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Evaluation of morphogenetic diversity for grain indices in some common bean population in Kosovo

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Abstract

Grain indices, such as size and shape, are very important parameters used in the morphogenetic characterization and evaluation of bean populations. For this purpose during the years 2016-2017 in the Experimental Didactic Farm of the Faculty of Agriculture and Veterinary in Prishtina, grain indices were analysed in 20 common bean populations, cultivars and lines. The investigated parameters were grain elongation in three orientations (Ew, Et, Ev), geometric mean diameter (Dg, mm), sphericity (φ, %), surface area (S, cm^2), geometric volume (V, cm^3) and grain density (Gd, g/cm^3). All parameters were analysed using geometric calculations and formulas based on average values obtained, respectively length, width, thickness, and replacement volume. The results of the study show that the higher average values of the geometric diameter of the grain had the FAGB194 population, which at the same time had higher grain mass, volume and surface area values. Whereas, regarding the sphericity, the highest values had the FAGB191 population, but associated with lower grain density values compared to other populations. Regarding the elongation in the vertical and the thickness orientation, the highest average values had the population Trenaria, while the lowest values were found in the population FAGB189. According to the physical traits of the grain, the studied populations were divided into two groups: the first group includes populations with elliptic shaped grain, while in the second group the populations were grouped kidney shaped grains, which correlate with sub-compressed and compressed grain forms. Since the grain morphological traits determined by genetic factors, the studied populations could be used in genetic improvement programs for the creation of ideotypes suitable for different environments and cultivation methods.

Keywords: Common bean, shape, sphericity, geometric diameter, ideotype.

1. Introduction

The common bean (Phaseolus vulgaris L.) is the most widely grown edible legume species in the world. In Kosovo, the common bean is cultivated in all regions on an average area 3 958.55 ha [1] and cultivation mainly based on seed landraces [2].

The visual appearance of agricultural products is the primary criterion and main information for consumer preference, which is characterized by the properties such as size, shape, color, form, absence of defects and abnormalities [3, 4, 5, 6, 7]. Among these properties, the size and shape of agricultural products are the most important quality and processing parameters [6, 7, 8, 9, 10]. Grain morphological traits have been useful for the analysis of taxonomic relationships in a wide variety of plant families and genus.

Quantitative evaluation of the shapes of different plant organs is often required in various research fields, such as agronomy, genetics, ecology, and taxonomy [11]. Grain morphology is useful in genotype discrimination [12] and the results are of signifcance in systematics. Measures of size and shape in grains, their correlation, and relationship are important in breeding for seed yield [13]. Knowledge of the relation between seed shape and agronomic characteristics may be useful to improve yield or quality [28].

Most of researchers used an image analysis system to measure the size, shape and other physical traits of different plant organs, such as seed, fruits, etc. [14, 15, 6, 9, 16, 17]. Therefore both seed shape and size are useful parameters to analyze biodiversity in plants.

Information on the size and shape features of bean cultivars such as their dimensions (length, width and thickness), projected area, mass, volume, elongation at different orientations and sphericity is considerably important in the seed technology process ing but also for bean cultivars calsification [18].

Therefore, the objective of the study was to determine morphogenetic diversity of 20 common bean population in Kosovo, based on the grain size and shape. An analyse using geometric calculations and formulas based on average values obtained from grain measurments, respectively length, width, thickness, and replacement volume, was used in order to determine the morpho-physical properties of bean.

2. Material and Methods

2.1. Research material

The research trial was set up during 2016-2017 at the Experimental Didactic Farm (EDF) of the Faculty of Agriculture and Veterinary in Pristina. As research materials were used 20 Common beans (Phaseolus vulgaris L.) populations, cultivars and line, collected in different regions of Kosovo and abroad and stored in the Gene Bank of Kosovo for Plant Resources in the form of seed accessions. The experimental design was randomized block with three replications. The measurements were carried out in the laboratory; where for each of repetition were taken three plants from which the grains of the 10 randomly chosen pods were taken, i.e. 100 grains per population. Grains were analyzed separately for morphometric parameters (dimensions), including measurement of length, width and thickness. Grain dimensions are measured using a nonius ruler, while the true volume was determined by replacement method in 96% ethanol using a graduated cylinder. Based on the values obtained from these measurements, the geometric methods and equations were used to determine the grain size and shape properties of the studied populations, including the elongation at the width orientation (Ew), elongation at the thickness orientation (Et) and elongation at the vertical orientation (Ev), geometric mean diameter (Dg, mm), sphericity (φ,%), geometric volume (Vg, cm^3), grain density (Gd, g/cm^3) and grain surface area (S, cm^2). Elongation at the three orientations was calculated using the following geometric equations, according to the method of [16]:

Elongation at the width orientation:

$$E_w = \frac{L}{W} \qquad (1)$$

Elongation at the thickness orientation:

$$E_T = \frac{L}{T} \qquad (2)$$

Elongation at the vertical orientation:

$$E_V = \frac{W}{T} \qquad (3)$$

Depending on the values obtained for these parameters, then the bean populations are classified according to [19]: ellipticus (ellipsoid) for the values of ratio L/W = 1.51 - 1.71), oblongus (long cylindroid, kidney shaped) when L/W = 1.85 - 2.31), subcompressus (sub-compressed and long when the value (W/T)×L = 1.29 - 2.08), and compressus (more compressed and broad, when the ratio (W/T)×L = 2.17 - 3.51). The mean geometric diameter (Dg, mm) and sphericality (φ,%) are calculated for each grain using the following equations according to [20]:

$$D_g = (L \cdot W \cdot T)^{1/3} \qquad (4)$$

$$\varphi = \left(\frac{D_g}{L}\right) \cdot 100 \qquad (5)$$

The surface area of the grain (S, mm2) was calculated from the below equation [21, 22]:

$$S = \pi \cdot D_g{}^2 \qquad (6)$$

Whereas, the calculation of the geometric volume and grain density is conducted according to the following equations:

$$V = \left(\frac{\pi}{6}\right) \cdot D_g{}^3 \qquad (7)$$

$$G_d = \left(\frac{G_m}{V}\right) \qquad (8)$$

where *Gm* is the grain mass, which is determined using an analytical electronic balance Denver with 0.01 mg resolution.

2.2. Statistical analysis

Statistical data analysis was carred out using the software JMP 13 and Microsoft Excel. The data were subject of ANOVA in order to analyse of variance and to determine signifcant differences at the level LSD0.05 and LSD0.01.

3. Results and Discussion

3.1. Grain mass

The mean values for grain size and grain density are shown in Table 1 and vary from 0.37 g to 1.66 g for a grain mass and 370 – 1656 g for 1000 grain mass, from which it can be concluded that the highest values for both of these parameters had the population FAG194 (1.66 g, respectively 1656 g), while the lowest values are found in population L232 (0.37 g, respectively 370.14 g). The differences between the studied populations for these parameters were highly significant (LSD0.01). Our research data is also higher compared to other authors. In a study conducted by [23] in seven bean cultivars, values of 1000 grains ranged between 209.1 and 467.6 g, while in another study by [16] also in seven bean cultivars was found 1000 grains mass values 171.7 to 613.2 g. The results of our study are also higher than the findings of [18], who found grain mass values from 0.180 to 0.656 g, respectively 180 to 656 g for the 1000 grains mass.

The population FAGB190 had the highest mean values for grain density (1.67 gcm^{-3}), while the population FAGB191 had the lowest (0.81g cm^{-3}) and difference between them were highly significant (LSD0.01). Approximately but lower values also were found by the authors [16], respectively 1.220g cm^{-3}, and 1.192-1.317gcm^{-3} [18] as well as 1.279 g cm^{-3} [24].

Table 1. Mean values and standard deviation for grain mass and density of common bean populations.

Population	*Grain mass (g)*	*Thousand grain mass (g)*	*Grain density (g cm^{-3})*
FAGB129	0.59±0.01	590.79±8.93	1.32±0.10
FAGB153	0.55±0.01	547.00±5.33	1.44±0.16
FAGB170	1.49±0.07	1490.62±67.78	1.02±0.06
FAGB187	0.75±0.05	754.35±57.78	1.67±0.22
FAGB189	0.69±0.03	692.98±26.55	1.09±0.10
FAGB190	0.71±0.09	714.21±89.17	1.67±0.44**
FAGB191	1.27±0.04	1268.08±39.26	0.81±0.08
FAGB194	1.66±0.06**	1656.18±59.11**	0.97±0.05
FAGB195	1.25±0.05	1249.83±48.12	0.93±0.04
FAGB202	0.62±0.01	615.85±7.08	1.36±0.09
FAGB204	0.64±0.03	639.15±34.28	1.32±0.18
FAGB205	0.63±0.05	634.05±47.53	1.37±0.18
FAGB206	0.67±0.06	672.43±55.90	1.32±0.17
FAGB208	0.67±0.05	669.39±49.89	1.22±0.12
Kallmet	0.51±0.02	507.95±17.81	1.23±0.07
Lapardha	0.56±0.02	558.84±17.97	1.32±0.14
L 232	0.37±0.09	370.14±90.54	1.18±0.35
L 13-2	0.46±0.03	463.91±25.47	1.34±0.33
Trenaria	0.76±0.06	763.54±60.64	1.47±0.11
Peja	0.59±0.03	591.90±29.30	1.31±0.08
LSD0.05	0.0775	77.5	0.3049
LSD0.01	0.102	102	0.4014

3.2. Grain volume

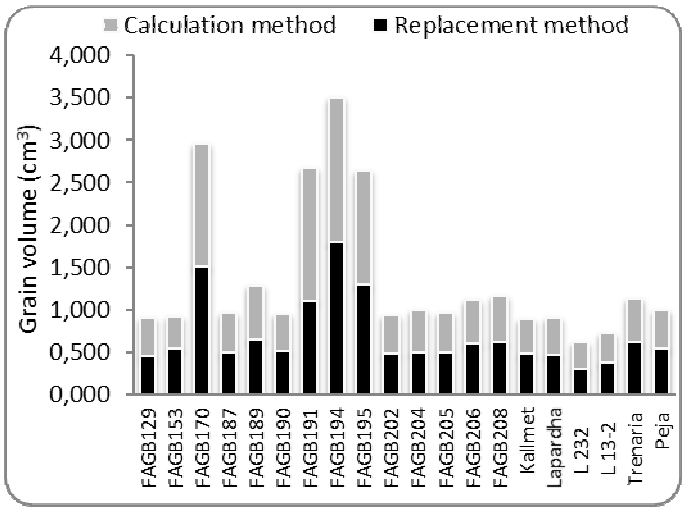
Regarding the results for the grain volume, the higher mean values were found in the population FAGB194 (1.803 for true volume, respectively 1.700 cm3 for geometric volume) as for replacement method also for the

calculation method (geometric equation), although the differences in accuracy of the methods were about 10%. Meanwhile, the lowest mean value for grain volume had the population L232 (0.300 and 0.317 cm3 respectively) with negative trend of calculation method up to -1.68% (Table 2). These values are consistent with the findings of the authors who found seed volume values between 0.531 cm3 and 0.137 cm3 with a precision difference of the method from 0.7% to 7.2% [18].

As seen in Fig. 1, in some of the bean populations there is a large difference in percentage between the replacement and the calculation method. This may possibly be related to the shape and other physical characteristics of the grain.

Table 2. Mean values and standard deviation, as well as the differences in accuracy of methods for grain volume of common bean populations.

Population	*Replacement method (cm^3)*	*Calculation method (cm^3)*	*Difference*
FAGB129	0.453±0.015	0.449±0.038	0.467447
FAGB153	0.540±0.010	0.383±0.036	15.68247
FAGB170	1.503±0.015	1.461±0.018	4.252122
FAGB187	0.503±0.006	0.456±0.030	4.77003
FAGB189	0.650±0.020	0.637±0.038	1.335975
FAGB190	0.507±0.012	0.439±0.076	6.727829
FAGB191	1.100±0.030	1.567±0.138	-46.7371
FAGB194	1.803±0.015**	1.700±0.034**	10.33272
FAGB195	1.300±0.030	1.344±0.014	-4.36204
FAGB202	0.487±0.035	0.455±0.026	3.188117
FAGB204	0.500±0.010	0.493±0.080	0.727262
FAGB205	0.503±0.015	0.469±0.081	3.440194
FAGB206	0.600±0.020	0.515±0.086	8.505318
FAGB208	0.613±0.021	0.553±0.047	6.079701
Kallmet	0.477±0.015	0.415±0.015	6.159771
Lapardha	0.473±0.006	0.427±0.032	4.638043
L 232	0.300±0.020	0.317±0.027	-1.68645
L 13-2	0.370±0.020	0.356±0.071	1.371757
Trenaria	0.617±0.035	0.520±0.054	9.707657
Peja	0.543±0.042	0.454±0.032	8.954704
LSD0.05	0.0353	0.098	
LSD0.01	0.0465	0.129	



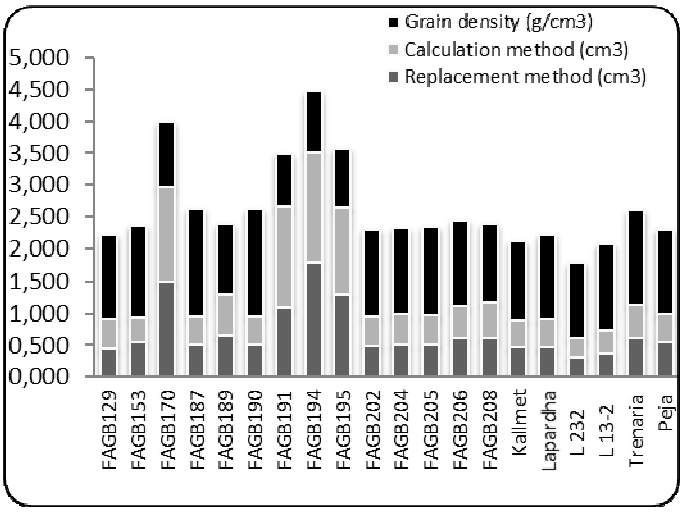


Figure 1. Differences in grain volume based on the method of measurement.

Figure 2. Graph of the ratio between grain volume and grain density of common beans populations.

3.3. Grain dimensions and clasification

The mean values for the length, width and grain thickness of the common beans populations are shown in Table 3. The minimum and maximum values vary from 12.73 and 22.93 mm for length, 7.83 and 14.57 mm for width as well as 5.07 and 9.80 mm thickness. The highest grain length values were found in the population FAGB170 (22.93 mm), while the lowest in the population L232 (12.73 mm). Meanwhile, the highest mean values for grain width had the population FAGB194 (14.57 mm), while the lowest the population L232 (7.83 mm). In terms of grain thickness, the highest values were found in the population FAGB191 (9.80 mm), while the lowest values were at the population Trenaria (5.07 mm).

Our results regarding the grain dimensions values are consistent and in some cases are even higher than the findings of some other authors who found different values of grain size from 7.8 to 22.6 mm in length, 4.9 to 11.8 mm for width and 2.3 to 7.7 mm of thickness [18]. Other authors [23] reported mean grain length between 8.6 and 15.0 mm, while [25] up to 16.68 mm.

Based on the data presented in Table 3, bean populations are classified according to their size and shape [19]. As seen from the table, one bean population (FAGB129) was of the compressus type, one was oblongus (FAGB187), while others were combined types oblongus-compressus, ellipticus-compressus and ellipticus-subcompresus.

Table 3. Mean values and standard deviation for grain dimensions, as well as the classification of bean populations based on the values of ratios for different grain dimensions.

Population	*Length (mm)*	*Width (mm)*	*Thickness (mm)*	*(W/T)xL*	*L/W*	*Classification*
FAGB129	15.86±0.76	9.17±0.35	5.90±0.52	2.48	1.73	C
FAGB153	16.00±0.70	8.37±0.60	5.47±0.25	2.46	1.92	O/C
FAGB170	22.93±0.78**	14.27±0.06	8.53±0.29	3.84	1.61	E/C
FAGB187	16.63±0.40	8.17±0.15	6.40±0.17	2.12	2.04	O
FAGB189	16.00±0.00	9.53±0.29	7.97±0.25	1.91	1.68	E/C
FAGB190	16.57±1.21	8.53±0.40	5.90±0.35	2.4	1.94	O/C
FAGB191	21.43±0.51	14.23±0.81	9.80±0.17**	3.11	1.51	E/C
FAGB194	22.83±0.65	14.57±0.32**	9.77±0.25	3.41	1.57	E/C
FAGB195	21.03±0.25	13.17±0.15	9.27±0.06	2.99	1.6	E/C
FAGB202	17.53±0.40	9.40±0.26	5.27±0.06	3.13	1.87	O/C
FAGB204	17.63±1.10	9.37±0.60	5.67±0.35	2.92	1.88	O/C
FAGB205	16.77±1.34	9.00±0.30	5.90±0.35	2.56	1.86	O/C
FAGB206	19.00±0.30	9.67±0.42	5.33±0.65	3.47	1.97	O/C
FAGB208	19.40±0.61	10.07±0.12	5.40±0.36	3.62	1.93	O/C
Kallmet	16.23±0.55	8.23±0.25	5.93±0.12	2.25	1.97	O/C
Lapardha	16.10±0.53	7.87±0.12	6.43±0.32	1.97	2.05	O/SC
L 232	**12.73±0.50**	**7.83±0.29**	6.07±0.40	1.65	1.63	E/SC
L 13-2	13.47±1.10	8.17±0.42	6.13±0.51	1.8	1.65	E/SC
Trenaria	18.87±0.31	10.37±0.84	**5.07±0.06**	3.86	1.83	O/C
Peja	17.47±0.47	9.53±0.21	5.20±0.17	3.2	1.83	O/C
LSD 0.05	1.1416	0.6798	0.5271			
LSD 0.01	1.5027	0.8948	0.6939			

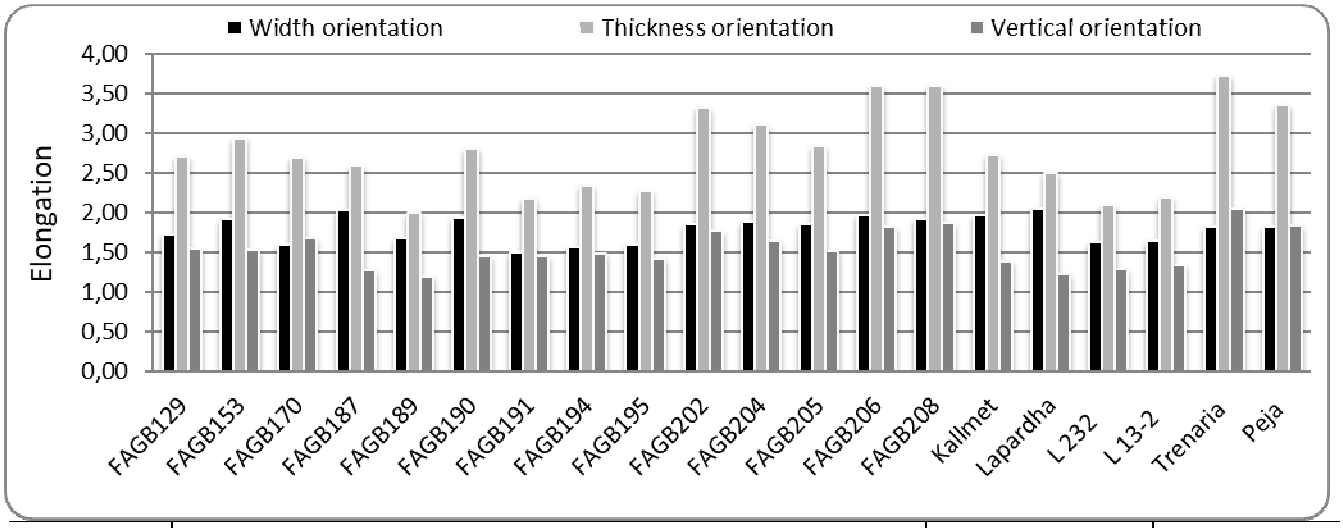
*C – compressus; O – oblongus; O/C – oblongus/compresus; E-ellipticus; E/C - ellipticus/compresus; SC - subcompresus.

As the physical grain properties, the geometric mean diameter and the grain surface area are the function of the length, width and grain thickness values, while the sphericity is defined as the ratio of the geometric mean diameter and the length of the grain [20]. Among the common bean populations the largest geometric mean diameter had FAGB194 (14.81 mm), which at the same time had a larger grain surface area (3.68 cm^2). The highest values of grain sphericity had the population FAGB191 (67.2%), while the population FAGB206 had the lowest values (52.21%). Meanwhile, in terms of shape factors, respectively width and thickness orientation, the bean populations of Lapardha and Trenaria among others had higher values (2.05 and 3.72 respectively).

Our findings regarding the geometric mean diameter, grain surface area and sphericity are consistent to the data of [18] who found a range of values from 8.1-9.8 mm for geometric mean diameter; 0.206 - 0.301 cm^2 for surface area and 58.9 -70% for sphericity. Whereas the values for shape factors in our study were higher. Our results are also consistent with the findings of [26] which found values of average arithmetic diameter of 7.30 - 10 mm, grain surface are from 1.53 to 3.47cm^2 and sphericity of 45-67%, while shape factors had lower values (0.82 - 1.015). The sphericity and aspect ratio of more than 70 per cent implied that grain was more as spherical and tend to rather roll than slide [27].

Table 3. Mean values and standard deviation for the grain geometric mean diameter, surface area and sphericity. as well as shape factors.

Population	*Geometric mean diameter (mm)*	*Surface area (cm^2)*	*Sphericity (%)*	*Shape factor*	
				Width orientation	Thickness orientation
FAGB129	9.49±0.27	0.258±0.04	59.96±4.23	1.73±0.14	2.71±0.38
FAGB153	9.01±0.29	0.188±0.03	56.3±0.72	1.92±0.07	2.93±0.21
FAGB170	14.08±0.06	2.717±0.07	61.43±1.99	1.61±0.05	2.69±0.18
FAGB187	9.54±0.21	0.265±0.03	57.38±0.46	2.04±0.03	2.6±0.03
FAGB189	10.67±0.22	0.517±0.06	66.69±1.35	1.68±0.05	2.01±0.06
FAGB190	9.41±0.54	0.251±0.09	56.87±1.68	1.94±0.09	2.81±0.12
FAGB191	14.40±0.43	3.144±0.55	67.2±0.80**	1.51±0.07	2.19±0.02
FAGB194	14.81±0.10**	3.681±0.15**	64.89±2.24	1.57±0.08	2.34±0.13
FAGB195	13.69±0.05	2.299±0.05	65.1±0.86	1.6±0.04	2.27±0.04
FAGB202	9.54±0.18	0.264±0.03	54.41±0.36	1.87±0.01	3.33±0.07
FAGB204	9.78±0.55	0.315±0.10	55.48±0.82	1.88±0.02	3.11±0.17
FAGB205	9.62±0.54	0.286±0.10	57.44±1.32	1.86±0.09	2.84±0.07
FAGB206	9.92±0.56	0.344±0.11	52.21±2.17	1.97±0.07	3.59±0.38
FAGB208	10.18±0.3	0.391±0.07	52.45±0.27	1.93±0.08	3.6±0.13
Kallmet	9.25±0.11	0.22±0.02	57.04±1.33	1.97±0.11	2.74±0.06
Lapardha	9.34±0.24	0.233±0.04	58.01±0.57	2.05±0.06**	2.5±0.08
L 232	8.45±0.25	0.129±0.02	66.46±3.35	1.63±0.12	2.11±0.18
L 13-2	8.77±0.60	0.166±0.06	65.17±1.66	1.65±0.06	2.2±0.12
Trenaria	9.97±0.35	0.346±0.07	52.82±1.25	1.83±0.13	3.72±0.04**



Peja	9.53±0.23	0.263±0.04	54.57±0.30	1.83±0.05	3.36±0.03
LSD0.05	0.5653	0.3568	2.9718	0.1244	0.2652
LSD0.01	0.7441	0.4696	3.9119	0.1638	0.3491

Figure 3. Elongation values determined in three orientation (length, width and thickness).

4. Conclusions

Based on the results of this study could be drawn the following conclusions:

- The common bean population FAGB194 had the highest mean values for some geometric and gravimetric traits such as grain mass, volume, surface area and geometric mean diameter.
- FAGB190 had the highest grain density values, while the lowest had the population FAGB191, despite the larger enough of grain mass.
- The highest mean value for grain length had FAGB170, while the highest grain thickness values were found in the FAGB194 population. Whereas, the lowest values for both grain length and grain width were found in the L232.
- The largest grain thickness had the populations FAGB191, while population Trenari had the lowest one.
- The highest mean values of sphericity had the FAGB191 and lowest the population FAGB206.
- Based on the ratio of the dimensions: length/width and width/thickness, among the 20 studied bean populations, one population (FAGB129) had compressed grains (compressus), one had elongated (oblongus), six populations (FAGB189, FAGB191, FAGB194, FAGB195, L232, L13-2) were elliptic (elipticus) but of width orientation compressus or subcompressus, and nine populations (FAGB190, FAGB202, FAGB204, FAGB205, FAGB206, FAGB208, Lapardha, Trenaria and Peja) were oblongus type with compressus width orientation.

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