



## Genetic Improvement of Guava (*Psidium guajava*): Utilization of the Diversity of Native Germplasm

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**Abstract:** The guava (*Psidium guajava* L.) belongs to the Myrtaceae family and originated in the tropical and subtropical regions of Mesoamerica and South America. In Mexico, a great phenotypic and genetic diversity of this fruit crop has been reported. Guava is an important fruit crop worldwide. In Mexico, 21,127 hectares are cultivated, with an annual production of 300,000 tons. For the past three decades, INIFAP (National Institute of Forestry, Agriculture and Livestock Research) has conducted studies on the collection, characterization, and *ex-situ* conservation of *P. guajava* germplasm to obtain the greatest genetic diversity to be used in the genetic improvement and the development of new varieties with comparative advantages. Currently, INIFAP maintains an *ex-situ* collection of *P. guajava* germplasm, comprising approximately 100 accessions from various states across the country. This collection includes information on the morphological characteristics of the fruit, revealing a wide range of diversity. Simultaneously it was carried out an evaluation and characterization of a group of outstanding selections from the Calvillo-Cañones region, from which the first five clonal varieties were derived and registered in the National Catalog of Plant Varieties of the National Seed Inspection and Certification System (SNICS). The registered varieties and their main fruit characteristics are: 1) **Calvillo Siglo XXI**: ovoid fruit, cream pulp, with a mesocarp thickness of 6 to 8 mm and a °Brix content of 12 - 14; 2) **Huejucar**: ovoid fruit with pale pink-cream pulp, mesocarp of 7 to 8 mm and °Brix of 12 - 14; 3) **Hidrozac**: truncated fruit, pink pulp, mesocarp of 10 to 12 mm and °Brix of 11 - 13; 4) **Caxcana**: round fruit, white-cream pulp, mesocarp of 8 to 9 mm and °Brix of 11 - 13; 5) **Merita**: ovoid fruit, cream pulp, mesocarp of 7 to 8 mm and °Brix of 12 - 14. These varieties have shown fruit yield greater than 15.0 tons ha<sup>-1</sup>, which is the average obtained at the national level.

**Keywords:** Morphological characterization, germplasm diversity, new varieties.

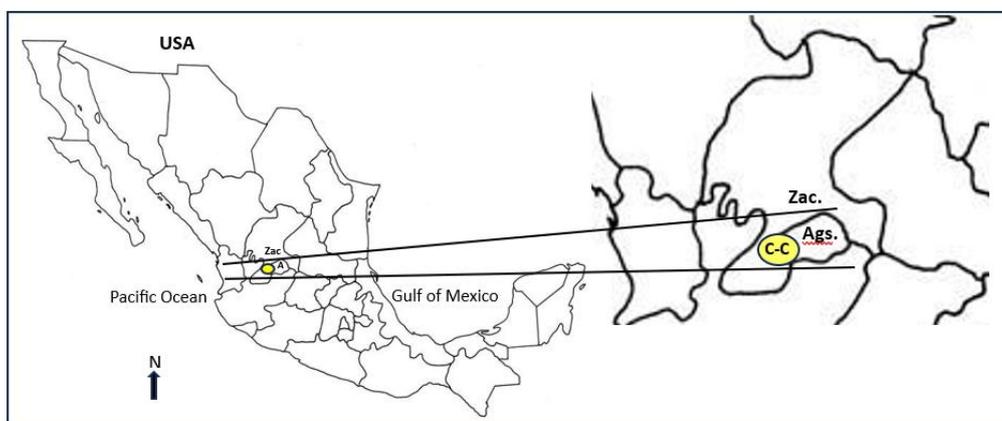
### INTRODUCTION

Guava (*Psidium guajava* L.) belongs to the Myrtaceae family and is primarily distributed in tropical and subtropical climates all around the world. Its origin was primarily located in the Mesoamerican region (Borys and Leszczyńska, 2001; Mitra and Sanyal, 2004; Negi and Rajan, 2007; CONABIO, 2020). However, more recently it has been proposed that the guava ancestor could be originated in South America, since archeological registers are older and more numerous than in the Mesoamerica region (Arévalo-Marín et al., 2021). The oldest archaeological record of this species in Mesoamerica is cited by Morcote-Ríos (2006), who mentions the discovery of guava seeds in the Tehuacán Valley, indicating its cultivation alongside other fruit trees and dating back 8,450-5,950 years. Currently, guava cultivation

is of great importance in several countries worldwide, including Mexico. In addition, the guava fruit has important nutritional attributes such as high vitamin content and others phytochemicals, which are important for human health (Chauhan et al., 2015).

Global guava production in 2018 was 7.8 million tons, of which 5.1 million tons were produced in Asia, mainly in India (4.1 million tons) and Pakistan (0.49 million tons). Africa produced 1.25 million tons, with Sudan and Egypt contributing 0.47 million tons and 0.31 million tons, respectively. Latin America and the Caribbean accounted for 0.86 million tons, with Brazil and Mexico being the main producers at 0.35 million tons and 0.30 million tons, respectively (Mendes et al., 2016; FAO, 2020). In Mexico, guava is among the top 10 fruit trees cultivated under irrigation with an average of 21,127 hectares during the last decade (2011-2020) and the main producing states are Michoacán (10,070 ha), Aguascalientes (6,347 ha) and Zacatecas (3,180 ha), which together represent 93% of the total area and contribute a production volume of 0.28 million tons annually (SIAP, 2021). Nevertheless, guava is also cultivated in another 15 states of the country where it plays an important socioeconomical role in the fruticulture of small scale.

The National Institute of Forestry, Agricultural and Livestock Research (INIFAP) through the Experimental Station of Pabellón, located in the Aguascalientes state has been working since the 1970s on developing technology for guava crop, primarily in the Calvillo-Cañones region, which encompasses the states of Aguascalientes and Zacatecas (Figure 1). Until the beginning of the 21st century, this region was the most important guava-producing region in the country, with an average cultivated area of 12,490 has during the last ten years (1991 - 2000), reaching a production of almost 150 thousand tons per year. (SIAP, 2021).



**Figure 1:** Localization of the Calvillo-Cañones (C-C) region, one of the largest producing guava areas, located in the Aguascalientes (Ags.) and Zacatecas (Zac.) states in Mexico.

INIFAP's research on this crop has included various aspects, among the most important being nutrition, control of major pests and diseases and germplasm collection, conservation and characterization (Padilla et al., 1999; Padilla and González, 2008). Regarding the work on the genetic resources of *P. guajava* for genetic improvement purposes, it has intensified significantly at INIFAP in the last three decades. It is important to point out that although *P. guajava* is mainly a self-pollinated crop, some cross pollination does occur, resulting in a large variability in the seedling population (Mitra and

Thingreingam, 2018). The main results obtained showed a great morphological diversity of the native guava germplasm (Padilla et al., 2010; Padilla et al., 2016b; Ventura-Medina et al., 2025) indicating the importance of its utilization on the genetic improvement programs to develop guava varieties having comparative advantages for producers as well as consumers. Thus, this work presents the process followed to obtain the first guava varieties in Mexico.

## **MATERIALS AND METHODS**

The success of a genetic improvement program is considered to be based on the availability of a wide range of genetic variability in the available germplasm (Bellon et al., 2009; Rimieri, 2017). Therefore, special emphasis has been placed on selection, collection, characterization, and *ex situ* conservation efforts, with the aim of obtaining the greatest possible diversity of *P. guajava* germplasm for the genetic improvement program. This diversity will allow for the development of varieties with comparative advantages in terms of yield and fruit quality. The first efforts to select outstanding guava material were carried out in Calvillo, Aguascalientes, starting in the late 1960s (Pérez, 1970). Subsequent studies demonstrated the great phenotypic and genetic diversity of the *P. guajava* germplasm, especially in various fruit characteristics such as: size, shape, external/internal color, number of seeds, total soluble solids/vitamin C content, etc. (Laksminarayana and Moreno, 1978; Perales and Silguero, 1995; Padilla et al., 2002; Padilla and González, 2010; Padilla et al., 2016b; Cortes et al., 2016).

Currently, INIFAP maintains an *ex-situ* collection of *P. guajava* germplasm, comprising just over 100 accessions from different states of Mexico. These collections began in 2004. In addition, there is a group of genotypes that were selected in the Calvillo-Cañones region starting in the early 1980s. All the *P. guajava* germplasm was established under field conditions (1,111 plants ha<sup>-1</sup>) at the “Los Cañones Experimental Site”, located in municipality of Huanusco, Zacatecas (21° 44.7'; 102° 58.0'; 1,508 m), which belongs to INIFAP. Information on the morphological characterization of the fruit, based on the UPOV (1987) descriptors was carried out during several crop cycles for the germplasm collections.

From the 126 guava selections collected in the Calvillo-Cañones region and established at the Los Cañones Experimental site since the 1980s, a group of twelve outstanding genotypes were selected. Fruit yield was evaluated on these genotypes over nine annual production cycles (2000-2009). From this group, the first five guava varieties in Mexico were chosen and registered. These varieties exhibited an average yield exceeding 25 tons ha<sup>-1</sup> during the evaluation period (Padilla et al., 2010; Padilla et al., 2016a). Furthermore, their morphological characteristics were determined according to the UPOV (1987) descriptors for registration purposes. The descriptors given by the UPOV for *P. guajava* includes a total of 57 descriptors (27 for fruits, 21 for leaves, 5 for flowers, 2 for shoots, 1 for tree branches and 1 for earliness (period from flowering to fruit maturity)).

## **RESULTS AND DISCUSSION**

Regarding the guava collections, some of the fruit characteristics of the evaluated accessions showed the following data: Fruit weight: 27.1-306.7 g; Polar Diameter: 3.4-8.6 cm; Equatorial Diameter: 3.3-8.0 cm; DP/DE ratio: 0.87-1.48; Pulp thickness: 4.5-15.0 mm;

Total soluble solids: 6.9 - 15.2 °Brix; Number of seeds per fruit: 50.4-337.7. Concerning fruit shape and pulp color, the following have been observed: ovoid, pear-shaped, round and truncated, and pulp color mainly cream, pale pink, white, pale cream-pink and pink. The vitamin C content in the fruit has shown values ranging from less than 100 to more than 400 mg of ascorbic acid per 100 g of fresh tissue (Padilla et al., 2014; Padilla et al., 2016b; Padilla et al., 2018). This information reveals the great diversity of the *ex-situ* guava collection, making its conservation and utilization important (Figure 2).



**Figure 2:** Fruit diversity of the *ex-situ* collection of *P. guajava* germplasm from INIFAP.

At the world level, approximately 400 guava varieties are reported (Mitra and Thingreingam, 2018), whereas in Mexico there were no registered varieties of guava prior to this work. Most of the germplasm used corresponds to native germplasm which is generically called as “Media china”. Although, Media china cultivars have good adaptation to soil and climate conditions, as well as producing fruit that is well accepted by consumers, there is great heterogeneity between and within guava orchards (Martínez et al., 2004). Thus, the availability of varieties with competitive advantages allowed the establishment of homogeneous guava orchards that produce uniform and quality fruit for the industry or fresh market.

Therefore, another contribution to guava genetic improvement, including the establishment of a *ex-situ* collection of about 100 accessions showing a great phenotypical diversity, has been the selection, evaluation, and characterization of a group of outstanding selections from the Calvillo-Cañones region, from which the first five clonal varieties registered with the National Seed Inspection and Certification Service (SNICS) were obtained (Padilla et al., 2010). Table 1 shows some of the fruit characteristics and the registration numbers of these five varieties in the SNICS-National Catalog of Plant Varieties. These varieties have showed fruit yields exceeding the national average of 15.0 tons ha<sup>-1</sup> during its agronomical evaluation.

**Table 1: Fruit Characteristics of the guava varieties registered by INIFAP.**

Trait	Variety					
	Calvillo XXI	Siglo	Huejucar	Hidrozac	Caxcana	Merita
Fruit form	Ovoid		Ovoid	Truncated	Round	Ovoid
Fruit weight	60-80 g		70-80 g	70-90 g	70-80 g	60-80 g
Fruit diameter	4.5 a 5.0 cm		4.8 a 5.5 cm	5.0 a 5.5. cm	4.8 a 5.5.	4.5 a 5.0 cm
Pulp color	Cream		Pale Pink-Cream	Pink	White-Cream	Cream
Pulp thickness	6 - 8 mm		7 - 8 mm	10 - 12 mm	8 - 9 mm	7 - 8 mm
Seeds/fruit	190 - 210		175 - 200	200 - 230	300 - 310	150 - 170
°Brix	12 - 14		12 - 14	11 - 13	11 - 13	12 - 14
Register Number	GUA-005-160709		GUA-001-160709	GUA-002-160709	GUA-003-160179	GUA-004-160179
						

Although the main criterion in the evaluation of these new varieties was the yield potential and fruit quality similar to the "Media china" type, which has good acceptance for its aroma and flavor, in the medium and long term, the objectives in the development of new varieties that satisfy the national and export market, should also include other aspects such as: fewer seeds, attractive skin and pulp color, longer shelf life, higher content of soluble solids and vitamin C, tolerance and/or resistance to pests and diseases.

## CONCLUSIONS

The work carried out by INIFAP in Aguascalientes in the field of *P. guajava* genetic resources has yielded a group of accessions that represent a wide variability in fruit characteristics. This will allow for the development of new varieties with comparative advantages for both the domestic and export markets. Additionally, the first five registered guava varieties in Mexico, which were obtained from germplasm selected in the Calvillo-Cañones region, it will be possible to establish homogeneous guava orchards for the production of higher-quality fruit.

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