

## PEASANT AND SCIENTIFIC CRITERIA FOR THE CHARACTERIZATION OF NATIVE MAIZE, ACAMBAY, MEXICO

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### ABSTRACT

Farmers and scientists use multiple criteria to categorize native maize varieties. However, these criteria are documented separately, and farming knowledge or scientific knowledge is omitted. This research was carried out from August 2022 to May 2024, with the aim of analyzing farming and scientific criteria for the characterization of native maize, to help reevaluate the peasant biocultural heritage of two communities in Acambay, State of Mexico. To identify these criteria, 20 semi-structured interviews were applied to peasants from San Pedro de los Metates and Ganzda, in the municipality of Acambay (5 women and 5 men per community); also, a workshop for dialogue was developed with 7 scientists, who are experts in native maize. Responses were openly coded, using the ATLAS.ti 2024 software; they were organized using a categorization matrix and analyzed with Microsoft Power.BI. Between them, farmers and scientists use 175 criteria to characterize native maize varieties. These criteria are classified into 10 categories, the most important of which are uses, morphology, processing, resistance and phenology. 41.7% of these criteria correspond to intrinsic qualities and 58.3% to extrinsic factors; closely related to native maize varieties. The criteria used by Otomi peasants and scientists together improve understanding of the nature of native maize and strengthen the reevaluation of this biocultural heritage.

**Keywords:** characterization, native maize varieties, otomi, peasant knowledge, scientific knowledge.

### INTRODUCTION

Mexico is recognized as the center of origin, for domestication, and diversification of maize (Kato *et al.*, 2009). Within its borders, there is the greatest abundance of maize biodiversity worldwide that includes 59 native races and thousands of varieties (Flores-Pérez *et al.*, 2015). The importance of native maize lies in the fact that it is closely related to food concerns and political, economic, social, and cultural aspects in the communities where it was developed (Lazos and Chauvet, 2011). This relationship is so symbiotic that they can be said to represent a single entity (Tutoral, 2023). Maize diversity

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constitutes the most important contribution made by Mesoamerican cultures to humanity (Toledo and Barrera, 2020). Multipurpose use is the factor that most influences the development of existing varieties, among which the following stand out: food, fodder, medicinal, ornamental and ritual uses (Guevara-Hernández *et al.*, 2023). However, when revaluing the biocultural heritage of peasants, only intrinsic phenotypical characteristics are taken note of (González-Martínez *et al.*, 2019; SNICS, 2024) or on a separate basis, sociocultural aspects associated with these varieties (Arias-Yero *et al.*, 2022). Attempts have been made to integrate these aspects, which have shown that the complementarity between peasant knowledge and scientific knowledge leads to a greater understanding of the nature of native maize varieties (Cruz *et al.*, 2016; Flores *et al.*, 2018). In this sense, some previous research such as that carried out by Sánchez *et al.* (2015) and Flores *et al.* (2018) combined peasant and scientific knowledge and thus expanded the criteria with which maize is identified and, therefore our understanding of it. However, each biocultural region has its own particularities that determine the characteristics of native maize varieties. It is thus necessary to conduct local studies related to culture and environment, so the objective of this study was to analyze peasant and scientific criteria for the characterization of native maize that contribute to the revaluation of the peasant biocultural heritage of two Otomi communities in Acambay, State of Mexico.

## THEORETICAL FRAMEWORK

Native maize is the product of peasant intervention over more than 300 generations, who have influenced its development for more than 9,000 years (Piperno *et al.*, 2009). This has been possible thanks to long processes of selection, propagation and conservation, where farmers have prioritized desirable traits (Guevara-Hernández *et al.*, 2019); resulting in 59 races and thousands of varieties of native maize (Heck, 2016), distributed and adapted to different regions of Mexico, to date. Each of these varieties of native maize presents particular qualities and attributes, which are clearly identified by farmers and scientists; the latter actors are key to conserving peasant biocultural heritage (Vázquez and Córdova, 2014; Toledo *et al.*, 2019).

Firstly, peasants identify their maize varieties according to criteria of use: food (González and Reyes, 2014), forage (Fernandes *et al.*, 2022), medicinal (D'Alessandro and González, 2017) and ritual (Kandonwangko *et al.*, 2020; Ahmad *et al.*, 2021), morphological (Rodríguez *et al.*, 2015; Castillo, 2016; Ahmad *et al.*, 2021), resistance or tolerance to different climatic conditions (Rodríguez *et al.*, 2015; Castillo, 2016), adaptation to different soil conditions (Reyes, 2016), worldview (Romero *et al.*, 2004; Lozada, 2014) and linguistic denomination (D'Alessandro and González, 2017; González-Valdivia *et al.*, 2017).

Likewise, scientists have criteria that diverge and converge from those of peasants, mainly morphological (Wellhausen *et al.*, 1951; Hernández and Alanís, 1970; Ortega, 1985), phenological (Quishpe, 2010), genetic (Chan-Chan *et al.*, 2021), organoleptic (Xochipa-Morante, 2021), nutritional (Antúñez, 2023) and edaphoclimatic (Pizarro *et al.*, 2014).

The theoretical viewpoint of this article considers that understanding the nature of native maize can only be promoted through the complementarity of knowledge systems. Blanco and Pirela (2022) define this as a proposal for the integration of approaches to the study of the same problem or object of study, through the use of different methods, designs, techniques, procedures for data collection and analysis, considering different options, according to the criterion selected to carry out the integration exercise; that is, recognizing that peasant knowledge and scientific knowledge are equally valuable and can enrich each other for the understanding and preservation of the biocultural heritage of maize (Cruz *et al.*, 2016). In one sense, the participation of scientists contributes with methodologies for genetic, phenological, morphological and taxonomic analysis (Vega *et al.*, 2022); and likewise, farmers contribute with an appreciation beyond the intrinsic characteristics of the varieties, to include extrinsic processes that they relate to: environment, uses and worldview (Castillo, 2016).

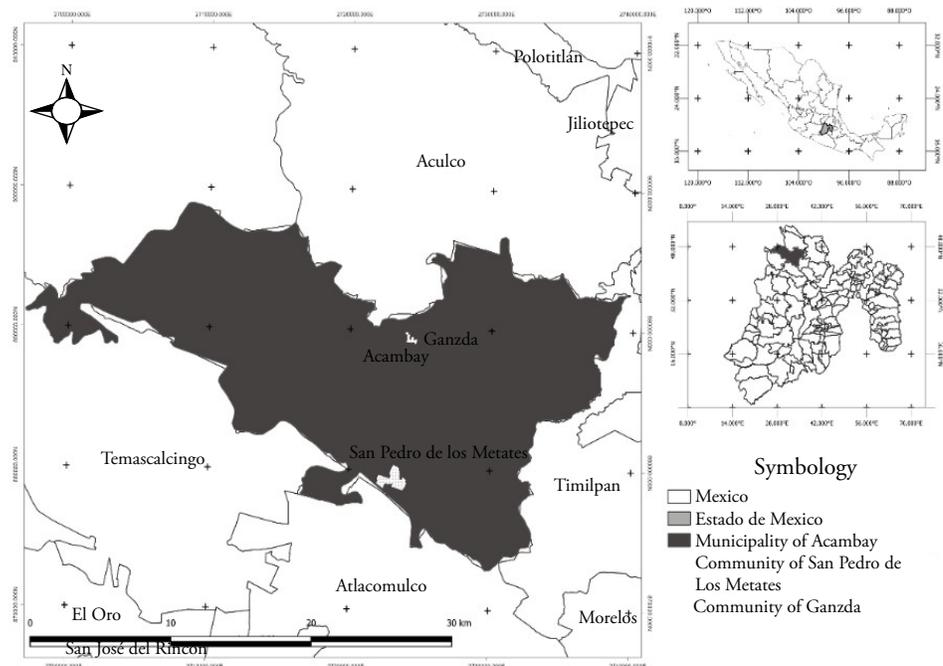
Some projects have made progress in integrating scientific and peasant criteria that characterize native maize varieties, and thus comprehension of their nature has been expanded. For example, Sánchez *et al.* (2015) used the manual of Carballo and Benítez (2003) to describe native maize varieties, along with peasant descriptors and identified not only phenotypical characteristics but also use and organoleptic criteria. For their part, Flores *et al.* (2018) used the CIAT methodology and peasant criteria, and the appreciation of the varieties studied was greater, as they combined use, with criteria referring to origin and morphology. These studies are the starting point to continue building methodologies that integrate and allow us to understand the complexity of the nature of native maize in its entirety (Escobar-Moreno, 2006). This, together with the above enables us to comprehensively characterize the diversity of native maize in each region, in this case, those from the municipality of Acambay, State of Mexico; and consequently, to defensively protect the peasant biocultural heritage.

## METHODOLOGY

This study was carried out in Ganzda and San Pedro de los Metates; communities in the municipality of Acambay, State of Mexico, Mexico. The criteria for including these two communities were: constituting rural localities, with more than 50% of indigenous Otomi population involved in peasant agriculture. The work period was from August 2022 to May 2024.

### Location and characteristics of the study area

The participating communities, Ganzda and San Pedro de los Metates belong to the municipality of Acambay, State of Mexico (Figure 1), which is made up of a total of 120 communities. Ganzda is located in the northern part of the municipality; its geographical coordinates correspond to 19°59'23" N and 99°50'50" W. It is situated at an elevation of 2,800 meters above sea level. It has a population of 2,089 inhabitants, where seasonal agriculture predominates and represents the fourth community in the municipality, in terms of greatest number of inhabitants, of whom 66% self-identify as members of the Otomi ethnic group. For its part, San Pedro de los Metates is located between the geographic coordinates 19°53'44" N and 99°51'33" W, at an average elevation of 2,500 meters above sea level, where irrigated agriculture is predominant. The 2,993 inhabitants in the community make it the fifth largest in the municipality and of this total, 59.35% are part of the original Otomi group (INEGI, 2020). The two communities selected are representative of the area, due to the type of agriculture they practice, their social organization and cultural affiliation. The Otomi abide by their uses and customs; in this system, the delegation, committees and religious positions predominate; one of the main economic



Source: self-elaborated.

**Figure 1.** Geographical locations of the communities of Ganzda and San Pedro de los Metates, Acambay, Estado de México, México.

activities is agriculture, where maize is mainly established as a monoculture although in some cases, it is combined with beans, broad beans and squash.

### **Selection of collaborators**

For the purpose of this research, two groups of collaborators were established: farmers and scientists; for both groups, the discretionary convenience sampling method was applied (Otzen and Manterola, 2017). Criteria for the selection of the collaborating farmers complied with the peasant typology of Sánchez *et al.* (2015): 1) Otomi speaker, 2) plants native maize, 3) self-selects their seeds, 4) seeds must be more than 5 years old, 5) be grown on their own plot, and 6) same number of men participating as women. In each of the participating communities, 10 people were selected, 5 men and 5 women; a total of 20 participants between the two communities. Regarding the selection of collaborating scientists, virtual research was also used (Ruiz and Aguirre, 2015). For these, eligibility criteria were established as follows: 1) experts on native maize, 2) knowledge of the varietal characterization of native maize, and 3) members of an agricultural research institution. In total, seven scientists, who are experts in native maize participated, pertaining to the following agricultural institutions: Colegio de Postgraduados (Campus Montecillo), Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Tecnológico del Valle de Oaxaca, Universidad Autónoma Chapingo, Universidad Intercultural del Estado de México, Universidad Nacional Autónoma de México and Secretaria de Ciencias, Humanidades, Tecnología e Innovación.

### **Data collection**

In order to identify the peasant and scientific criteria applied to varieties of native maize in two communities in Acambay, State of Mexico; two procedures were established conforming to each context. A semi-structured interview was designed for the farmers, based on 45 questions organized into nine categories: 1) personal data (5), 2) plant morphology (10), 3) phenology (6), 4) uses (7), 5) resistance (3), 6) edaphoclimatic conditions (4), 7) worldview (3), 8) management (5) and 9) organoleptic characteristics (2) (Xochipa-Morante *et al.*, 2021; Beltrán, 2021). Interviews were applied during the two-month period of December 2022 - January 2023. These were applied personally during the daily work schedule, with an average duration of one hour. For the scientists, a virtual dialogue workshop was designed on February 6, 2023, using the Zoom platform. Prior to the workshop, each participant answered the question: What criteria do you consider important for the characterization of native maize that are not considered in official procedures? This question was applied using Google Forms, allowing 20 minutes for their response. Answers

were downloaded immediately in XML format using the Excel 2021 software. The data retrieved was used to make a list of principal concepts, which were categorized according to the similarity of the area studied, relating to each category (Romero, 2005). Based on this list of 40 concepts, a discussion was initiated with the participating scientists, so they could express their arguments clearly. This discussion lasted 1.5 hours. The workshop session was recorded and downloaded in Zoom.

### **Systematization and data analysis**

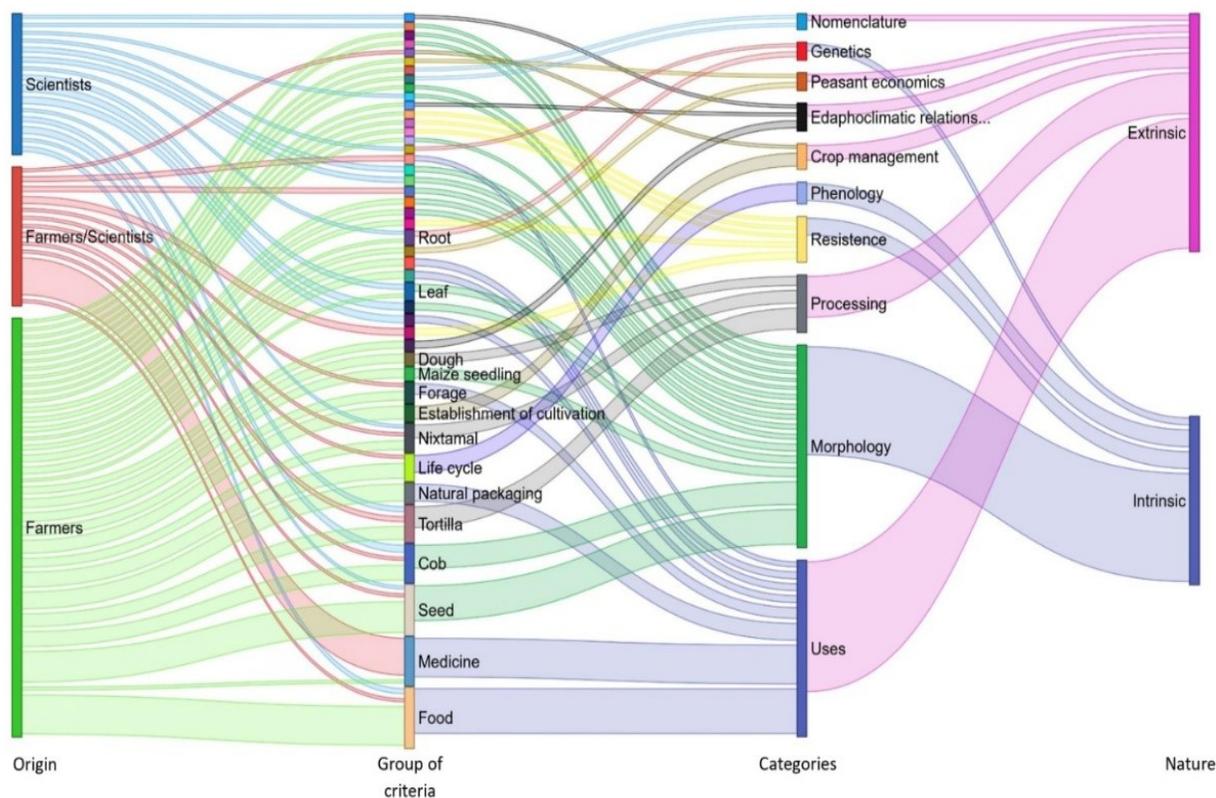
Audios from the semi-structured interviews applied to farmers were transcribed into .docx format, using Microsoft Word 2021 software. Subsequently, these files were converted to PDF format, to be exported to the ATLAS.ti 2024 program. Open coding was used with this program, following the method proposed by Monge (2015), with which relevant segments of the data were identified, codes corresponding to emerging themes were assigned and then these codes were organized into groups, according to their position in the hierarchy and relationship with other codes. Finally, a categorization matrix was developed using qualitative analysis. In this matrix, the codes were organized into categories, groups, and type (intrinsic and extrinsic). The responses to the questionnaire applied to the scientists were downloaded and systematized in Excel 2021 software. The open coding method (Monge, 2015) facilitated the grouping of data according to similarities. Then, through qualitative analysis, a categorization matrix was created following that of Romero, 2005; the codes were organized in the same way as those of farmers. Finally, both categorization matrices were combined and loaded into the Microsoft Power BI tool, so that data analysis could be carried out by generating Sankey diagrams.

## **RESULTS**

### **Farmer and scientific criteria**

The interviewed farmers from the municipality of Acambay and the scientists specializing in maize, participating in this study use 175 criteria to distinguish, characterize and assign significance to native maize varieties. Of all the criteria identified; farmers and scientists coincided in the case of 19.4%, 65.7% were only put forward by farmers and 14.8% only by scientists (Figure 2).

The main categories are arranged from highest to lowest frequency of mention and relate to criteria that include uses for food and medicinal, wrapping, forage, religious, fertilizer, combustion and artisanal purposes. Criteria (from the most to the least numerous) related to morphological aspects that include seed, cob, maize seedling, nodes, leaf, grain, adventitious roots, cob, mucilage adventitious roots, plant habit, pollen, stigma, raceme and internodes.



Source: self-elaborated from collected data.

**Figure 2.** Convergences and divergences between peasant and scientific criteria that distinguish, characterize and assign significance to native varieties of maize.

Processing criteria include nixtamalization (production of dough) and tortilla making. Criteria related to resistance include pests in storage facilities, diseases or pests in the field, droughts and frosts. And phenological criteria that relate to the life cycle of maize.

### Criteria for use

Apparently, food is the largest group of the 44 identified, with 65 criteria; 38 mentioned only by farmers, 5 by scientists and 22 where they coincide. The criteria that peasants consider when consuming the stem, cob, spike and grains, principally include color, shape, phenological stage, management, dish to be prepared, and presence or absence of another organ in the plant. For example, if the maize stalk is to be consumed, they consider whether there are any more pollen grains in the spike, whether the stalk has any more cobs, yellowish color in the leaves and stem and poor fertilization; in the case of cob consumption, they may prefer a specific color (white,

blue, yellow, pink), whether the spike has a curved shape, also there should be no more pollen in the spike and grains should be in a milky state; to consume ears of corn, it is important to make sure that they are still fresh, so that they can be adequately ground to make the dough for tortillas, or not so well ground, to make “gorditas” (small thick tortillas). For grain consumption, the relationship between degree of ripeness and the dish to be prepared is taken into account; going from less to more ripe: “esquites” grains removed from the cob, maize on the cob, maize bread, “gorditas” (small thick tortillas), toasted grains, and when they are hard “pinoles” (roasted ground maize), tortillas, atoles (maize gruel), “tamales” (maize dough with a filling) and “tostadas” (toasted maize biscuit). There is a close relationship between the color, flavor and texture of the grains, and depending on the dish that the peasant family prepares; this will be their choice. For example, for tortillas, white, black and pink grains are preferred, which are sweet and the dough has a gelatinous texture; for tamales, white grains have a neutral flavor and gelatinous dough texture; for atole, white, black and pink grains have a sweet flavor and give it a soft and floury texture; for pinole, black grains have a sweet flavor and result in soft, floury texture (Table 1).

Medicinal use is the second largest group with 19 criteria, and both peasants and scientists pointed out its importance. It is noteworthy that peasants were the ones who specified the parts of the plant and how to use them. The parts they use include the stigma, grain, plant leaf, cob leaf and the “huitlacoche” fungus. The criteria they consider for their use are color, the part used, means of preparation and the diseases they cure. For example, when stigmas are used, they consider whether they are black, pink or white corn and whether they are fresh to prepare a tea for bone pain, headache, stomach pain, prostate pain and fright. In the case of black grains, the largest is roasted over a slow fire to make a tea that relieves stomach pain, loss of appetite and hangovers. The leaves from the plant, from pink, black and white maize, green or dried with either purple or pink hues, are prepared as tea for colds, fever, headaches, stomach aches, kidney and body pain. The leaves from the white maize cob are prepared as tea to relieve fever. And the huitlacoche fungus, which is from black or white corn, is dried, and the powder is spread on cancer, wounds or gangrene.

### **Morphological criteria**

After uses, morphological criteria are the most important for describing and characterizing native maize varieties. Criteria are listed, going from most to least numerous: seed, cob, maize seedling, nodes, leaf, grain, adventitious roots, cob, root mucilage, plant shape, pollen, stigma, spike and internodes.

**Table 1.** Grain criteria that peasants consider when preparing dishes.

Dish	Criteria				% of replies
	Madurity	Colour	Flavour	Texture	
Esquites/elote	Creamy	White	Sweet	Soft	30
Maize bread		White	Sweet	Soft	5
Gorditas	Soft dough	White	Neutral-sweet	Soft	10
Grains toasted		Black	Savoury	Crunchy	10
Pinole		Black	Sweet	Soft -floury	35
Tortillas		White, black and pink	Sweet	Gelatanous	100
Toasted	Mature	White and black	Sweet	Firm and chewy	5
Atole		White, black and pink	Sweet	Soft-floury	50
Tamales		White	Neutral	Gelatanous	70
Popcorn		Yellow	Savoury	Hard	5

Source: self-elaborated from collected data.

For example, the criteria that farmers take into account for seeds and cobs relate to shape, size, health, color, structure and management (Table 2).

### Criteria for processing

Another important aspect that peasants and scientists take into account to distinguish varieties of native maize refers to nixtamalization, dough and tortilla processes. The criteria that both consider for the production of nixtamal include requirements for lime, as well as yield and energy consumption. In the case of dough, these include yield, texture, color and aroma; whereas, for the production of tortillas they relate to cooking, texture, flexibility, size, yield, shelf life and reconstitution capacity. For example, farmers and scientists prefer tortillas that cook quickly, are soft, and flexible so they do not break when bent, that facilitate the production of tortillas of different sizes and produce the greatest number of tortillas per kilo of dough, which when reheated, recover their freshly made attributes.

### Resistance criteria

Peasants also identify their maize in terms of resistance to pests in the field and during storage, lodging, frost and drought. They know that white maize seedlings are hardly ever attacked by the maize worm (*Phyllophaga* spp.), that white and yellow maize are more resistant to being attacked by the maize moth (*Sitotroga cerealella*) during storage and that their shelf life is longer than that of pink and black maize. They also indicate that pink and black maize are highly resistant to drought and stalk lodging.

**Table 2.** Farmer and scientific criteria concerning the morphology of native maize cobs and seeds considered in the characterization of native maize.

Group	Criteria	Farmers	Scientists	Both
Maize	Diameter (base of the cob)			✓
	Apex of the cob			✓
	Number of cobs per plant	✓		✓
	Length	✓		
	Straight rows	✓		
	Number of cobs in the apex of the cob		✓	
	Percentage of big cobs	✓		
	Solid structure	✓		
	Humidity in the harvest	✓		
	Grain colour	✓		
	Ease for hand shelling		✓	
	Malformations		✓	
	Seed	Large cobs	✓	
Solid cobs		✓		
Cobs with greatest number of rows			✓	
Cobs with grain of uniform color		✓		
Cobs with straight rows		✓		
Cob with thin center		✓		
Whole		✓		
Full		✓		
Plague free		✓		
Not rotten		✓		
From the lower two-thirds of the cob		✓		
Varieties of local origin		✓		
White stalk		✓		
Tip of pedicel complete				✓
Low percentage of small grains		✓		
Low percentage of missing grains	✓			
Long term viability	✓			

Source: self-elaborated from collected data.

### Phenological criteria

At the same level of importance, peasants and scientists consider aspects related to the life cycle such as: level of precocity, month of sowing and harvesting, the lunar cycle and the position of the stars during sowing, as well as sowing technique, germination time and time taken to dry, prior to harvesting. Farmers know that white and yellow maize tend to be sown in the months of March and April, coinciding with the full moon. The first sprouts appear 15 days after sowing, which in most cases is accomplished using a tractor. These long-cycle varieties are harvested in December. In contrast, pink and black maize are sown at the end of April or during May. The germination period is faster, as the first sprouts appear eight days after sowing. In hilly areas, this sowing is still undertaken using a team of horses. Both pink and

black maize are considered short-cycle, as they can be harvested from mid-November onwards.

### Complementarity between peasant and scientific criteria

Individually, peasants contributed 149 criteria and scientists 60. The sum of both contributions is 175 criteria (Table 3). This total not only considers categories with greater criteria for peasants and scientists (uses, morphology and processing), but also those with fewer criteria (genetics, nomenclature and peasant economy).

Of the total number of criteria, 41.7% correspond to intrinsic qualities and 58.3% are extrinsic. Of the 149 criteria conceived by peasants, most represent extrinsic factors (62.4%); this assessment is similar among scientists; 58.3% of the 60 criteria they conceive. For peasants, as for scientists, the most numerous criteria are those of use (40.3 and 45%, respectively), in second place, those of morphology (26.2 and 31.7%, respectively) and in third place those of processing (11.5 and 10%, respectively); for peasants, in fourth place are also the criteria of resistance (5.3%) and phenology (5.3%).

## DISCUSSION

The 175 criteria that peasants and scientists involved in this study use to identify, characterize or assign significance to their native maize varieties are explained by the fact that maize varieties have resulted from a long process involving selection and distribution controlled by humans, where numerous introgressions between different genetic materials have occurred (Quevedo *et*

**Table 3.** Categories, groups and intrinsic and extrinsic criteria considered by peasants and scientists to distinguish, characterize and assign significance to native maize varieties.

	Category	Group	Criteria			Total
			Farmers	Scientists	Both	
Intrinsic	Morphology	16	35	15	4	54
	Phenology	1	7	0	1	8
	Genetics	2	1	2	0	3
	Resistance	5	5	0	3	8
Extrinsic	Use	8	38	5	22	65
	Relationship edaphoclimatic	3	4	1	0	5
	Cultivation management	2	6	0	1	7
	Nomenclature	2	2	0	0	2
	Economy farmer	2	3	0	0	3
	Process	3	14	3	3	20
Total		44	115	26	34	175

Source: self-elaborated from collected data.

*al.*, 2017). Besides this, the influence of the cultural context, geographic niche (McClintock *et al.*, 1981) and socioeconomic conditions of the peasant (Quevedo *et al.*, 2017) are also directly combined. This set of factors encourages native maize to be selected, produced, conserved, diversified and domesticated, based on the needs of farmers (Noriero and Massieu, 2018). An example of the above is that 88.6% of the criteria were found in the majority categories and groups such as: use (food-medicinal), morphology (seeds-maize cob), processing (nixtamal-dough-tortilla), phenology (life cycle) and resistance (frost-loam-drought-pests), aligning with peasant preferences. This contradicts studies that claim that variations in maize only result from genetic recombination that is carried out through the flow of pollen and the movement of seeds by peasants.

There is complementarity between criteria provided by peasants and scientists, when what is missing in one factor is fulfilled by another, in order to enhance its scope or benefits (Foyer *et al.*, 2014). This assertion is manifested in the 10 categories and 44 groups, which concentrate the contributions made by the group of participants, and with which, it is possible to advance the spectrum of understanding concerning the nature of native maize, as by only considering peasant criteria (149) or only scientific (60), important characteristics would have been omitted. This complementary approach not only makes it possible to combine knowledge and know-how, but has also proven to be effective for extending the scope of research (Blanco and Pirela, 2022), that is, although the majority trend of peasant contributions was towards use criteria (38 criteria), where there is a broad understanding of the management and local adaptation of crops, based on empirical observations and cultural practices rooted in the environment (Acuña, 2010). This was complemented with scientific criteria, mainly of morphological type (15), tending more towards the analytical and methodological (Vázquez, 2001). Likewise, this approach enabled greater verification and convergences in categories such as medicinal use, which represents 67.6% of the total.

## CONCLUSIONS

The criteria identified by peasants and scientists that characterize their native maize varieties are classified into 10 categories: use, morphology, processing, resistance, phenology, crop management, soil-climate relationship, peasant economy, genetics and nomenclature. The first five categories make up the greatest number of criteria (88.5%).

The criteria for characterizing native maize included 149 peasant criteria and 60 scientific criteria, totaling 175 criteria. This combination significantly broadened the perspective from which native maize varieties are described and offered a more complete view than if only one group had been considered.

The analysis of peasant knowledge and scientific knowledge allowed us to identify 175 criteria that characterize native maize. The recording and complementarity between these two viewpoints illuminate the broad nature and importance of the varieties of native maize present in the two communities of Acambay, State of Mexico. This work thus contributes to the revaluation and conservation of peasant biocultural heritage.

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