

Characterization and evaluation of common bean (*Phaseolus Vulgaris* L.) Accessions stored in the Albanian genetic bank

Valbona Hobdari¹, Sokrat Jani¹, Fetah Elezi²

¹Institute of Plant Genetic Resources, Agricultural University of Tirana, Tirana, Albania

²Lector, Agricultural University of Tirana, Tirana, Albania

vhobdari@ubt.edu.al; sokratjani@yahoo.com; elezi_fetah@yahoo.com

Abstract: Albanian farmers have and continue to cultivate farmer's bean cultivars because they are adapted to the country's conditions and to the cultivation practice of the farmer who uses low levels of chemical fertilizers in beans. But, in the current conditions, the landraces are at risk of genetic erosion due to socio-economic changes. Therefore, our concern and obligation is to preserve the common bean farmer's cultivars, not only to be cultivated but also to be used in genetic improvement programs. This was the aim of this study through which to know the genetic variation of the farmer's cultivars in order to increase the effectiveness of the genetic improvement programs of this plant of great value to the people. In the study, 40 accessions (farmer's cultivars) collected in the northeastern and eastern areas of Albania and stored in the Albanian Genetic Bank were taken.

Keywords: COMMON BEAN, LANDRACE, CHARACTERIZATION, EVALUATION, PHASEOLUS VULGARIS

1. Introduction

The common bean (*Phaseolus vulgaris* L.) is a diploid annual herbaceous plant ($2n = 2x = 22$) [1] with self-pollination of the Leguminosae (Fabaceae) family. It is the most important leguminous plant for human nutrition worldwide because it is a valuable source of high-quality proteins [7], carbohydrates [2], vitamins, minerals, fibers, plant nutrients (mainly phytosterols and flavonoids) and antioxidants [1,5,10]. Most of these constituents have significant positive effects on human health. Therefore, beans can be considered a potential functional food¹. It also plays an important role in sustainable agriculture due to its ability to fix atmospheric nitrogen, thus reducing the need to use nitrogen fertilizers [1].

The annual world production of common bean is over 27 million tons, cultivated on 29 million ha feeding more than 300 million people who are connected to the agricultural economy around the world [6,9,10]. Almost half of the world's dry bean production is provided by the American continent, where the main producers are Brazil, the USA, Mexico and Central American countries, while China, India and Myanmar are the main Asian producers [1]. As a potential healthy and inexpensive alternative to animal protein, common beans are also important for nutrition in developing countries in Africa. In Europe, cultivation is mainly concentrated in countries surrounding the Mediterranean basin, including the Iberian Peninsula, Italy, Greece and the Balkan regions. In Italy, the common bean is currently the most cultivated leguminous plant [1], with an annual dry bean production of about 12000 tons, in more than 6400 cultivated hectares (with a yield of about 1.87 tons/ha), although this production is not sufficient to meet the requirements of the country [1].

The common bean is cultivated all over the world for its dry grain as well as for its green pods [2,8]. The wild ancestor of *Phaseolus vulgaris* probably evolved in the Mesoamerican region, most likely in Mexico, although an Andean origin of the common bean cannot be excluded [1,3,7,10]. Based on archaeological data and morphological features as well as plant type, the common bean evolved from relatives of the wild bean, *Phaseolus vulgaris* var. *Mexicanus* [8]. Before domestication, wild bean forms widely spread from Northern Mexico to northwestern Argentina around 111000 years ago [1] in two main geographic gene pools, namely Mesoamerican and Andean¹. Both of these geographically isolated and genetically known wild gene pools (Andean and Mesoamerican) evolved from a common wild parent about 10000 years ago and, from these wild gene pools, nearly 8000 years ago, were domesticated independently in Mexico and South America [8], and today this agricultural crop is cultivated as a main food plant in many areas of America, Europe, Africa and Asia⁸. However, according to the hypothesis of a Mesoamerican origin of the common bean, recent findings indicate that both wild gene pools from South America originated from independent migrations of

Mesoamerican wild populations before the domestication of *Phaseolus vulgaris* [1]. Domestication from wild common beans took place separately in Mesoamerica and in the Andes of South America, leading to two main different gene pools within the cultivated forms. The existence of distinct domestication processes is well established, first by morphological and agronomic traits [1], by biochemical markers and, finally, by molecular markers covering wider genomic regions [1].

The stored protein in the bean kernel, *phaseolin*, helps identify common bean domestication patterns. The two main types of *phaseolin* found mainly in common beans are the "S" and "T" types, with Mesoamerican and Andean genotypes possessing the "S" and "T" types of *phaseolin*, respectively [8].

Variation between different populations belonging to the same genus was created by the evolution of cultivated plants in response to different environments [5]. Bean (*Phaseolus vulgaris* L.) is the most important leguminous plant of *Phaseolus* spp. in worldwide [2,5].

Ensuring the conservation of future resources is a major challenge for geneticists and plant breeders. Genetic seed banks aim to enable conservation of the world's plant genetic diversity against plant genetic erosion. Seed genetic banks are facilities for medium-term storage, i.e. for several decades of storage at 5–10°C, or for long-term storage, i.e. for many decades of storage at $-18 \pm 3^\circ\text{C}$, of samples of seed as a means of maintaining plant or species diversity. Genetic banks that store the seed of agricultural crops, i.e. accessions, are used as a source of genes that confer desirable characteristics [5].

The vegetative period of the common bean varies from 60 to 90 days for the determinate bush type of the plant, to 250–300 days for the indeterminate growth type of the plant. The pods can be harvested 25–30 days after flowering obtaining a yield of 5.0–7.5 tons/ha of green pods (Ecocrop, 2013; Wortmann, 2006). Beans grown for dry grain require 23–50 days after flowering to fill the grain. Average bean yield per dry grain is 0.5–1.5 tons/ha, but yields of 2.8–5.0 tons/ha have also been reported (Wortmann, 2006). A yield of 16.0 tons/ha of green biomass was reported (CNC, 2004) [3].

As a result of the domestication process, a large number of varieties have been obtained that show variation in qualitative morpho-agronomic traits, including grain size, grain quality and plant cycle, and this variation has been widely used in genetic improvement programs or studies of diversity [5]. The purple color of the seed has been found to be exclusively Andean, while the pink, brown and black color of the seed are mainly of Mesoamerican gene pool origin. Cream, yellow and red colored grains were found in both gene pool groups. Andean common beans tend to have higher grain iron concentrations and lower grain zinc concentrations than those of Mesoamerican origin and putative hybrids between gene pools [5].

In Albania, the majority of common bean production relies on local populations and varieties grown by smallholder farmers who use low-input production systems. The landraces are well adapted to the specific growing conditions and microclimatic agro-environments and show great morphological diversity of the seed.

Since the genetic diversity of valuable species is affected by anthropogenic factors, there is an urgent need for the conservation and use of local plant resources for the genetic improvement of plant species⁸. The United Nations announced 2010 as the "Year of Biodiversity" emphasizing the need to preserve and use biological diversity for the development of human society. Common bean landraces have gained greater importance in view of the deterioration of the biophysical resource base and the possible threats of climate change [8].

2. The purpose of the study

The purpose of the study was to know the morphological characteristics and the qualitative and quantitative features of the Albanian common bean accessions, which are stored in the Albanian Gene Bank.

3. Objectives of the study

The objective of the study was that, through the characterization and evaluation of the common bean accessions, represented by the farmer's cultivars, with the aim of evidencing their genetic variation for some of the traits and characteristics to make them more likely to be used in genetic improvement programs or other researchers.

4. Materials and methods

Materials used in the study

In the study, 40 accessions of the common bean (*Phaseolus vulgaris* L.) were obtained, which are farmer' cultivars, stored in the Albanian Genetic Bank, collected in the north-eastern and eastern areas of Albania, as follows: in the district of Shkodra 5 landraces, in the district of the Malësi e Madhe 5 landraces, in the Dibra district 5 landraces, in the Bulqiza district 2 landraces, in the Korça district 10 landraces, in the Përmet district 8 landraces and in the Erseka district 5 landraces (table no. 1).

The study was conducted in Rrile, Lezhë district (latitude: 41.735807N; longitude: 019.645346 E; altitude: 1 m). The field trial was conducted in 2022. The experimental design was a randomized complete block, with four replications. All bean accessions were planted on April 29, 2022. Each variety was planted in 3 rows of 5 m length and 60 cm row spacing; the seed was planted 8 cm apart in each replication. So each variant was represented with an area of 9 m². During the vegetation, all necessary agro technical services of the common bean culture were performed. Field observations were made for the condition of the field trial, and germination, flowering and ripening dates were recorded for each accession and, based on these data, the sowing-germination period, germination-flowering period, flowering-ripening period and germination-ripening period were calculated.

Qualitative characteristics: On the materials in the study, the following qualitative characteristics were obtained in order to characterize the bean accessions: plant growth type, leaf shape, and flower color, pod curvature, grain color and resistance to diseases.

Quantitative traits: In order to evaluate bean accessions, quantitative traits of 10 plants taken at random were measured, counted and recorded such as: length of pod, number of pods per plant, number of seeds per pod, number of seeds per plant, grain length, grain width, absolute weight (weight of 1000 grains) and grain weight per plant.

Vegetative data (qualitative traits) and quantitative indicators of the common bean accessions under study were evaluated and recorded according to the relevant descriptors [7].

Statistical analyses: The qualitative characteristics data were grouped according to the categories of relevant descriptors for each qualitative characteristic in order to evaluate their variation. The quantitative traits were subjected to analysis of variance, first to validate the accuracy of the experimental data of the quantitative

indicators and, then, to detect and estimate the genetic variation of those traits.

Table no. 1: Accession number, accession name and site of collection

| No. of accession | Accession name | Site of collection |
|------------------|-----------------------------|--------------------|
| AGB3015 | E Bardha e Thethit | Shkodër |
| AGB3018 | Fasule e Kalasë së Dodës | Dibër |
| AGB3019 | Fasule e Luznisë | Dibër |
| AGB3020 | Fasule e Drishtit | Shkodër |
| AGB3021 | Fasule e Voskopojës | Korçë |
| AGB3022 | Kokërrvogla e Peshkopisë | Dibër |
| AGB3023 | Fasule kokërrvogël | Malësi e Madhe |
| AGB3617 | Mashurkë Pikë e zezë | Përmet |
| AGB3622 | Fasule Korçe | Përmet |
| AGB3623 | Barbunjë laramane Pacomit | Përmet |
| AGB3624 | Fasulja e Fejzos | Përmet |
| AGB3626 | Aishe Kadëna | Përmet |
| AGB3641 | Mashurkë jeshile | Korçë |
| AGB3642 | Fasule e bardhë | Korçë |
| AGB3645 | Fasule e thatë kacavjerrëse | Korçë |
| AGB3646 | Mashurkë dhe e thatë | Korçë |
| AGB3647 | Mashurkë e verdhë | Korçë |
| AGB3648 | Mashurkë jeshile | Korçë |
| AGB3651 | Mashurkë e hershme | Ersekë |
| AGB3652 | Mashurkë e vonshme | Ersekë |
| AGB3654 | Fasule e zakonshme | Ersekë |
| AGB3655 | Mashurkë e verdhë | Ersekë |
| AGB3659 | Mashurkë jeshile | Ersekë |
| AGB3663 | Mashurkë jeshile | Korçë |
| AGB3664 | Mashurkë | Korçë |
| AGB3665 | Fasule e zakonshme | Korçë |
| AGB3667 | Barbunja Grosha mishi | Bulqizë |
| AGB3668 | Fasule e Gjoricës | Bulqizë |
| AGB3671 | Fasule e vogël e Luznisë | Dibër |
| AGB3673 | Mashurka e Gjoricës | Dibër |
| AGB3679 | Fasule e Koplikut | Malësi e Madhe |
| AGB3680 | Mashurkë e verdhë | Shkodër |
| AGB3681 | Fasule e zakonshme | Shkodër |
| AGB3682 | Fasule e zakonshme | Shkodër |
| AGB3683 | Fasule e zakonshme | Malësi e Madhe |
| AGB3684 | Mashurkë e gjatë | Malësi e Madhe |
| AGB3686 | Barbunjë e gjatë | Malësi e Madhe |
| AGB3801 | Mashurkë e shkurtër | Përmet |
| AGB3813 | Mashurkë e shkurtër ploçake | Përmet |
| AGB3817 | Mashurkë kacavjerrëse | Përmet |

5. Results and discussion

5.1 Analysis of characterization features (qualitative features)

Quality descriptors of common bean accessions include assessment of plant growth type, leaf shape, flower color, pod shape, seed coat darker colour, and disease susceptibility. The data of the characterization features, that is, of the morphological features, of the common bean accessions under study (table no. 2), show a wide variation for the type of plant growth, for the shape of the leaf, for the color of the flower, for the pod curvature, for disease susceptibility, etc.

5.2 Morphological characteristics of the plant

According to the data of the common bean plant growth type study (table no. 2, chart no. 1), the accessions in the study are represented by three classes: 23 accessions (57.5% of the total number) had the growth type of plant determinate bush (class 1), another 15 (37.5%) had the growth type of plant indeterminate with semi-climbing main stem and branches (class 4), while 2 accessions (5.0%) were presented with plants of indeterminate with moderate climbing ability and pods distributed evenly up the plant (class 5).

5.2.1 Leaf characteristics

For the leaf shape, the common bean accessions in the study were distributed in two classes where most of them, 22 accessions (55.0%) had quadrangular leaves (class 2) and another 18 accessions (45.0%) had triangular leaves (class 1).

Table no. 2: Summary analysis of quality traits of 40 bean accessions, year 2022

| No. | Traits | Descriptors | Number of accessions |
|-----|------------------------------|---|----------------------|
| 1. | Plant type | 1. Determinate bush | 23 |
| | | 4. indeterminate with semi-climbing main stem and branches | 15 |
| | | 5. indeterminate with moderate climbing ability and pos distributed evenly up the plant | 2 |
| 2. | Leaf shape | 1. Triangular | 18 |
| | | 2. Quadrangular | 22 |
| 3. | Colour of standard of flower | 1. Whight | 28 |
| | | 3. Lilac | 2 |
| | | 9. Purple | 10 |
| 4. | Pod curvature | 3.Straight | 4 |
| | | 5.Slightly curved | 7 |
| | | 7.Curved | 28 |
| | | 9.Recurving | 1 |
| 5. | Seed coat darker colour | 1. Black | 2 |
| | | 2.Brown, pale to dark | 3 |
| | | 4.Grey, brownish to greenish | 3 |
| | | 6.Pale-cream to buff | 14 |
| | | 7.Pure white | 18 |
| 6. | Disease susceptibility | 3.Low susceptibility | 19 |
| | | 5.Medium susceptibility | 20 |
| | | 7.High susceptibility | 1 |

5.2.2 Characteristics of fruiting bodies

For flower color, the variation extends into three categories: With white flowers, class 1, 28 accessions (70.0%) were found, with purple flowers (class 9) 10 accessions (25.0%) and 2 accessions (5,0 %) had lilac/rose colored flowers (class 3).

Even the degree of pod curvature was characterized by wide variation (table no. 2); accessions for this trait were grouped into four classes, of which 28 accessions (70.0 %) had curved pods (class 7), 7 accessions (17.5 %) had slightly curved pods (class 5), 4 accessions (10.0%) had straight pods (class 3) and only 1 accession (2.5%) with recurving pods (class 9).

The seed coat darker colour was characterized by wider variation; accessions for this trait were distributed in 5 classes, of

which 18 accessions (45.0 %) had pure white grain (class 7), 14 accessions (35.0 %) pale-cream to buff (class 6), 3 accessions (7.5 %) with brown, pale to dark color (class 2), 3 other accessions (7.5 %) with grey, brownish to greenish color (class 4) and 2 accessions (5.0 %) with black color (class 1).

For disease susceptibility, common bean accessions were distributed into three classes, of which 20 accessions (50.0 %) were medium susceptibility, another 19 accessions (47.5 %) appeared low susceptibility (resistant), and only 1 accession (2.5%) presented with high susceptibility.

5.2 Analysis of evaluation indicators (quantitative features)

For the assessment of common bean germplasm, the data of eight quantitative indicators were recorded and analyzed: pod length, number of pods per plant, number of seeds per pod, number of seeds per plant, seed length, seed width, seed weight and weight of seeds per plant (yield per plant).

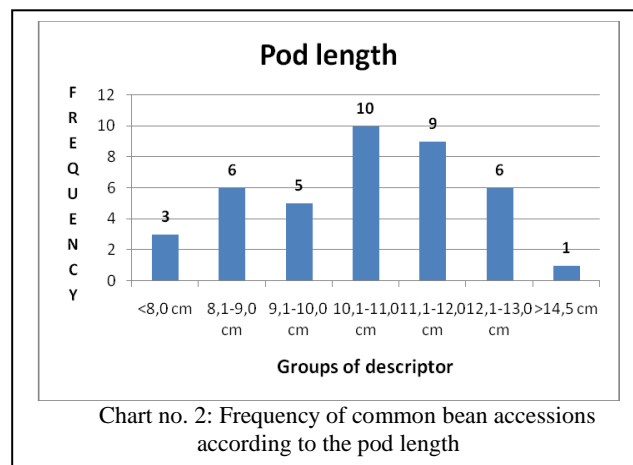
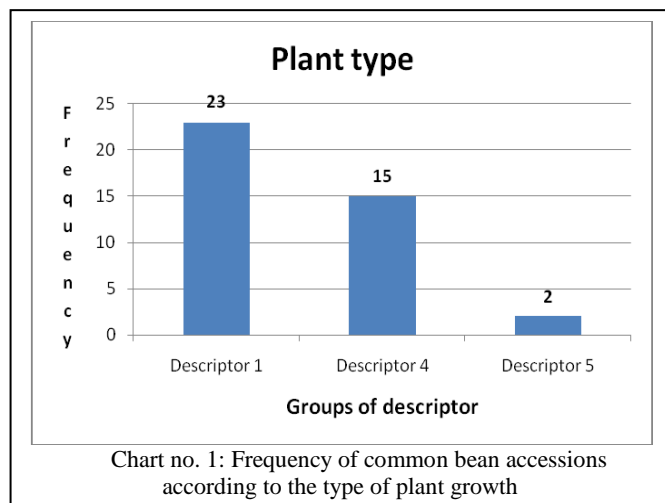
Initially, the analysis of variance was performed for the data of the eight quantitative descriptors, which showed that the genotypic differences were confirmed at the $P < 0.01$ level.

Based on the study data, all eight quantitative characteristics (descriptors) have expressed very good variation. Thus, for example, while the average value for the length of the pod for all 40 accessions in the study was 10.6 cm, its extreme values were 7.4 cm minimum length and 14.5 cm maximum value (table no. 3, chart no. 2). Accession AGB3641 was found with the minimum value, while accession AGB3667 was found with the longest pod. For the number of pods per plant, the average value was 9.7 pods/plant, while the smallest number was 4 pods (AGB3623, AGB3626, AGB3647, AGB3648 and AGB3667) and the largest number was 25.0 pods/plant (table no 3, chart No. 3).

The number of seeds in the pod also varied widely. For example, of 4.8 seeds/pod that was the mean value of all 40 accessions, the lowest number was 3.0 seeds/pod (AGB3019 and AGB3023) and the highest number was 16.0 seeds/pod (table no. 3, Chart no. 4). The number of seeds per plant (table no. 3, graph no. 5) had an average value of 46.3 seeds per plant, the smallest value was 14.8 seeds per plant (AGB3647) and the largest number was 166.0 seeds per plant (approximately 3.6 times the average number). Seed size data also show good variation for these descriptors. For example, the average seed length was 11.7 mm, while the smallest length was 6.0 mm (AGB3023) and the largest seed length was 17.4 mm (AGB3673). As for seed width, the average value was 6.3 mm, the smallest seed width was 4.1 mm (AGB3683) and the largest seed width was 8.4 mm (AGB3664).

The average of seed weight was 390.2 mg (table no. 4, graph no. 6), while the smallest weight was 160.0 mg (AGB3015) and the largest weight was 601.0 mg (AGB3019). So the smallest seed was in the accession (AGB3015), while the largest seed was the accession AGB3019.

Common bean accessions also expressed wide variation for the yield descriptor per plant. The average production per plant was 16.2 g per plant while the highest production was 48.8 g per plant



(AGB3673) which is three times higher than the average production; whereas the lowest production was 5.8 g per plant, or approximately 2.8 times lower than the average production (table no. 4, graph no. 7).

Table no. 3: Average statistical data for quantitative characteristics of common bean landraces

| No. | Descriptors | Descriptor data | | |
|-----|----------------------|-----------------|---------|---------|
| | | Minimum | Maximum | Average |
| 1 | Pod length (cm) | 7.4 | 14.5 | 10.6 |
| 2 | Pods per plant | 4.0 | 25.0 | 9.7 |
| 3 | Seeds per pod | 3.0 | 16.0 | 4.8 |
| 4 | Seeds per plant | 14.8 | 166.0 | 46.3 |
| 5 | Seed length (mm) | 6.0 | 17.4 | 11.7 |
| 6 | Seed width (mm) | 4.1 | 8.4 | 6.3 |
| 7 | Seed weight (mg) | 160.0 | 601.0 | 390.2 |
| 8 | Plant production (g) | 5.8 | 48.8 | 16.2 |

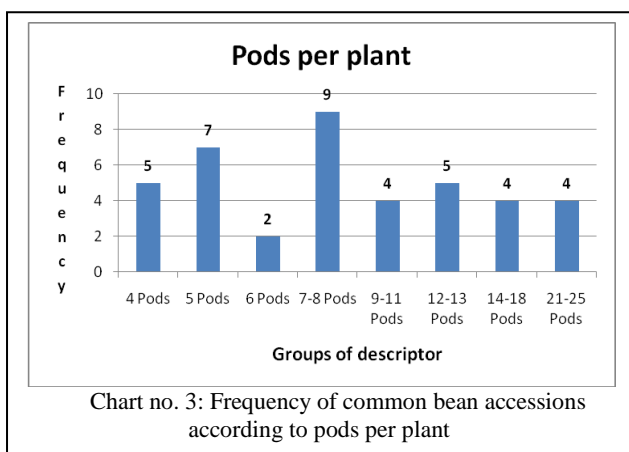


Chart no. 3: Frequency of common bean accessions according to pods per plant

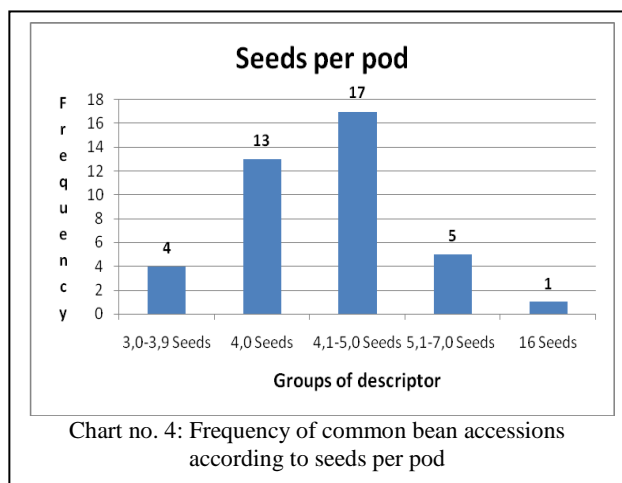


Chart no. 4: Frequency of common bean accessions according to seeds per pod

6. CONCLUSION

Based on the data of the study, as well as on their review and discussion, some conclusions emerge. Common bean germplasm (of farmer's cultivars), evaluated based on plant growth type, four morphological characteristics, plant disease resistance and eight quantitative traits, showed wide genotypic variation, as follows:

1. The germplasm of common bean, based on the type of plant growth, was represented by satisfactory variation where the determinate bush type prevailed (57.5%);
2. For the shape of the leaf, the germplasm variation was dominated by the quadrangular leaf (55.0%);
3. For the color of the flower, the farmer's cultivars were divided into three classes (descriptors), with a predominance of white colored flowers (70.0%);

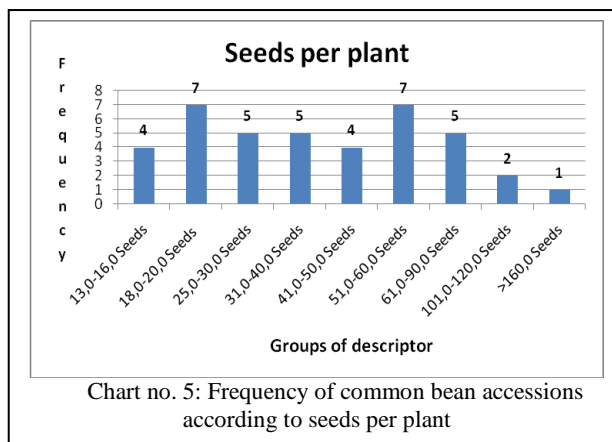


Chart no. 5: Frequency of common bean accessions according to seeds per plant

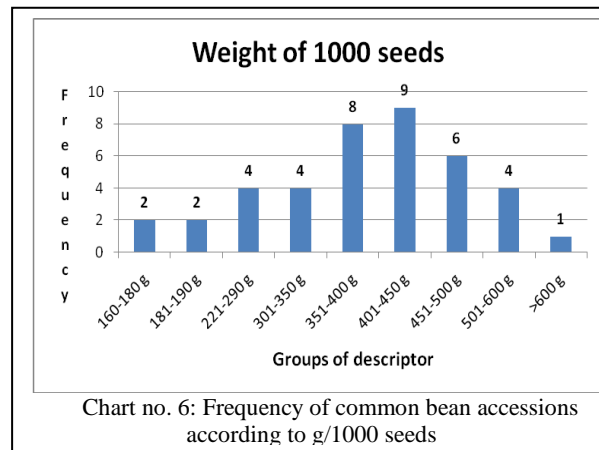


Chart no. 6: Frequency of common bean accessions according to g/1000 seeds

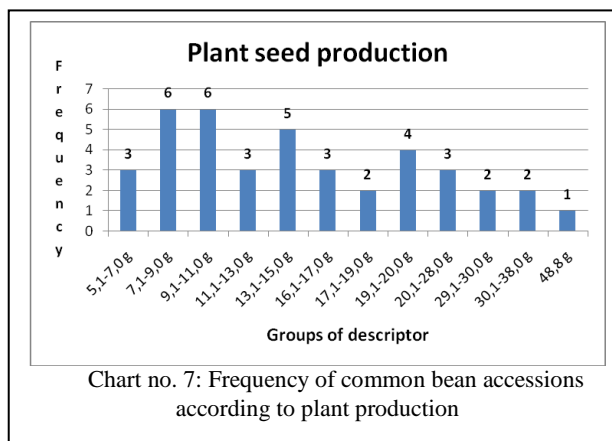


Chart no. 7: Frequency of common bean accessions according to plant production

4. Based on the pod curvature, all 40 bean accessions in the study were distributed in 4 descriptors, of which the curved pod prevailed (descriptor 7), with 70.0%;
5. According to the seed coat darker colour, the common bean accessions were distributed among 5 descriptors, predominantly the pure white color of the seed (describe 7), with 45%;
6. According to the assessment of the resistance of common bean plants to diseases, the accessions are distributed in three descriptors, with a predominance of two descriptors, medium susceptibility plants with 50.0% and low susceptibility plants with 47.5% of the accessions;
7. According to pod length, the common bean accessions were characterized by wide variation, with an average length of 10.6 cm, with the shortest pod 7.4 cm and the longest one 14.5 cm;
8. For the number of pods per plant, common bean accessions had an average number of 9.7 pods/plant, with a minimum number of 4.0 pods/plant and a maximum number of 25.0 pods/plant.

9. Regarding the number of seeds per pod, the variation of the germplasm was very wide, with the smallest number 3.0 seeds/pod and the largest number 16.0 seeds/pod;
10. Even the number of seeds per plant showed wide variation; with an average number of 46.3 seeds/plant, but with a minimum number of 14.8 seeds/plant and a maximum number of 166.0 seeds/plant;
11. The length and width seed showed wide variation, with the corresponding minimum and maximum values for seed length 6.0 and 17.4 mm, for seed width 4.1 and 8, 4 mm;
12. The grain weight had the smallest value 160.0 g and the largest weight 601.0 g/1000 seeds;
13. The production of plant was between 5.8 g seed/plant and 48.8 gseed/plant;
14. All these results are useful information for the genetic diversity of common bean in the Albanian Genetic Bank;
15. This diversity of characterization and evaluation of common bean accessions may also be important for use in bean genetic improvement programs.

7. REFERENCES

1. Catarcione Giulio, Rita Anna Paolacci, Alicandri Enrica, Gramiccia Elena, Taviani Paola, Rea Roberto, Costanza Maria Teresa, De Lorenzis Gabriella, Puccio Guglielmo, Francesco Mercati and Ciaffi Mario. (2023). Genetic Diversity and Population Structure of Common Bean (*Phaseolus vulgaris* L.) Landraces in the Lazio Region of Italy.
2. FAOSTAT (2015). Chapter 1. Common Bean (*Phaseolus vulgaris*). OECD Working Group for the Safety of Novel Foods and Feeds, with Brazil as the lead country.
3. Heuzé V., Tran G., Nozière P., Lebas F. (2015). Common bean (*Phaseolus vulgaris*). Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. <https://feedipedia.org/node/266> Last updated on October 20, 2015, 14:50.
4. International Board for Plant Genetic Resources (1982). Descriptors for *Phaseolus vulgaris*. IBPGR SECRETARIAT, Rome, 1982.
5. Lovro Sinkovič, Barbara Pipan, Eva Sinkovič, and Vladimir Meglič (2017). Morphological Seed Characterization of Common (*Phaseolus vulgaris* L.) and Runner (*Phaseolus coccineus* L.) Bean Germplasm: A Slovenian Gene Bank Example.
6. Nasar Sidra, Shaheen Hamayun, Murtaza Ghulam, Tinghong Tan, Arfan Muhammad and Idrees Muhammad (2023). Socioeconomic Evaluation of Common Bean (*Phaseolus vulgaris* L.) Cultivation in Providing Sustainable Livelihood to the Mountain Populations of Kashmir Himalayas.
7. Šajgalik Michal, Ondreičková Katarína, Hauptvogel Pavol, Mihálik Daniel, Glasa Miroslav and Ján Kraic (2019). Higher Effectiveness of New Common Bean (*Phaseolus vulgaris* L.) Germplasm Acquisition by Collecting Expeditions Associated with Molecular Analyses.
8. Sofora Jan, Irshad Ahmad Rather, Parvaze Ahmad Sofi, Mohd Altaf Wani, Farooq Ahmad Sheikh, Mohammad Ashraf Bhat, Reyazul Rouf Mir. (2021). Characterization of common bean (*Phaseolus vulgaris* L.) germplasm for morphological and seed nutrient traits from Western Himalayas.
9. Rivera Ana, Plans Marçal, Sabaté, Casañas Francesc, Casals Joan, Rull Aurora and Simó Joan (2018). The Spanish Core Collection of Common Beans (*Phaseolus vulgaris* L.): An Important Source of Variability for Breeding Chemical Composition.
10. Mark A. Uebersax, Karen A. Cichy, Francisco E. Gomez, Timothy G. Porch, Jim Heitholt, Juan M. Osorno, Kelvin Kamfwa, Sieglinde S. Snapp, Scott Bales (2022). Dry beans (*Phaseolus vulgaris* L.) as a vital component of sustainable agriculture and food security—A review.