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Plant physiology

Short article

Fruit and seed morphometry of "ají mochero" *Capsicum chinense* Jacq.

Eloy López Medina[1], Angélica López Zavaleta[1], Armando Efraín Gil Rivero[1]*, José Mostacero León[1], Anthony J. De La Cruz Castillo[1], Luigi Villena Zapata[2]

[1] Universidad Nacional de Trujillo. Trujillo, Peru
[2] Universidad César Vallejo. Trujillo, Peru

* Corresponding author: Universidad Nacional de Trujillo. Av. Juan Pablo II, Trujillo 13011, Trujillo, Peru. arivero@unitru.edu.pe

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Abstract

Capsicum chinense Jacq. "aji mochero" is cataloged a gastronomic heritage for its pleasant spicy or pungency degree that flavors many internationally recognized Peruvian dishes. The gastronomic boom in Peru has led to the export of many national inputs, including *ají mochero*. Therefore, many basic agronomic studies that provide information on the productive state of fruits and seeds of this crop are necessary. Accordingly, the aim of this study was to determine the morphometry of fruits and seeds of "ají mochero" *C. chinense*. For this, fruits from the Moche district, province of Trujillo, department of La Libertad were collected; in the laboratory, the weight of the fruit and pulp were evaluated, in addition to the length, width and number of seeds. A descriptive statistical analysis was performed with 50 repetitions for each component evaluated. The average fruit weight is 2.4 g and the average pulp weight is 2.1 g. The seed has an average length of 4.3 mm, and an average width of 1.4 mm. An average of 16.4 seeds per fruit were recorded. A high coefficient of variation and a high correlation ($p < 0.01$) were found between the evaluated parameters. It is concluded that the morphometry of fruits and seeds of "ají mochero" *C. chinense* differentiates it from other species and varieties such as *C. annuum, C. baccatum, C. frutescens*, and *C. pubescens*. This information is essential to promote its industrialization and support its designation of origin.

Keywords: *Capsicum*, chili, designation of origin, plant morphology, seed characteristics

Morfometría de frutos y semillas del "ají mochero" *Capsicum chinense* Jacq.

Resumen

Capsicum chinense Jacq. "ají mochero" es catalogado como patrimonio gastronómico de Perú por su agradable grado de picor, que condimenta numerosos platos reconocidos internacionalmente. El *boom* gastronómico en Perú ha conllevado a la exportación de diferentes insumos nacionales, incluyendo el ají mochero, por lo que se requieren estudios agronómicos que brinden información sobre el estado productivo de los frutos y las semillas de este cultivo. El estudio buscó determinar la morfometría de los frutos y las semillas de *C. chinense* "ají mochero". Para ello, se recolectaron frutos procedentes del distrito de Moche (provincia de Trujillo, departamento de La Libertad) y en el laboratorio se evaluó el peso del fruto y de la pulpa, así como las dimensiones y el número de semillas. Se realizó un análisis estadístico descriptivo con 50 repeticiones por cada componente evaluado. El peso promedio del fruto fue de 2,4 g y el peso promedio de la pulpa, de 2,1 g. La semilla registró una longitud promedio de 4,3 mm y un ancho promedio de 1,4 mm, y se reportaron 16,4 semillas por fruto. Se identificó un alto coeficiente de variación y una alta correlación ($p < 0,01$) entre los parámetros evaluados. Se concluyó que la morfometría de los frutos y las semillas de *C. chinense* "ají mochero" permite diferenciar esta de otras especies y variedades como *C. annuum, C. baccatum, C. frutescens* y *C. pubescens*. Esta información es primordial para promover su industrialización y fundamentar su denominación de origen.

Palabras clave: ají, *Capsicum*, características de semillas, denominación de origen, morfología vegetal

Introduction

Chili peppers belong to the *Capsicum* genus, Solanaceae family. They have a high content of vitamins and minerals such as phosphorus, calcium, potassium, and iron, and their fruits are a source of antioxidants such as phenols, flavonoids, and capsaicinoids. Its culinary use as a condiment or spice is due to the presence of capsaicin, which gives it the spicy or pungent flavor that stimulates the appetite (Tejada-Tovar et al., 2017; Viloria et al., 2017).

The centers of origin of the chili peppers are the Central Andean region and Mesoamerica, where between 20 and 30 wild ancestors have been reported, of which 11 exist in Peru (Mendoza, 2006; Pérez-Castañeda et al., 2015). Since ancient times, chili peppers have been used to give flavor to food; evidence of this are the findings of *huacos* and vessels with illustrations of *C. chinense* in the Huaca Prieta archaeological complex (2,500 B.C.) located in the Chicama valley (La Libertad). It was the Spanish conquerors who promoted its consumption in Europe (Sociedad Peruana de Gastronomía et al., 2009; Saur Palmieri et al., 2018; Trillo, 2016).

In Peru, 19 varieties of native chili peppers are used, having a considerable potential to enter international markets given the demand for high nutritional value food (Jäger et al., 2013). "Ají mochero" C. *chinense* Jacq. has a leading role in the cuisine of northern Peru, in which *ceviche* is the most internationally recognized dish. Currently, this endemic species in the Moche Valley seeks to achieve the designation of origin to increase its demand and, above all, its export potential (Gerencia Regional La Libertad, 2018; Andina Agencia Peruana de Noticias, 2018). It is crucial to know the commercially valuable attributes of this product such as its fruit and seed morphometry, to plan its production and industrialization in the competitive agricultural sector, which is associated with production and yield. This constitutes the first step for subsequent crop improvement studies and conservation programs (Jäger et al., 2013; Méndez & Alcorcés, 2007; Onamu et al., 2012).

Morphometric studies of the fruit are based on visual color recognition, a criterion for evaluating the quality and maturity state of the plant material. Likewise, in chili peppers, it is necessary to recognize the shape of the fruits, which can be elongated, round, triangular, bell-shaped or heart-shaped (Melgarejo et al., 2004; Pérez Campomanes, 2018). The registration of the length, width and weight of the fruits is also required; the weight of the pulp is a key factor for industrialization and agro-export.

In seeds, length, width, weight, and number per fruit are recorded, as these are agronomically important data that can be supplemented with information on viability and germination. An analytical balance (Ohaus) and a precision caliber (Vernier) were used to carry out this registration (López et al., 2017; López et al., 2018, López Medina et al., 2019; Orantes-García et al., 2019). Given the need for more basic

knowledge in this area, the aim of the current study is to determine the morphometry of the fruits and seeds of the chili pepper "aji mochero" *C. chinense*.

Materials and methods

Collection and registration

Fruits of "aji mochero" *C. chinense* with physiological and organoleptic maturity were collected from the Moche district, Trujillo province, La Libertad department (Peru), at coordinates 17L 718299 9098225 UTM. Three accessions were located, and cropping management was identified as traditional in small agricultural plots, where the farmer cultivates this crop for self-consumption and to sell it in the local market. One of the main characteristics of the Moche Valley is its fertile agricultural soils with a sandy-loam or clay-loam substrate, in which gravity irrigation predominates. A botanical sample per accession was collected with flowers and fruits; it was prepared to be included as a herbarium specimen and identified using taxonomic codes and by comparison with specialized bibliography (Brako and Zarucchi, 1993). The specimen is housed in Herbarium Truxillense (HUT) of Universidad Nacional de Trujillo with the code 59434.

Measurement variables

Fruits were collected, selected, and transported in paper bags previously labeled to the Biotechnology Laboratory of Instituto de Papa y Cultivos Andinos, Universidad Nacional de Trujillo. The environmental conditions were 18 °C ± 6 °C of temperature and relative humidity of 80 ± 9%.

Fruit characteristics

Fruit color was established in the laboratory, and its shape was evaluated based on the classification of Melgarejo et al. (2004); according to these authors, chili pepper fruits can be elongated, round, triangular, bell-shaped and heart-shaped. With an Ohaus analytical balance and a precision grade of 0.0001 g, the total weight of each fruit was calculated. Then, the seeds were separated to calculate the weight of the pulp.

Seed characteristics

Once the fruits were opened, the number of seeds per fruit were recorded. Besides, the length and width of the seeds were measured with a Vernier precision caliber, on a measurement scale between 0-150 mm.

Data analysis

Descriptive statistical analysis with a sample of 150 ripe fruits was performed, of which 50 were randomly selected to comprise the number of repetitions for each component evaluated. The results obtained were statistically analyzed with the R software; the standard deviation, coefficient of variation, and correlation analysis were estimated.

Results and discussion

The shape of the fruit in the species of the genus *Capsicum* shows high variability. *C. chinense* "ají mochero" shows slightly elongated fruits (figure 1b), which is a distinctive feature compared to the rounded fruits of *C. pubescens* Ruiz & Pav. "Rocoto" and *C. chinense* "charapita," the triangular fruits of *C. annuum* "cerezo", and the very elongated fruits of C. *baccatum* var. *pendulum* (Willd.) Eshbaugh "ají escabeche" and *C. chinense* "ají panca" (Melgarejo et al., 2004; Programa de Hortalizas, 2012).

Regarding color, the ripe fruits of *C. chinense* "ají mochero" have a yellow color (figure 2b), while *C. pubescens* "rocoto" and *C. frutescens* L. "pinguita de mono" have red fruits, and *C. baccatum* var. *pendulum* (Willd.) Eshbaugh "ají escabeche" has orange fruits. On the other hand, depending on the variety, the fruits of *C. annuum* "morrón" and *C. chinense* "ají limo" have different shades between red, orange and yellow (Jäger et al., 2013; Yánez et al., 2015). Fruit color is an important trait to determine the optimal harvest moment since the organoleptic quality of the product and the physiological state of the seeds depend on it (Ayala-Villegas et al., 2014; Bezerra et al., 2014).

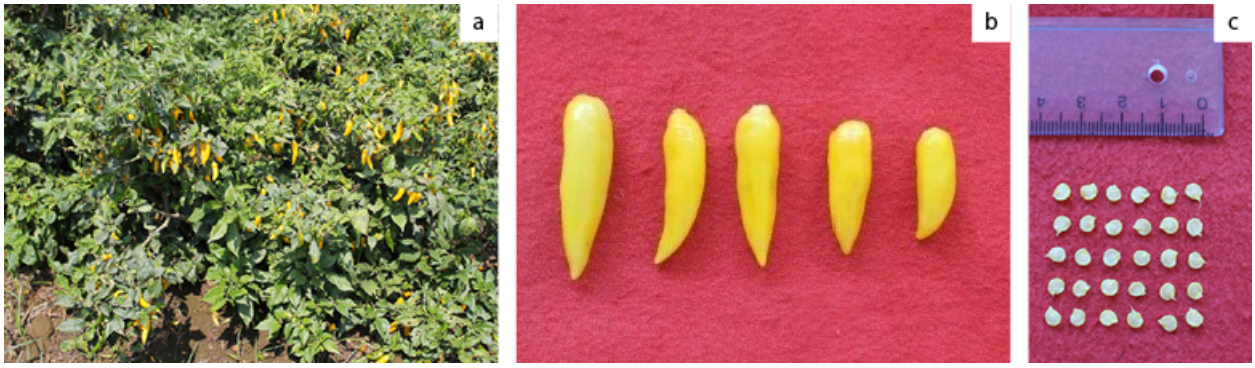

Figure 1. "Ají mochero" *C. chinense*. a. Plant habit; b. Fruits; c. Seeds.
Source: Elaborated by the authors

Regarding fruit weight, *C. chinense* "ají mochero" has a lower average weight (2.397 g) compared to *C. pubescens* "rocoto" (8.30 g), *C. frutescens* "ají tabasco" (3.70 g), *C. annuum* "ají ratón" (2.60 g), *C. chinense* "ají limo" (9.5 g), *C. annuum* "cerezo" (5.6 g), and *C. baccatum* var. pendulum (Willd.) Eshbaugh "ají escabeche" (21.4 g), among others. However, the species that shows the lowest fruit weight is *C. frutescens* "pinguita de mono" (0.9 g) (Rojas et al., 2016; Yánez et al., 2015). The pulp weight of *C. chinense* "ají mochero" is 2,096 g; despite being relatively low, this information is useful to determine the fresh production of a cultivable area and to project its industrialization for the preparation of sauces and condiments, since the organoleptic characteristics of the final product are preserved in the pulp (Rocha et al., 2016; Yánez et al., 2015) (table 1).

Table 1. Statistical analysis of the morphometry of fruits and seeds of "ají mochero" *C. chinense*

Variable	Repetition	Mean	SD	CV (%)
Fruit weight (g)	50	2.397	0.968	40.384
Seed length (mm)	50	4.272	0.805	18.844
Seed width (mm)	50	1.398	0.207	14.807
Pulp weight (g)	50	2.096	0.830	39.599
Number of seeds per fruit (units)	50	16.36	10.176	62.200

SD: standard deviation; CV: coefficient of variation

Source: Elaborated by the authors

The seeds of *C. chinense* "ají mochero" are 4.27 mm long and 1.40 mm wide. This is a descriptor for all the accessions belonging to *C. annuum, C. chinense*, and *C. frutescens*; this is not the case for the accessions belonging to *C. pubescens*, which show black seeds with a diameter of 2 mm to 3 mm (Melgarejo et al., 2004) (table 1).

Likewise, *C. chinense* "ají mochero" has an average of 16.4 seeds per fruit, a higher number compared to the *C. annuum* accessions, which produce 9 seeds per fruit. However, a higher number of seeds (72 to 133) have been recorded in the different ecotypes of *C. pubescens* (López-España et al., 2016; Oliva et al., 2018) (table 1). These morphometric data on seeds are of agronomic interest, especially when analyzing the propagation of the species, and can be complemented with studies of germination, vigor, and viability. Some researchers have shown a correlation between the size, the number of seeds, and the quality of these (García-Ruiz et al., 2018; Hernández-Verdugo et al., 2010).

In the statistical analysis of *C. chinense* "ají mochero" the variables with the highest variability are number of seeds (CV = 62.20 %), fruit weight (CV = 40.384 %), and pulp weight (CV = 39.599 %) (table 1). This finding may represent an indication of high population genetic variability or may be the result of the influence of environmental and nutritional factors (Silva et al., 2018).

Pearson (r) and Spearman's (rs) correlation coefficient values for the variables fruit weight, pulp weight, seed length, seed width, and number of seeds showed a highly significant and positive correlation ($p < 0.01$) (table 2). This is corroborated by visual inspection of the scatter diagrams for each pair of variables (figure 2), in which an almost straight line is observed, indicating a positive linear relationship between each pair of variables. However, the highest association is found between fruit weight and pulp weight (r = 0.997), due to the dependence between both variables on the profitability of the fruit product (Hinkle et al., 2003).

Table 2. Correlation analysis of the variables considered

Variable	Fruit weight (g)	Seed length (mm)	Seed width (mm)	Pulp weight (g)	Number of seeds (units)
Fruit weight (g)	1	r=0.931** (p=0.000)	r=0.891** (p=0.000)	r=0.997** (p=0.000)	r_s=0.915** (p=0.000)
Seed length (mm)		1	r=0.773** (p=0.000)	r=0.933** (p=0.000)	r_s=0.853** (p=0.000)
Seed width (mm)			1	r=0.895** (p=0.000)	r_s=0.796** (p=0.000)
Pulp weight (g)				1	r_s=0.899** (p=0.000)
Number of seeds (units)					1

r: Pearson's correlation coefficient; rs: Spearman's correlation coefficient
** Correlations are highly significant $p < 0.01$.

Source: Elaborated by the authors

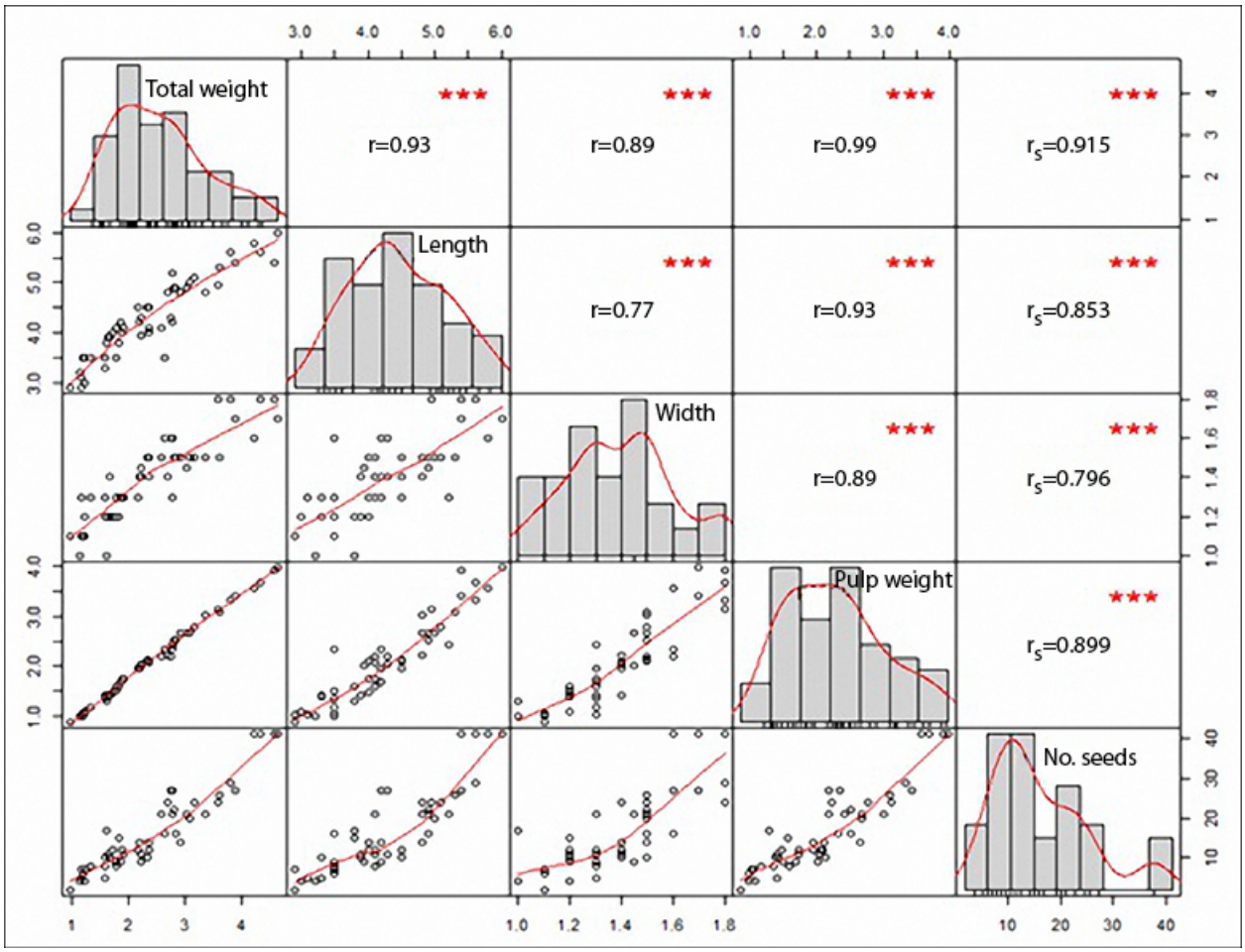

Figure 2. Scatter diagram and correlation of the variables.
r: Pearson's correlation coefficient; rs: Spearman's correlation coefficient
*** Correlations are highly significant $p < 0.01$.
Source: Elaborated by the authors

Conclusions

It is concluded that the morphometry of the fruits and seeds of *C. chinense* "ají mochero" allows differentiating it from *C. annuum, C. baccatum, C. frutescens*, and *C. pubescens*, among other species and varieties. This information is essential to promote its industrialization and support its designation of origin.

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Disclaimers

All authors made significant contributions to the document, agree with its publication, and declare that there are no conflicts of interest in this study.

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