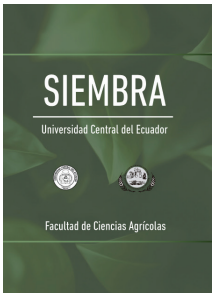
Physical and physiological attributes of coffee seeds (Coffea arabica L)

Atributos físicos y fisiológicos de las semillas de café (Coffea arabica L)



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Resumen

El café es una de las bebidas más consumidas y comercializadas a nivel mundial, y además la fuente de sustento para millones de personas. El conocimiento de las características físicas es esencial para el diseño y fabricación de equipos para el beneficio del grano. Este trabajo se realizó en el laboratorio de semillas de la Universidad Nacional Agraria La Molina usando 12 accesiones de *Coffea arabica.* En cada material genético se cuantificaron las características físicas y fisiológicas, como el diámetro polar, ecuatorial y el grosor, así también el diámetro aritmético, diámetro geométrico, grado de esfericidad, área superficial, volumen y porcentaje de germinación. Los resultados indicaron que UNACAF-172 y UNACAF-146 mostraron mayor diámetro polar, aritmético y geométrico. Además, presentaron mayor área superficial, volumen y peso de plántula. Al contrario, estas mismas accesiones tuvieron menor porcentaje de germinación. Asimismo, UNACAF-119 y UNACAF-90 mostraron bajos atributos físicos, aunque alto porcentaje de germinación y bajo peso de plántulas. En conclusión, el componente genético tiene un papel importante en los atributos físicos y fisiológicos de las semillas de café.

Palabras clave: accesión, cultivares, germinación, tamaño de semilla.

Abstract

Coffee is one of the most consumed and traded beverages worldwide and also the source of livelihood for millions of people. Knowledge of physical characteristics is essential for the design and manufacture of equipment for processing of coffee beans. This work was carried out in the seed laboratory of the Universidad National Agraria La Molina using 12 accessions of *Coffea arabica*. In each genetic material, physical and physiological characteristics were quantified such as polar and equatorial diameter, and thickness, as well as arithmetic diameter, geometric diameter, degree of sphericity, surface area, volume and percentage of germination/volume and germination percentage. The results indicated that UNACAF-172 and UNACAF-146 showed greater polar, arithmetic and geometric diameter. In addition, they showed greater surface area, volume and seedling weight. On the contrary, these same accessions had a lower germination percentage. Similarly, UNACAF-119 and UNACAF-90 showed low physical

attributes, although high germination percentage and low seedling weight. In conclusion, the genetic component plays an important role in the physical and physiological attributes of coffee seeds.

Keywords: accession, cultivars, germination, seed size.

1. Introduction

Coffee is one of the most consumed products after water (Preedy, 2015); indeed, an average of 2.25 billion cups of coffee are consumed daily in the world (Dadi et al., 2018; Jiménez-Zamora et al., 2015). Peru is one of the main Arabica coffee producing countries. It is also the first traditional agricultural export product and is a source of employment for more than two million Peruvians throughout the agro-productive chain (Ministerio de Desarrollo Agrario y Riego [MIDAGRI], 2022). In producing areas, it represents an important source of income for 230 thousand families (Junta Nacional del Café [JNC], 2020).

Regarding coffee bean processing, knowledge of the size, shape and physical properties is essential for the design and manufacture of sorting, processing and packaging equipment (Tabatabaeefar, 2003; Tabatabaeefar and Rajabipour, 2005). There are studies on physical characteristics in watermelon (Koocheki et al., 2007), cocoa (Bart and Baryeh, 2003), quinoa (Jan et al., 2019), maize (Perez Mendoza et al., 2006), capers (Dursun and Dursun, 2005), carob (Olajide and Ade-Omowaye, 1999), sesame (Tunde-Akintunde and Akintunde, 2004) and soybean (Moreano et al., 2013). However, work with coffee cultivars is still scarce (Saparita et al., 2019; Tesfa et al., 2019; El-Gendy et al., 2011; Dias, 2007), thus limiting the design of appropriate equipment for coffee processing, which is a major threat to the quality of this beverage.

Physiological quality can be defined as the capacity of the seed to germinate, emerge and develop vigorous and uniform plants. These, are essential qualities for decision making, as they provide necessary information on the particularity of germination and vigor of each cultivar to producers of coffee seeds and seedlings (Reis et al., 2010). Likewise, physiological quality can be directly related to the genetic materials studied (Alixandre et al., 2021). In addition, this characteristic can be used to measure plant tolerance to certain abiotic stresses, such as lack of water (Nijabat et al., 2023) and salinity (Rosas et al., 2019).

As previously mentioned, both the physical and physiological characteristics of seeds in general, and particularly those of coffee, are directly related to the cultivars and the climate in which they grow. Therefore, it is important to constantly evaluate these attributes in order to providing farmers with better tools to improve the management of their coffee plantations.

2. Materials and Methods

This work was carried out in the seed laboratory of the Universidad Nacional Agraria La Molina [UNALM], Lima, Peru. The plant material used was Coffea arabica seeds from the coffee germplasm bank of UNALM, geographical coordinates 75º21'8.17'' west longitude and 11º5'43.84.84'' south latitude, located in the province of Chanchamayo, Junín region, which presents a temperature and precipitation of 21-24 ºC and 1829 mm yr-1, respectively (Servicio Nacional de Meteorología e Hidrología del Perú [SENAMHI], 2019).

The treatments consisted of seeds from coffee accessions UNACAF-24a, UNACAF-90, UNACAF-97, UNACAF-115, UNACAF-119, UNACAF-132, UNACAF-134, UNACAF-143, UNACAF-146, UNACAF-151, UNACAF-172, and UNACAF-202, which were collected from fully mature cherries (Table 1 and Figure 1). After harvesting, the cherries were pulped manually to avoid damaging them. The parchment was also removed from the seeds and then 50 fresh seeds of each accession were selected for weighing to determine their physical characteristics.

Physical characteristics such as polar diameter (L, mm), equatorial seed diameter (A, mm) and thickness (W, mm) of each seed were quantified. With these variables, other indexes were calculated, such as arithmetic diameter (mm) (equation [1]), geometric diameter (mm) (equation [2]), degree of sphericity (%) (equation [3]), surface area (mm2) (equation [4]), volume (mm3) (equation [5]), (Mohsenin, 1971).

$$\left[{}^{(L+A+W)}/_{3}\right] \quad [1]$$

Table 1. Coffee accessions from the germplasm bank of the La Molina National Agrarian University.

Accession	Cultivar	Weight of 50 fresh seeds (g)	Origin
UNACAF-172	Borbón rojo	17,50	Cuzco
UNACAF-146	Villa Sarchí	12,70	Cuzco
UNACAF-202	Brasilero	13,60	Huánuco
UNACAF-134	Pache	11,57	Cajamarca
UNACAF-115	Pache	11,72	San Martín
UNACAF-97	Típica	11,40	Piura
UNACAF-24a	Típica	11,90	Chanchamayo
UNACAF-151	Típica	9,67	Cuzco
UNACAF-132	Típica	9,99	Amazonas
UNACAF-143	Geisha	11,40	Cuzco
UNACAF-119	Típica	9,70	San Martín
UNACAF-90	Colombia	9,30	Piura

Figure 1. Germinated seeds used for this trial.

$$\left[(L * A * W)^{1/3}\right] \quad [2]$$

$$\left[(L * A * W)^{1/3} / L\right] \quad [3]$$

$$\left[\pi * \left(\left((L * A * W)^{1/3}\right)^{2}\right)\right] \quad [4]$$

$$\left[\pi/6 * \left(\left((L * A * W)^{1/3}\right)^{3}\right)\right] \quad [5]$$

The physiological attribute was evaluated by quantifying the germination percentage, which was carried out in a SEEDBURO germination chamber at 26 °C and in dark conditions. This evaluation was carried out from August 7 to August 20, giving a total of thirteen days. Each treatment had five replicates and each replicate consisted of ten seeds. Germinated seeds were considered to be those that showed a radicle greater than 1 mm. At the end of this evaluation period, the length of the radicle and the weight of each seedling were measured.

The data obtained were used to perform ANOVA analysis. Subsequently, the difference of means was quantified with Tukey's test (95 %).

3. Results and Discussion

Coffee is one of the most traded goods worldwide. This beverage is obtained from beans that have been previously pulped, selected, dried and roasted. For all the aforementioned activities, producers use equipment that is designed according to the physical properties of the seeds, which are also used to distinguish cultivars (Tesfa et al., 2019). Also, physiological and genetic characteristics contribute to define the physical properties of the seeds (Anandakumar et al., 2022; Hu et al., 2021; Jiang et al., 2013; Kaliniewicz et al., 2018).

In this evaluation, physical attributes of coffee accessions were examined. As mentioned, the genetic component plays an important role in seed size. In fact, accessions UNACAF-172 (12.76 mm) and UNACAF-146 (12.40 mm) had the longest polar diameter, while accessions UNACAF-119 (9.29 mm) and UNACAF-90 (9.13 mm) were the shortest. The difference between these groups was almost 30 % ($p \leq 0.05$). For equatorial diameter, accession UNACAF-146 had the highest value (7.78 mm), while accessions UNACAF-151 (6.67 mm), UNACAF-132 (6.87 mm), UNACAF-119 (6.79 mm) and UNACAF-90 (6.79 mm) had the lowest value.

Thickness was also measured. For this variable it could be observed that accessions UNACAF-172 (4.47 mm) and UNACAF-202 (4.47 mm) were thicker than accession UNACAF-119 (3.78 mm) ($p \leq 0.05$) (Figure 2). These results can be associated with the cultivars studied.

Physical characteristics are important indicators for the analysis of bean quality. Likewise, physical characteristics are essential for the design, construction and operation of equipment (Ospina Machado, 2001) used in coffee processing. If a good analysis is carried out, the quality of the coffee itself is maintained or enhanced, but if not, the product will be harmed. The objective of the analysis is to improve quality through the exaltation of attributes. The factors that determine the quality of coffee are the genotype, the environment, the agronomic management and post-harvest treatment (Peñuela Martínez and Sanz-Uribe, 2021).

In the evaluation of physical indices for arithmetic and geometric diameter, accessions UNACAF-146 (21.65 mm and 7.49 mm) and UNACAF-172 (21.57 mm and 7.45 mm) had the highest values, while accessions UNACAF-119 (17.33 mm and 6.18 mm) and UNACAF-90 (17.20 mm and 6.20 mm) were the lowest ($p \leq 0.05$) (Figure 3). For the degree of sphericity, accession UNACAF-143 (0.70 %) had the highest value, while UNACAF-172 (0.58 %) and UNACAF-146 (0.60 %) had the lowest value ($p \leq 0.05$). Sphericity is the degree of approximation that a seed has to a sphere and, in any seed, it is a function of its basic dimensions such as length, width and thickness. This characteristic describes the ability of a seed to roll during processing. Accession UNACAF-143 has a sphericity value of 0.70 %, being in the range of 0.7 to 0.8, considered spherical for a seed (Bande et al., 2012).

In terms of surface area, accessions UNACAF-146 (177.35 mm^2) and UNACAF-172 (175.57 mm^2) were significantly larger than accession UNACAF-119 (120.63 mm^2) which was smaller. The results showed that

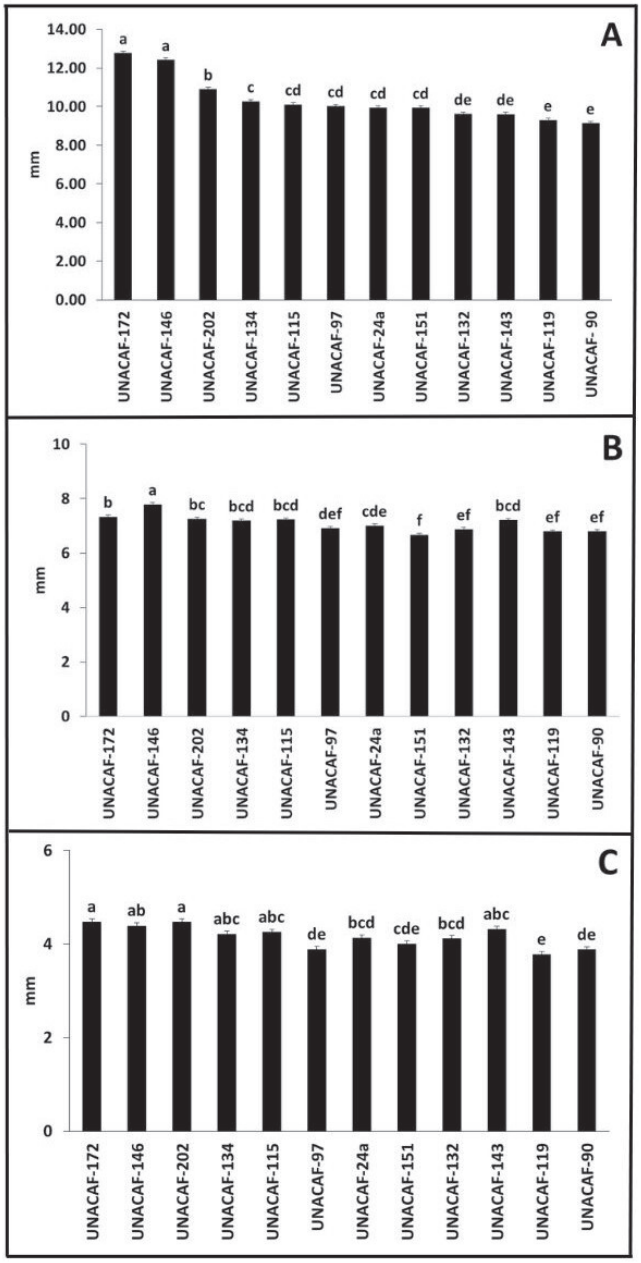

Figure 2. Physical traits evaluated in this experiment. A) the polar diameter (L) (mm), B) the equatorial seed diameter (mm) and C) the thickness (W) (mm).

surface area, geometric diameter and arithmetic diameter would not necessarily have a relationship with the degree of sphericity. The surface area of a seed is of interest in the design of hoppers and processing chambers (Bande et al., 2012). Both surface area and geometric diameter play an important role in the drying process for the determination of terminal velocity, drag coefficient and Reynolds number (Mohsenin, 1986).

Volume was also measured. It was observed that accessions UNACAF-146 (223.55 mm^3) and UNACAF-172 (220.54 mm^3) were higher ($p \leq 0.05$) compared to accessions UNACAF-119 (125.17 mm^3) and UNACAF-90 (126.18 mm^3). Knowing the volume is essential both for the roasting process, when the kernel expands; and, to consider drying simulation models (Franca et al., 2005).

In relation to germination (Figure 4), the results showed that accessions UNACAF-202 (0.98 %) and UNACAF-134 (1 %) have (a) higher germination percentage, while accessions UNACAF-172 (0.62 %) and UNACAF-146 (0.80 %) have (a) lower germination percentage ($p \leq 0.05$). According to Popinigis (1985), seed size in many species is indicative of their physiological quality, so that, within the same lot, large and medium size seeds have a higher germination and vigor index than small size seeds; which appears to be related to the

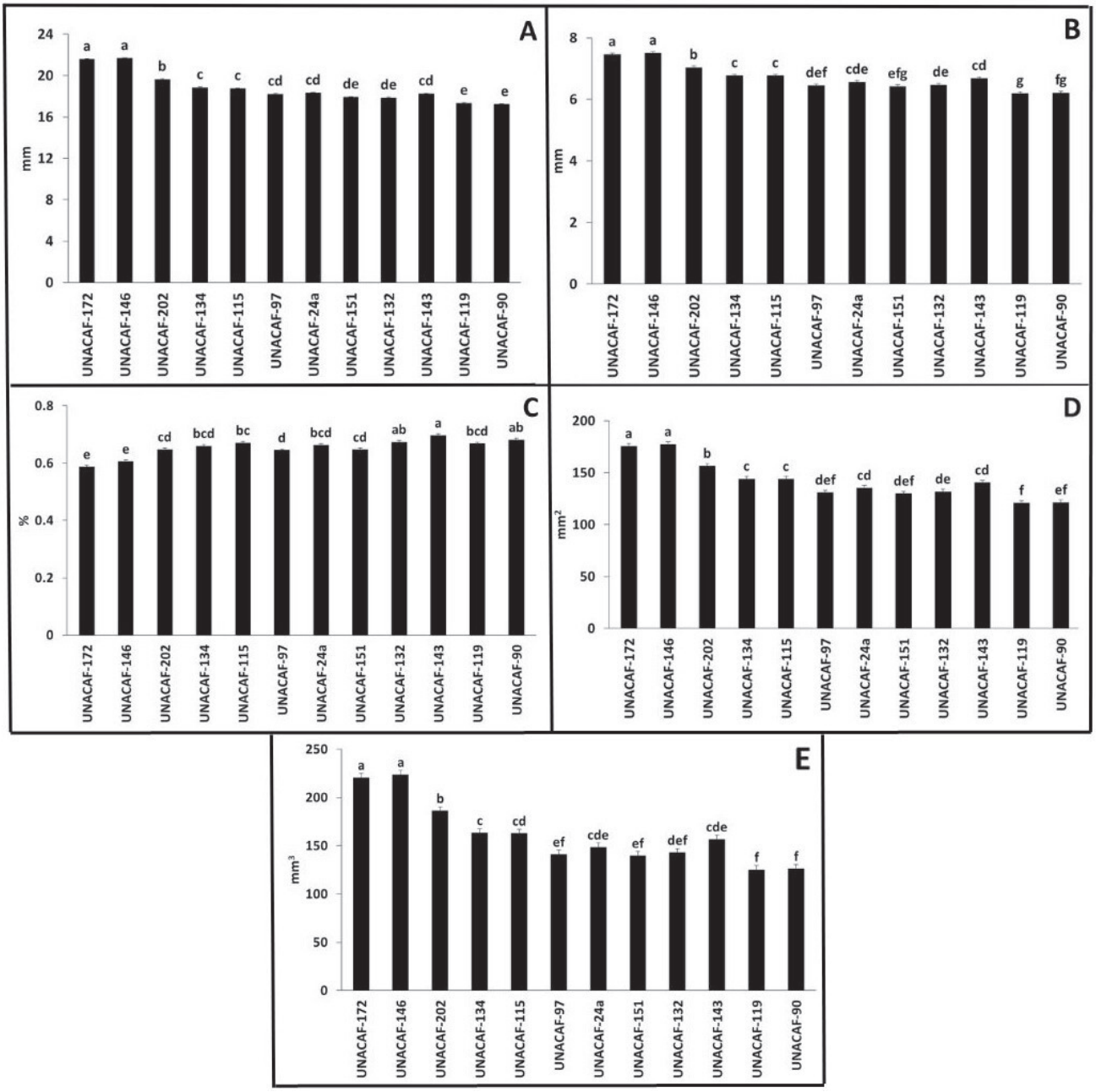

Figure 3. Physical indices evaluated in this experiment. A) arithmetic diameter (mm), B) geometric diameter (mm), C) degree of sphericity (%), D) surface area (mm^2) and E) volume (mm^3).

results obtained in Figure 2. This is important as the germination capacity of a seed lot is determined by the proportion of normal plant production (Carvalho and Nakagawa, 2012). Seed morphological variables can act on germination physiology. Seed shape is influenced by genetic and environmental factors. In maize, shape has an effect on physiological seed quality: seed germination, seed emergence, and germination speed (Adebisi et al., 2005). Quantifying seed morphological variation can help to understand the course of imbibition, as well as differences between related genotypes. However, when obtaining seedling weights, accessions 172 and 146 have higher weights, which would indicate that germination percentage is not necessarily related to seedling weight (Adebisi et al., 2005).

Describing the physical attributes of coffee seeds is important because seeds are mechanically damaged during processing, which not only reduces their quality in terms of germination and viability, but also cup quality. The agricultural production technology of coffee influences 40 % of the cup quality attributes of the coffee beverage, while the remaining 60 % of the (beverage) quality attributes are determined by the post-harvest processing technology (Hameed, 2018).

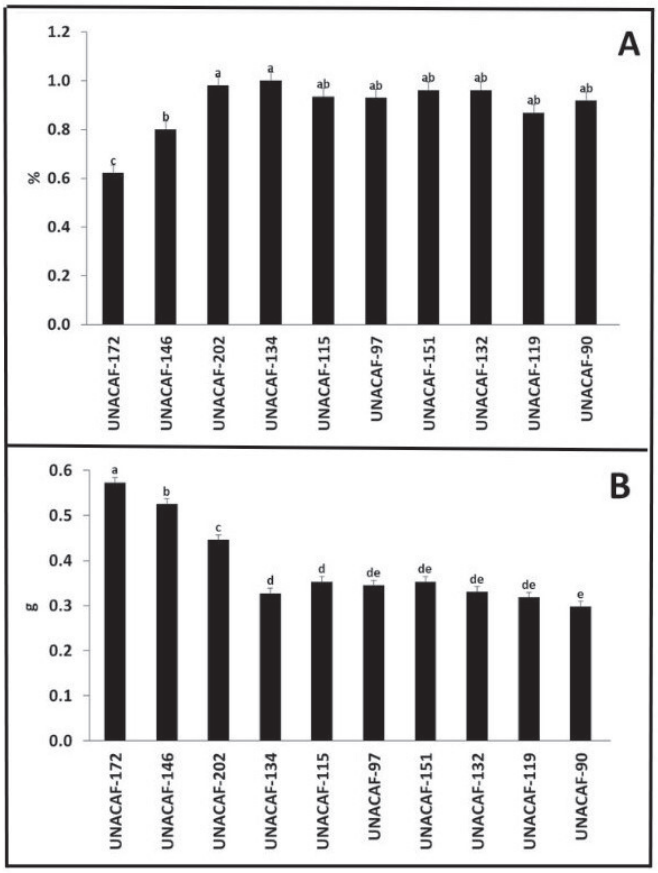

Figure 4. Germination percentage (A) and seedling weight (B).

4. Conclusions

The results showed that physical and physiological characteristics vary depending on the genetic material studied. In fact, we found marked differences for the attributes studied. Thus, accessions UNACAF-172 and UNACAF-146 showed greater polar, arithmetic and geometric diameters, as well as greater surface area, volume and seedling weight. On the contrary, these same accessions had lower germination percentages. Similarly, UNACAF-119 and UNACAF-90 showed low physical attributes, although high germination percentage and low seedling weight.

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Contributor Roles

- Claudia Andrea Vidal-Tejeda: conceptualization, formal analysis, investigation, methodology, supervision, writing – review & editing.

- Alberto Julca-Otiniano: investigation, methodology, writing - revising and editing.
- Viviana Castro-Cepero: investigation, methodology, writing – review & editing.
- Leonel Alvarado-Huaman: investigation, methodology, writing – review & editing.
- Ricardo Roberto Borjas-Ventura: conceptualization, formal analysis, supervision.

Ethical Issues

Ethics approval Not applicable.

Conflict of Interest

The authors declare that there are no financial or non-financial conflicts of interest that could have influenced the work presented in this article.

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