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BIOMETRICAL ANALYSIS OF FIVE CHICKPEA (*CICER ARIETINUM* L.) CULTIVARS

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ABSTRACT

Chickpea (Cicer arietinum L.) cultivars can differ substantially in seed biometric and physical characteristics, which are relevant to cultivar characterization and may influence seed processing and utilization. This study aimed to characterize and compare five Kabuli chickpea cultivars (Alamo, Flamenco, Maragià, Reale, and Sultano) grown under the same field conditions in Constanța County, Romania. Seeds were evaluated for diameter, estimated volume, thousand-seed weight (TSW), density, water imbibition, seed coat proportion, and seed coat color using digital RGB analysis. Significant cultivar-dependent differences were observed for several seed traits. TSW ranged from 264 g in Sultano to 418 g in Alamo, with Alamo, Maragià, and Reale showing the highest values. Water imbibition ranged from 111 to 124%, while seed coat proportion varied from 6.43 % in Flamenco to 11.33 % in Sultano. Alamo, Maragià, and Reale also showed the largest mean seed diameters, whereas Sultano had the smallest seeds and the highest mean seed tissue density. Seed coat coloration was generally similar among cultivars, although Sultano showed a distinctive RGB profile with a higher contribution of the red component. Overall, the results demonstrate substantial cultivar-dependent variability in seed biometric and physical characteristics among Kabuli chickpeas grown under the same environmental and management conditions. The combined assessment of seed weight, dimensions, hydration behavior, seed coat proportion, and color provides a practical basis for cultivar characterization and contributes to the evaluation of chickpea germplasm cultivated under local conditions.

INTRODUCTION

Legumes (*Fabaceae*) are among the most important crop plants worldwide, being used for human food and animal feed and contributing to sustainable cropping systems through biological nitrogen fixation. Among grain legumes, chickpea (*Cicer arietinum* L.) is widely cultivated across temperate, Mediterranean, semi-arid and tropical regions. Although Europe accounts for a relatively small proportion of global chickpea production, interest in this crop has increased in recent years, particularly because of its suitability for cultivation under water-limited conditions (Ciontu et al. 2024; Dimitrova et al. 2026). In Romania, chickpea cultivation has also attracted increasing interest, with the cultivated area expanding during recent years (Pânzaru et al. 2022; Ciontu et al. 2024).

Chickpea exhibits considerable genetic and phenotypic diversity, which is reflected in agronomic performance as well as in seed morphological, physical and

compositional characteristics. Genetic diversity within *C. arietinum* provides substantial variation that can be exploited for cultivar selection and breeding, particularly for adaptation to different environmental conditions and end uses (Shahnaz et al. 2025). Recent evaluations conducted under European growing conditions have also demonstrated significant variability among chickpea varieties in agronomic and seed-related characteristics, highlighting the importance of cultivar selection under specific environmental conditions (Georgieva et al. 2026). Under Romanian conditions, genotype and crop management factors such as sowing time have also been reported to influence chickpea performance (Barcan et al. 2024).

Seed characteristics represent an important component of chickpea cultivar differentiation and quality assessment. Previous studies have reported substantial variation among chickpea genotypes in seed size, weight, seed coat characteristics, hydration behavior and other physical properties (Upadhyaya et al. 2006; Sastry et al. 2014; Sarika et al. 2019). These characteristics are relevant not only for cultivar characterization but also for processing and end-use quality. Seed dimensions, seed coat properties and water absorption behavior can influence hydration and processing performance, as demonstrated in comparative evaluations of chickpea cultivars (He et al. 2019). Moreover, differences between Kabuli and Desi chickpeas extend beyond external seed characteristics to their chemical and nutritional composition (Xiao et al. 2023), while recent comparisons between improved and local cultivars have further demonstrated cultivar-dependent variation in nutritional characteristics (Mathew et al. 2024).

Seed traits are predominantly controlled by genetic factors, but their expression can also be influenced by growing conditions and crop management (Gan et al. 2003; Bhuker et al. 2023). Consequently, the characterization of commercial cultivars grown under the same environmental and agronomic conditions can provide useful information on their phenotypic variability and seed quality. Despite the increasing interest in chickpea cultivation in Romania, comparative information regarding the biometric and physical characteristics of seeds produced by different commercial cultivars under local growing conditions remains limited.

Therefore, the aim of this study was to compare five chickpea cultivars grown under the same field conditions in Constanța County based on seed biometric and physical characteristics, including seed diameter and volume, thousand seed weight, density, water imbibition, seed coat proportion and color. The study specifically aimed to identify cultivar-dependent differences in these traits and to provide comparative information for the characterization of chickpea cultivars grown under local environmental conditions. By integrating morphological, gravimetric, hydration, seed coat, and color characteristics, this study provides a multidimensional characterization of chickpea seeds and generates locally relevant information that may support cultivar evaluation and the selection of plant material for further agronomic and processing studies.

MATERIAL AND METHODS

The five cultivars were Alamo, Flamenco, Maragià, Reale and Sultano (Figure 1).

Alamo belongs to the Kabuli type, which is generally characterized by relatively large seeds with a light cream to beige seed coat and is predominantly cultivated in Mediterranean and temperate regions. Alamo has an early to medium

growth cycle and seeds characterized by a beige, wrinkled testa (Martoccia et al. 2025; Dimitrova et al. 2026). Flamenco is an early Kabuli cultivar, first registered in France in 1991, with a wrinkled seed coat (Bomers et al. 2025; Martoccia et al. 2025). Maragià is an Italian Kabuli cultivar developed in 2016 (Bomers et al. 2025). Reale is an Italian Kabuli cultivar registered in 2002 (Bomers et al. 2025). Sultano is an early-medium Kabuli cultivar characterized by a smooth beige seed coat. It was registered in Italy in 1990, where it is widely cultivated. It has small- to medium-sized seeds, shows drought tolerance, and is suitable for flour production (Cappelli et al. 2023; Bomers et al. 2025; Martoccia et al. 2025).



Figure 1. The five studied chickpea cultivars..

Chickpea seeds were collected from a field experiment conducted under farm conditions in Mereni, Constanța County, Romania, during the 2024–2025 agricultural year. The crop was established under minimum tillage conditions following winter wheat as the preceding crop, which had received organic manure at a rate of 30 t ha^{-1}.

All five cultivars were grown under identical agronomic conditions. Sowing was performed on 6 April 2025 at a depth of 6 cm, with a target density of 60 germinable seeds m^{-2}, corresponding to a seeding rate of 160 kg ha^{-1}, and a row spacing of 45 cm. Seedling emergence was slightly delayed by late spring frost events.

Climatic conditions during the March–July 2025 growing period were characterized by marked thermal variability and low and unevenly distributed precipitation. During the chickpea growing season, the absolute minimum temperature was −11.9 °C, while the absolute maximum reached 40.1 °C. Limited and unevenly distributed precipitation resulted in moderate drought conditions during the growing season.

For each cultivar, 100 seeds were analyzed for the biometric determinations. To obtain a representative sample, seeds were collected from multiple sampling

points within the cultivated area of each cultivar and subsequently pooled for analysis. Seeds were digitally photographed, and seed diameter was measured from the images using ImageJ software. Seed volume was subsequently estimated from the measured dimensions by approximating seed shape as spherical/ovoid.

Seed mass was determined using an electronic balance and expressed as thousand-seed weight (TSW). Seed density was calculated as the ratio between seed mass and estimated volume. To determine water imbibition, seeds were soaked for 48 h and subsequently reweighed, with water uptake expressed as the percentage increase relative to the initial dry seed mass. The seed coats (testae) were separated and weighed, and their proportion was expressed as a percentage of total dry seed mass.

Seed coat color was evaluated using digital image-based RGB color analysis. Digital photographs of the seeds were processed using Trigit software, and the visible seed coat area was selected as the region of interest. Color information was quantified according to the red (R), green (G), and blue (B) channels, and the relative contribution of each channel was expressed as a percentage of the total RGB signal. This analysis was performed to objectively characterize seed coat color and to identify potential cultivar-dependent differences in testa coloration among the five chickpea cultivars.

RESULTS AND DISCUSSIONS

The main parameters are shown in Figure 2: thousand-seed weight (TSW), water imbibition, and seed coat proportion. Thousand-seed weight varied from 264 g in Sultano to 418 g in Alamo, with statistically significant differences among the five cultivars ($F > 1{,}268$, $p < 0.001$). Based on the observed TSW values, Alamo, Maragià, and Reale showed similarly high seed weights, exceeding 413 g, whereas Flamenco and Sultano had considerably lower values, below 284 g. These differences reflect the marked cultivar-dependent variation in seed weight observed under the same growing conditions.

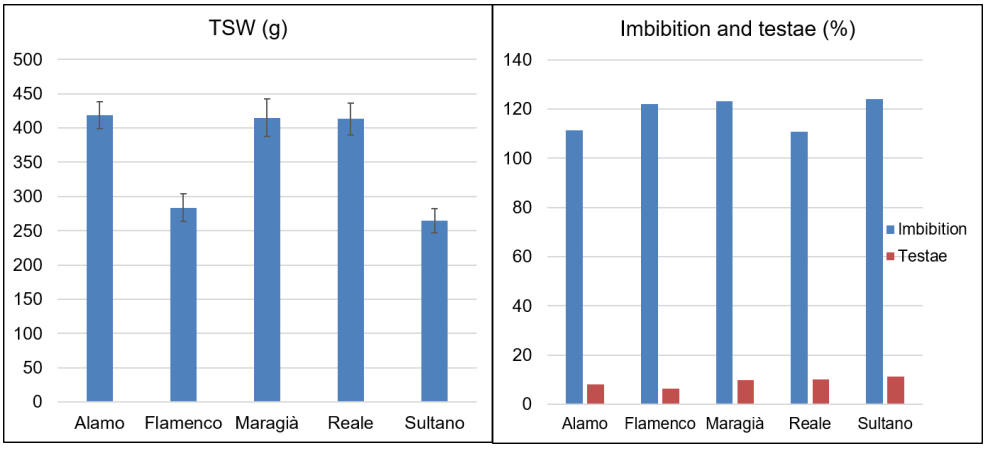


Figure 2. Main biometrical parameters of selected chickpea cultivars: thousand seed weight (g), percentual imbibition and percent of testae in seed weight.

After 48 h of soaking, seed weight ranged from 592 g TSW equivalent in Sultano to 925 g in Maragià. Relative to the initial dry seed mass, water uptake ranged from 111 to 124 %, with the highest values recorded for Flamenco, Maragià, and Sultano.

The proportion of seed coat (testa) in total dry seed mass ranged from 6.43% in Flamenco to 11.33 % in Sultano. Differences among cultivars were statistically significant ($F > 34$, $p < 0.001$).

Table 1 presents the remaining biometric characteristics measured at the individual-seed level. Alamo, Maragià, and Reale produced the largest seeds, with mean diameters above 0.80 cm, whereas Sultano had the smallest mean diameter. Significant differences among cultivars were detected for seed diameter ($F > 113$, $p < 0.001$), although Alamo and Maragià showed similar values. Seed volume also differed significantly among cultivars ($F > 95$, $p < 0.001$), with greater within-cultivar variability and no significant difference between Alamo and Maragià. Seed tissue density showed still greater within-cultivar variability, and differences among most cultivars were not significant, while Sultano exhibited the highest mean density.

Table 1. Biometrical data of seeds from selected cultivars

	Seed diameter (cm)	Volume (cm^3)	Dry seed tissue density (g/cm^3)
Alamo	0.87±0.09	0.36±0.11	1.29±0.44
Flamenco	0.73±0.04	0.21±0.07	1.47±0.50
Maragià	0.86±0.07	0.34±0.09	1.31±0.31
Reale	0.82±0.09	0.30±0.09	1.56±0.60
Sultano	0.67±0.07	0.16±0.05	1.78±0.65

Seed size and weight are highly variable traits among chickpea cultivars. A study conducted on 100 chickpea genotypes, including both Kabuli and Desi types, reported TSW values ranging from 138 to 526 g, with a tendency toward higher values in Kabuli genotypes (Sarika et al. 2019). Based on seed weight, Upadhyaya et al. (2006) classified chickpea seeds into small (30–75 g TSW), normal (75–140 g TSW), and medium (141–200 g TSW) categories, although their study focused primarily on Desi material. According to this classification, all five cultivars evaluated in the present study can be considered large-seeded, as their TSW values exceeded 200 g.

Seed diameter provides an additional criterion for characterizing chickpea seed size. Gan et al. (2003) distinguished small-seeded (0.71–0.90 cm) from large-seeded (0.90–1.20 cm) chickpeas based on seed diameter. According to this criterion, the cultivars evaluated in the present study fall within or close to the small-seeded range, with mean diameters ranging from 0.67 to 0.87 cm. This apparent discrepancy between classifications based on TSW and seed diameter indicates that seed size characterization may depend on the biometric criterion applied.

Seed coat proportion is another highly variable characteristic among chickpea genotypes. Sastry et al. (2014) reported seed coat proportions ranging from 4.0 to 16.2 % among 50 Indian chickpea accessions, with generally lower values in Kabuli types. In the present study, seed coat proportion ranged from 6.43% in Flamenco to 11.33 % in Sultano, therefore remaining within the range previously reported for chickpea germplasm. Seed coat characteristics are relevant to processing and nutritional quality because the testa contributes dietary fiber and influences hydration, cooking, and milling behavior (Sastry et al. 2014).

Water imbibition also varied among the studied cultivars. Sarika et al. (2019) reported water uptake values ranging from 91 to 135% among chickpea genotypes, with generally higher values in Kabuli material. The values recorded in the present study (111–124%) therefore fall within the range previously reported. Differences in water uptake can be associated with seed structure and composition, including cell compactness, cell wall characteristics, and seed coat thickness and permeability. Hydration capacity is particularly relevant to chickpea processing because soaking is an important stage prior to cooking and can also facilitate seed coat removal during processing (Sarika et al. 2019).

Digital RGB analysis (Figure 3) showed generally similar beige-yellow seed coat coloration among the five cultivars. Nevertheless, statistically significant differences in RGB profiles were detected among cultivars ($F > 5$, $p < 0.001$). Sultano showed the most distinctive color profile, with the highest relative contribution of the red channel (43.47 ± 1.59 %) and the lowest contribution of the blue channel (23.75 ± 1.67 %). In contrast, the green component showed little variation among cultivars, ranging from 32.95 to 33.04 %. The predominantly light beige coloration observed across the five cultivars is consistent with their classification as Kabuli chickpeas. Previous studies have reported genotype-dependent differences in chickpea seed coat characteristics and coloration (Bose et al. 2024). In the present study, RGB analysis was used as an objective descriptor of seed coat color and to identify differences in testa coloration among cultivars.

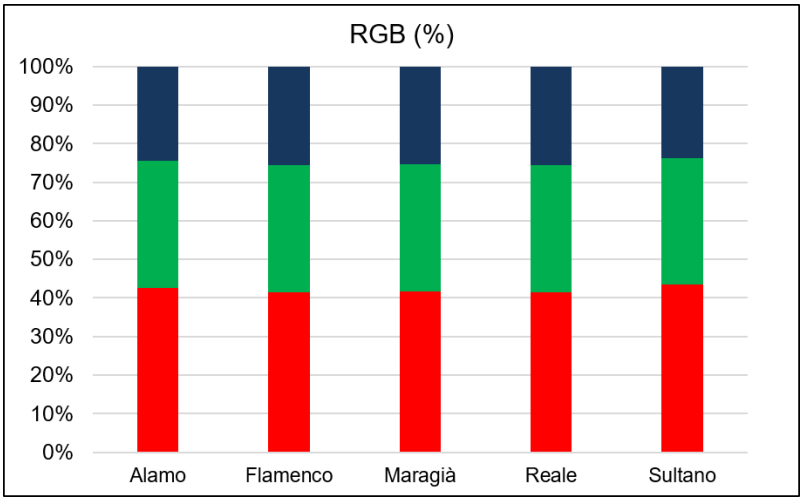


Figure 3. Red-green-blue (RGB) analysis of seed testae (%).

Seed biometric traits are largely influenced by genetic factors (Upadhyaya et al. 2006). However, their phenotypic expression may also be affected by environmental conditions and crop management practices, including seeding rate, planting depth, and other agronomic practices (Gan et al. 2003; Bhuker et al. 2023). Under the semi-arid conditions of Dobrogea, Stroe et al. (2026) also reported significant differences in thousand-seed weight and other biometric and productivity traits of pea in response to contrasting tillage systems, further indicating that seed-related characteristics in grain legumes may vary according to crop management conditions. Therefore, the differences observed among the five chickpea cultivars in

the present study likely reflect cultivar-specific characteristics expressed under the same local growing and management conditions.

From a practical perspective, the simultaneous evaluation of seed size, weight, hydration capacity, seed coat proportion, and color provides a more comprehensive basis for cultivar characterization than any single biometric trait. These characteristics are also relevant to subsequent technological evaluations because seed dimensions, testa proportion, and hydration behavior can influence handling, soaking, dehulling, milling, and cooking performance. However, these processing properties were not directly evaluated in the present study and should be addressed in future research.

CONCLUSIONS

The five chickpea cultivars showed clear differences in several seed biometric and physical characteristics under the same local growing conditions. Thousand-seed weight (TSW) ranged from 264 to 418 g, with Alamo, Maragià, and Reale showing the highest values, whereas Flamenco and Sultano had lower seed weights. Water imbibition ranged from 111 to 124 %, while seed coat proportion varied from 6.43% in Flamenco to 11.33 % in Sultano.

Differences were also observed in seed dimensions, with Alamo, Maragià, and Reale producing larger seeds and Sultano showing the smallest mean diameter and the highest seed tissue density. Seed coat coloration was generally similar among cultivars, although Sultano showed a distinctive RGB profile characterized by a higher contribution of the red component.

The results demonstrate measurable cultivar-dependent variability in seed biometric and physical traits among Kabuli chickpeas grown under the same environmental and management conditions. These findings provide comparative information for the characterization of chickpea cultivars under local growing conditions and support the importance of considering multiple seed traits rather than a single biometric parameter when describing cultivar variability.

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