45	139.15	0.405
FL-2	158.95	157.9	160.0	26. 3	19.8	476.85	158.95	2.645
SM-3	120.75	121.0	119.6	-12.2	-9.2	361.35	120.45	1.445
SH-5	115.65	155.0	155.7	22.85	17.23	466.35	155.45	0.125
							LSD – 1.8	
							S_X%-0.4	

Two-way analysis of variance (ANOVA) was done using Duncan's Multiple Range Test (DMRT) (95% signifi cance level) to determine the main.

All varieties showed minor yield variations, primarily influenced by the climatic conditions of the given year. Among the studied cultivars, the bushy forms of foreign cultivars FL-2 (158,95), SH-5 (155.45), Contender (158.35), Blue Lake (149.1), Dragon Tang (143.9), and SP-1 (139.15 c/ha) stood out with high yield indicators, surpassing the control Masisi banjarayin variety by 26.3, 22.85,.7, 16.5, 11.3 and 6.5, respectively, in terms of green bean pod harvest. The highest yield was obtained from the FL-2, Contender and SH-5 cultivars, providing an 17.23-19.8% increase compared to the control.

4 Conclusion

From the research results, it was evident that all bean cultivars were suitable for mechanized work in open fields, based on biological studies. Considering the existing criteria for processing green bean pods, including high quality and taste indicators during

technical ripening, smooth appearance, round shape, light color, absence of a foil layer, and soft seam nature, as well as taste and preservation of quality after heat treatment, several varieties stood out. Among the varieties studied, the imported green bean pods of Blue Lake, Contender, Sp-1, FL-2, and Sh-5 were suitable for canning. Additionally, all samples could be used for fresh and frozen consumption. Notably, the Contender variety exhibited early maturity, while FL-2, Contender and SH-5 cultivars demonstrated high yield indicators, resulting in an 17.23-19.8% increase in yield compared to the control variety. To sum up, the bean cultivars examined in the Ararat Valley show promising biological, phenological, and economic traits. These cultivars could potentially be used as the foundation for developing new selection varieties, enhancing the current base, and promoting cultivation.

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