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Morpho-agronomic characterization of native maize populations (*Zea mays* L.), province of Manabí, Ecuador

Caracterización morfoagronómica de poblaciones de maíz criollo (*Zea mays* L.), provincia de Manabí, Ecuador

Caracterização morfoagronômica de populações de milho crioulo (*Zea mays* L.), província de Manabí, Equador

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Rev. Fac. Agron. (LUZ). 2024, 41(4): e244132
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v41.n4.01

Crop production

Associate editor: Dr. Jorge Vilchez-Perozo
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela

Received: 08-07-2024
Accepted: 16-08-2024
Published: 16-09-2024

Keywords:
Genotypes
Landraces
Genetic variability
Conservation of genetic resources

Abstract

Ecuador is a country with a wide genetic diversity of maize and there are populations of native maize conserved by farmers that have not yet been characterized. These genetic resources could be conserved and used in plant breeding programs. The objective of this research was to characterize the morpho-agronomic diversity of 38 populations of native maize from the province of Manabí, Ecuador, using 19 quantitative and 11 qualitative morpho-agronomic descriptors. During the dry season of 2022 (July - December) at the Portoviejo Experimental Station of the National Institute of Agricultural Research (INIAP), plots of 8 m^2 were established for each population of native maize, with 0.3 m between plants and 0.8 m between furrows and each furrow was 5 m long. Cluster analysis showed the formation of four groups, where the populations of hard kernels with large ears and soft kernels with short ears were separated into different groups. The quantitative variables ear height, panicle length, percentage of lodging, number of kernels per row and biomass of the inflorescence rachis recorded "D" indices of 0.75, showing themselves as discriminant variables in the formation of the groups, while the most discriminating qualitative variables were kernel type (χ^2 = 49.09***, P= 0.742, V= 0.64), kernel color (χ^2= 51.955***, P= 0.75, V=0.64), kernel row arrangements (χ^2= 18.11*, P=0.56, V=0.39), and kernel surface shape (χ^2 = 20.52*, P=0.58, V=0.41). The native maize races identified were Candela, Cubano, Tuxpeño, Tusilla, and Uchima, observing significant genetic diversity in the populations studied. It was concluded that the characterized native maize populations were a valuable genetic resource for the conservation and use of this cereal.

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Resumen

Ecuador es un país con una amplia diversidad genética de maíz y existen poblaciones de maíz criollo conservadas por los agricultores que aún no han sido caracterizadas; estos recursos genéticos podrían ser conservados y usados en programas de mejoramiento genético. El objetivo de esta investigación fue caracterizar la diversidad morfoagronómica de 38 poblaciones de maíces criollos de la Provincia de Manabí, Ecuador, utilizando 19 descriptores morfoagronómicos cuantitativos y 11 cualitativos. Durante la época seca de 2022 (julio - diciembre), en la Estación Experimental Portoviejo del Instituto Nacional de Investigaciones Agropecuarias (INIAP), se establecieron parcelas de 8 m^2 por cada población de maíz criollo, con un distanciamiento de 0,3 m entre plantas y 0,8 m entre surcos; 5 m de longitud por surco. El análisis de clúster mostró la formación de cuatro grupos, donde las poblaciones de granos duros con mazorcas grandes y la de granos suaves con mazorcas cortas fueron separadas en grupos diferentes. Las variables cuantitativas altura de la mazorca, longitud de panoja, porcentaje de acame, número de granos por hilera y biomasa del raquis de la inflorescencia registraron índices “D” de 0,75, mostrándose como variables discriminantes en la formación de los grupos, mientras que las variables cualitativas más discriminantes fueron el tipo de grano (χ^2 = 49,09***, P= 0,742, V= 0,64), color de grano (χ^2= 51,955***, P= 0,75, V=0,64), disposición de hileras (χ^2= 18,11*, P=0,56, V=0,39), y forma de la superficie del grano (χ^2 = 20,52*, P=0,58, V=0,41). Se identificaron las razas de maíz criollo Candela, Cubano, Tuxpeño, Tusilla y Uchima, observándose una diversidad genética significativa en las poblaciones estudiadas. Se concluyó que las poblaciones de maíz criollo caracterizadas resultaron un valioso recurso genético para la conservación y el uso del cereal.

Palabras claves: genotipos, variedades locales, variabilidad genética, conservación de recursos genéticos.

Resumo

O Equador é um país com grande diversidade genética de milho e existem populações de milho crioulo conservadas pelos agricultores que ainda não foram caracterizadas. Esses recursos genéticos poderiam ser conservados e utilizados em programas de melhoramento genético. O objetivo desta investigação foi caraterizar morfo-agronomicamente 38 populações de milho crioulo da província de Manabí. Foram estabelecidas parcelas de 8 m2 para cada população, com uma distância de 0,3 m entre plantas e 0,8 m entre linhas e cada linha tinha 5 m de comprimento; na Estação Experimental de Portoviejo do Instituto Nacional de Pesquisa Agrícola (INIAP), na estação seca de 2022 (julho - dezembro); e foram utilizados 19 descritores morfoagronómicos quantitativos e 11 qualitativos. A análise de agrupamento mostrou a formação de quatro grupos, onde as populações de grãos duros com espigas grandes e grãos moles com espigas curtas foram separadas em grupos diferentes. As variáveis quantitativas altura de espiga, comprimento de espiga, porcentagem de acamamento, número de grãos por fileira e peso de espiga apresentaram índices “D” de 0,75, mostrando-se como variáveis discriminantes na formação dos grupos, enquanto as variáveis qualitativas mais discriminantes foram tipo de grão (χ^2 = 49,09***, P= 0,742, V= 0,64), cor do grão (χ^2= 51,955***, P= 0,75, V=0,64), arranjo de fileiras (χ^2= 18,11*, P=0,56, V=0,39) e formato da superfície do grão (χ^2 = 20,52*, P=0,58, V=0,41). Foram identificadas as raças de milho crioulo Candela, Cubano, Tuxpeño, Tusilla e Uchima, mostrando uma diversidade genética significativa nas populações estudadas. Estes resultados realçam a importância destas populações de milho crioulo como um recurso genético valioso para a conservação e utilização do cereal.

Palavras-chave: genótipos, variedades autóctones, variabilidade genética, conservação de recursos genéticos.

Introduction

Maize (*Zea mays* L.) is an annual grass native to Mexico, which is its center of origin and diversity (Bellon and Berthaud, 2006), from where it migrated to other parts of America (Eubanks, 2001). Three hundred and sixty-two (362) races are recognized, some of them distributed in Mexico (64 races), Peru (52 races), Argentina (43 races), Bolivia (40 races), and Ecuador (29 races) (Guzzon *et al*., 2021). In Ecuador, some 675 populations representing such 29 races were collected (Timothy *et al*., 1963), and currently, 36 races of maize have been recorded, 26 present in the Sierra (six of which are not well defined) and the rest in the Litoral and Amazon regions (Tapia *et al*., 2015; Tapia *et al*., 2017).

Maize plays a significant role in the food security of the population of Ecuador (Caviedes *et al*., 2020). The Food and Agriculture Organization of the United Nations (FAO, 2022), indicates an area of 362,473 ha, with an average yield of 4.52 $t.ha^{-1}$ and a total production of 164,113,123 t, approximately 80 % corresponded to hard maize and 20-22 % to soft maize. Manabí is one of the main producing provinces, with a harvested area of 83,000 to 113,945 ha in recent years (INEC, 2023).

Important research has been carried out on the morphological diversity of maize in all provinces of the Sierra region (Tapia *et al*., 2021), highlighting the continuity of 23 maize races, however, so far there is no important research history of the diversity of maize races on the Ecuadorian coast since 1963, this includes the province of Manabí where Timothy *et al*. (1963) documented the presence of the Candela, Cubano, Tuxpeño, and Chococeño races. Small efforts have been made to characterize the Candela race, in the Sancán commune, Jipijapa, Manabí (Fuentes *et al*., 2022).

Currently, there are races of native maize conserved by farmers in the province of Manabí that have not been studied, so it is imperative to investigate and deepen the knowledge of this subject. The objective of this research was to characterize the morpho-agronomic diversity of native maize populations (*Zea mays* L.) in the province of Manabí, Ecuador, identifying their races and evaluating their variability to develop conservation strategies and use in breeding programs.

Materials and methods

This research was carried out during the dry season of 2022 (July - December), at the Portoviejo Experimental Station (EEP) of the National Institute of Agricultural Research (INIAP) located in the Lodana parish, province of Manabí, Ecuador; 1º09’52.1’’ S; 80º22’53.7’’ W. Thirty-eight (38) maize populations collected in the rainy season (January to June) of 2022 in the Province of Manabí (figure 1A) were used, following the recommended methodology (FAO, 1994). However, the IPFR-013 population did not record values in the productive characteristics and was excluded from the analysis since it did not complete its productive stage, this is because this population presented a percentage of 100 % of lodging in the experimental plot before the maturity of the crop.

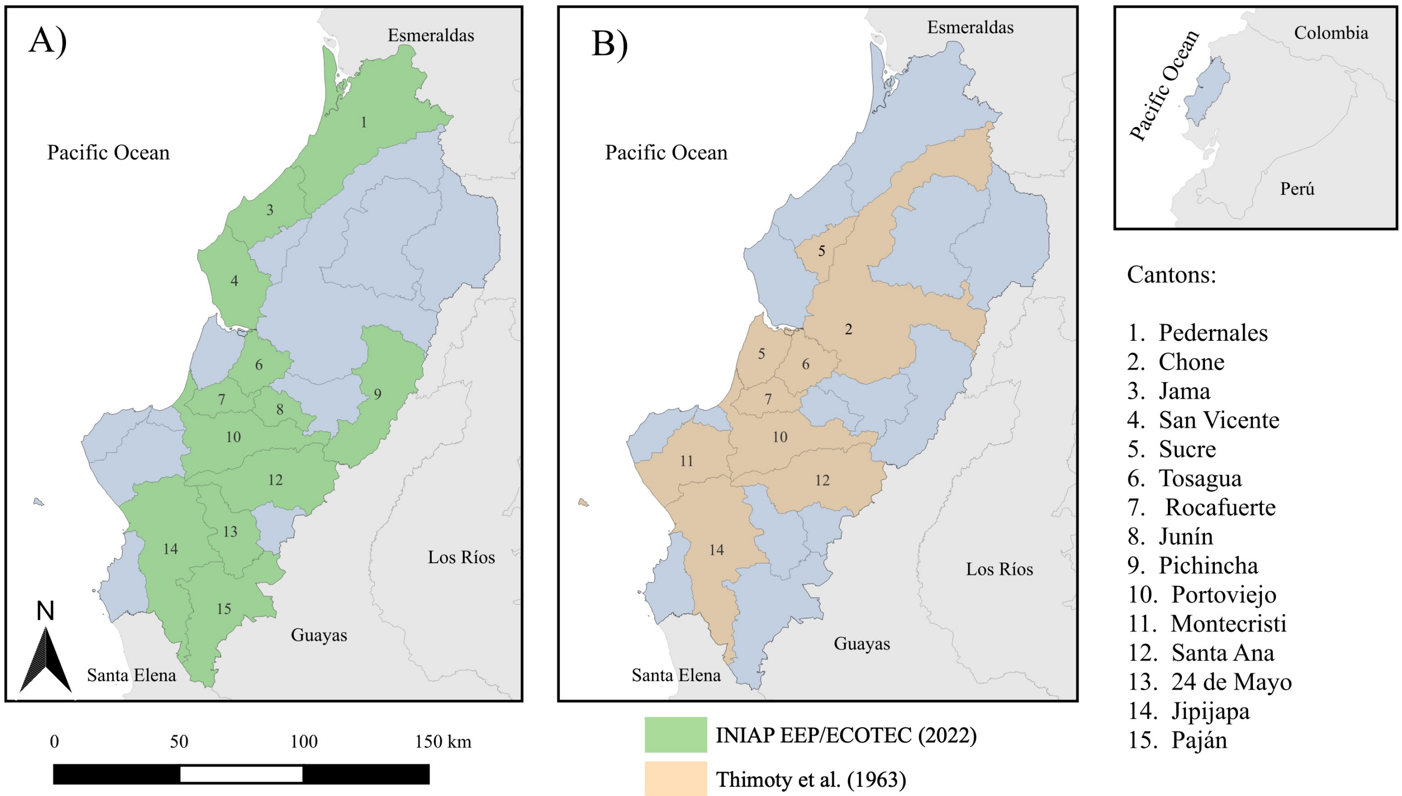

Figure 1. Cantons of the province of Manabí sampled. A) in the collection of native maize populations in 2022; B) in the collection of native maize populations carried out by Timothy *et al*. (1963).

The agronomic management of the experiment was in accordance with the commercial procedure in the region: To homogenize the soil and favor the decomposition of organic matter, the land was prepared mechanically using a plough pass and two harrows, thirty days before planting. Before planting, the seed was treated with the insecticide Semeprid (25 mL.kg of seed^{-1}). Planting was done manually, one seed was sown every 0.3 m between plants and 0.8 m between 5 m rows; two furrows per population.

For weed control, the pre-emergent herbicides, pendimethalin (3 L.ha-^{1}) + terbutryn (0.8 L.ha^{-1}), were applied at the time of planting. For emerged weeds, glyphosate (2 L.ha^{-1}) was used and supplemented with manual weeding at 40 to 45 days after planting (dds). Chlorpyrifos (1.5 L.ha^{-1}) was used to control insect pests predominant in the area, and for *Spodoptera frugiperda*, at 35 days, a chemical bait prepared with 25 kg of sand treated with 120 mL of chlorpyrifos was applied to the bud of each plant.

Chemical fertilization was performed based on a nutritional analysis and crop requirements, using triple superphosphate (46 % P_2O_5; 50 kg.ha^{-1}), muriate of potash (60 % K_2O; 50 kg.ha^{-1}), Nutrimenores® (22 % SO_4; 18 % K_2O; 22 % Mg; 46 kg.ha^{-1}), and urea (46 % N; 450 kg.ha^{-1}). The application of phosphorus and potassium was carried out in the bands on both sides, at 8 days, while the application of nitrogen was made at 15, 30, and 45 days, divided into three equal applications.

Prior to anthesis, the female inflorescence was covered with glassine envelopes to ensure homogeneity and avoid cross-contamination between populations. In the flowering stage, intra-population-directed cross-pollination was carried out. The harvest was carried out at physiological maturity. In each experimental plot, five plants' traits were recorded randomly, in different phenological stages (at the beginning of the anthesis, middle of the anthesis, and after the milky stage), whose ears were evaluated at harvest (20 kernels of each genotype). The percentage of lodging was determined in 10 plants. At the time of harvest, five ears from each plant were evaluated.

For the morpho-agronomic characterization, 30 descriptors were used, 19 quantitative and 11 qualitative (IBPGR, 1991; CIMMYT, 1995; Carballo & Ramírez, 2010). For the typification of native races, the characteristics described by Timothy *et al*. (1963), are based on traits of the plant (stem, leaves, and panicle), and of the ear (kernels and rachis of the inflorescence).

Descriptive statistics and multivariate analysis were used for data analysis. Hierarchical Cluster analysis (HCA) was performed with a mixed matrix of variables, using Gower's distance and Ward's hierarchical method. For the comparison of means between the groups, Duncan's test ($P < 0.05$) and Engels' "D" index (1983) were used. To identify the most discriminating qualitative descriptors, the methodology of Tapia (2003) was applied, using the Chi-square (X^2), Cramér's coefficient (V), and contingency coefficient (P) tests. Statistical analyses were performed in the R version 4.4.0 program (R Core Team, 2024).

Results and discussion

The morpho-agronomic characterization of 38 populations of native maize from 12 cantons of the province of Manabí (figure 1A) allowed the registration of five maize races: Candela, Cubano, Tuxpeño, Tusilla, and Uchima; the last two had not been reported in the province of Manabí. Timothy *et al.* (1963) in their tour of nine cantons (figure 1B) found: Candela, Tuxpeño, Cubano, and Chococeño.

The absence of Chococeño in this research could be explained in part by the discontinuation of the cultivation of this race. In this regard, Brush (1991) mentions that the loss of these centers of domestication and diversification of cultivation caused the erosion of races, customs, and knowledge that sustain these systems. It is also possible that sampling has not fully captured all existing diversity, especially in areas with less agricultural activity or limited access.

The variability of the maize populations collected in Manabí is evidenced by the coefficients of variation (CV) greater than 10 % in most quantitative characteristics (table 1). The variables with the greatest variation were the percentage of lodging (0 – 95 %), the biomass of the inflorescence rachis (6.8 – 38.2 g), and ear biomass (44 – 226.2 g), with CV of 78.6, 47.82, and 35.25 %, respectively. Similar results were obtained by González *et al*. (2020) and Flores *et al*. (2022) in studies of the diversity of the Cacahuacintle race in Mexico, with high variations in the variables biomass of the inflorescence rachis (CV: 23.5 %) and ear biomass (18.13 %) (table 1). The characteristics of the percentage of lodging, ear biomass, and the inflorescence rachis, are frequently used as a selection criterion by producers of native maize. For example, in the municipalities of Villaflores and Villa Corzo, Chiapas, Mexico, the most commonly used criteria for the selection of native maize are larger ear size, higher kernel weight, and lower plant height (Delgado-Ruiz *et al*., 2018).

In relation to lodging, Zhang *et al*. (2021) classified different maize populations whose percentages ranged from 0 to 80 % (table 1), demonstrating that lodging resistance was highly dependent on the morphological and mechanical traits of roots and stems, and identified the relationship between lodging resistance and high yield. According to Cardoso *et al*. (2000) maize cultivars with lower plant height and ear insertion, in addition to allowing the establishment of a greater number of plants per area, favor greater tolerance to root and stem lodging. García and Watson (2002) found that plant and ear height showed a moderate and negative correlation with lodging resistance.

On the other hand, the characteristics with the lowest variability were days to male flowering (57 – 68) (dds), days to female flowering (60 – 72 dds), and leaf length (90 – 120 cm), with CV of 3.99, 4.75 and 5.86 %, respectively (table 1). The low CV values were consistent with the studies by Hortelano *et al*. (2008) in the variables days to male and female flowering, with 2.44 and 2.58 % respectively, and González *et al.* (2020) with 4.1 and 3.9 % respectively. In leaf length, González *et al.* (2020) recorded a CV of 8.3 %.

Four groups of native maize populations were observed (figure 2A). Populations of hard kernels and large ears were agglomerated in group 1 (red color), followed by populations with intermediate-sized ears, and in group 4 the populations of soft kernels and short ears (lilac color) were concentrated. This grouping is similar to that of Tapia *et al.* (2017) who, using the same method (Gower's distance and Ward's hierarchical method), reported that maize races are agglomerated based on kernel type and shape. Flores *et al*. (2022) reported similar results with the unweighted pair group method with arithmetic mean (UPGMA), they formed four groups with 39 populations of the Cacahuancintle race based on the size of the ear, shape, and texture of the kernel, these being the most determining characteristics for the formation of the groups.

Table 1. Average values of 19 quantitative characteristics of 37 native maize populations in the province of Manabí, Ecuador.

Descriptor	Minimum	Maximum	Average	Std Error.	CV %
Stem diameter (mm)	15.9	26.3	21.2	0.4	10.6
Plant height (cm)	242.8	374.3	299.2	4.5	8.6
Height of the main ear (cm)	138.4	260.0	191.8	4.7	15
Leaf length (cm)	90.0	120.8	106.7	1.0	5.9
Leaf width (cm)	7.0	10.6	8.7	0.1	9.8
Length of the panicle (cm)	36.6	47.6	40.9	0.5	6.8
Days to male flowering	57.0	68.0	61.6	0.4	4.0
Days to female flowering	60.0	72.0	64.5	0.5	4.8
Percentage of lodging (%)	0.0	95.0	33.7	4.4	78.6
Number of rows	11.6	18.8	14.9	0.3	12.0
Number of kernels per row	16.3	39.0	27.0	0.8	18.0
Ear biomass (g)	44.0	226.2	122.8	7.1	35.3
Ear length (cm)	7.9	17.8	13.7	0.4	17.2
Ear diameter (mm)	31.6	52.8	43.3	0.8	11.8
Inflorescence rachis biomass (g)	6.8	38.2	18.9	1.5	47.8
Inflorescence rachis diameter (mm)	10.8	33.0	24.7	0.7	17.2
Kernel Length (mm)	8.4	12.9	11.3	0.2	9.4
Kernel width (mm)	7.1	10.9	8.7	0.1	9.1
Kernel thickness (mm)	3.7	8.6	4.6	0.1	17.4

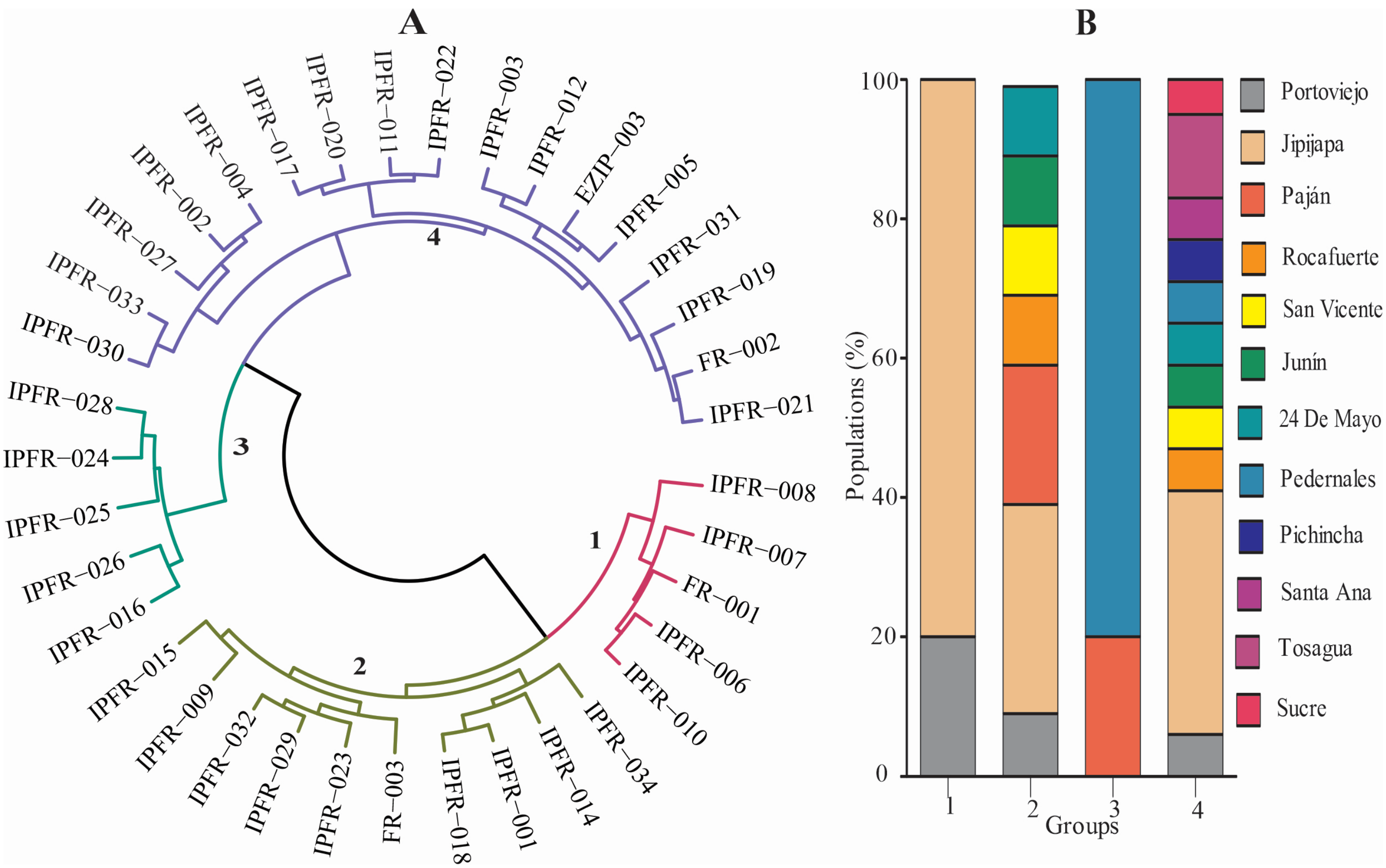

Figure 2. Hierarchical cluster analysis (HCA) of the morpho-agronomic characteristics of 37 native maize populations collected in 12 cantons of the province of Manabí, Ecuador. A) Dendrogram of similarity based on Gower's distance and Ward's hierarchical grouping method. Cophenetic correlation coefficient (r = 0.51); B) Origin of the native maize populations.

It was observed that the first group was formed by five populations, characterized by having plants with an average height of 280.4 cm, with the lowest ear insertion (171.1 cm), and days to female flowering (64.2). In addition, it was highlighted in the traits of the ear and the maize kernel (table 2), that 80 % of the populations presented orange kernels, with a serrated surface, and a straight arrangement of the rows on the ear (figure 3), resulting in these characteristics similar to those of the Cuban race, while an accession (IPFR-008) presented thin and conical ears with red coloration in the inflorescence rachis that resembles the Uchima race (Timothy *et al*., 1963). The second group was made up of ten populations that registered a higher number of kernels per row, ear biomass, and inflorescence rachis biomass with plants with smaller stem diameters, ear insertion height (table 2), orange (60 %), and white (40 %) kernel color in the populations, with dent maize kernels (80 %), and half of them have irregular row arrangement on the ear (50 %) (figure 3). The ears with white kernerls that were located in groups 1 and 2 corresponded to 20 and 40 % respectively presented characteristics such as large ears with dent maize kernels, being similar to the Tuxpeno race, introduced from Mexico, being its distribution center the Portoviejo Experimental Station (Timothy *et al*., 1963).

The third group, made up of five populations, registered greater development in their plants, with superior traits in stem diameter, plant height, ear insertion, and panicle length (table 2). Maize in this group was more susceptible to lodging and was shown to be the latest in male and female flowering, which showed unfavorable characteristics (figure 3).

In this regard, Dzib-Aguilar *et al*. (2016) indicated that the reduction in the frequency of cultivation of certain races was due to their elevated heights, so the winds cause the plants to fall and the ears to be damaged due to soil moisture, fungi, and rodents.

The populations of the third group presented distinctive ears due to their thin shape, with mostly yellow kernels (80 %), straight rows, and mostly round kernel surfaces (60 %) (table 2, figure 3), having characteristics similar to the Tusilla race. An accession (IPFR-024) presented characteristics of the Uchima race, attributing to this group two races (Tusilla and Uchima) that had not been previously reported in the province of Manabí. In this regard, the presence of new genetic materials in the province may be due to the exchange of seeds that takes place at agroecological fairs, or simply to the arrival of new farmers from other regions with their seeds.

Group 4 was the most numerous with 17 populations with smaller stem diameters, length, and ear biomass and the lowest number of kernels per row. These populations were mostly floury (83.3 %), and orange (88.2 %), with a lot of variation in the surface of the kernel, mostly round (41.2 %*)*, and irregular arrangement of the rows on the ear (58.8 %) (figure 3).

This scientific publication in digital format is a continuation of the Printed Review: Legal Deposit pp 196802ZU42, ISSN 0378-7818.

Table 2. Quantitative descriptors with greater discriminant value among the four groups of native maize populations collected in Manabí.

Variables	Groups				
	1	2	3	4	"D" Index
Stem diameter (mm)	19.5 b	20.9 b	23.5 a	21.1 b	0.5
Plant height (cm)	280.4 b	292 b	331.1 a	299.6 b	0.5
Height of the main ear (cm)	171.1c	172.5 c	227.4 a	198.7 b	0.75
Leaf length (cm)	111.8 a	108.9 ab	105.7 ab	104.3 b	0.5
Leaf width (cm)	9.0 a	8.9 a	8.4 a	8.6 a	0.25
Length of the panicle (cm)	39.3c	42.5 ab	42.8 a	40 bc	0.75
Days to male flowering	61.4 b	61.2 b	66 a	60.5 b	0.5
Days to female flowering	64.2 b	63.4 b	69 a	63.9 b	0.5
Percentage of lodging (%)	10.0 c	36.5 b	65 a	29.7 bc	0.75
Number of rows	15.4 a	14.5 a	14.8 a	14.9 a	0.25
Number of kernels per row	28.9 ab	31.9 a	26 bc	23.9 c	0.75
Ear biomass (g)	154.4 a	172 a	99.1 b	91.5 b	0.5
Ear length (cm)	15.0 a	16 a	14.3 a	11.8 b	0.5
Ear diameter (mm)	45.8 a	45.6 a	42.2 a	39.7 a	0.25
Inflorescence rachis biomass (g)	20.4 b	30.3 a	14.9 bc	12.8 c	0.75
Inflorescence rachis diameter (mm)	24.5 a	26.8 a	23 a	24.1 a	0.25
Kernel Length (mm)	11.8 a	11.7 a	10.5 a	11.2 a	0.25
Kernel width (mm)	8.2 b	9.5 a	8.4 b	8.6 b	0.5
Kernel thickness (mm)	4.3 a	4.8 a	4.6 a	4.5 a	0.25

Means followed by the same letter did not differ statistically from each other according to Duncan's test (P<0.05).

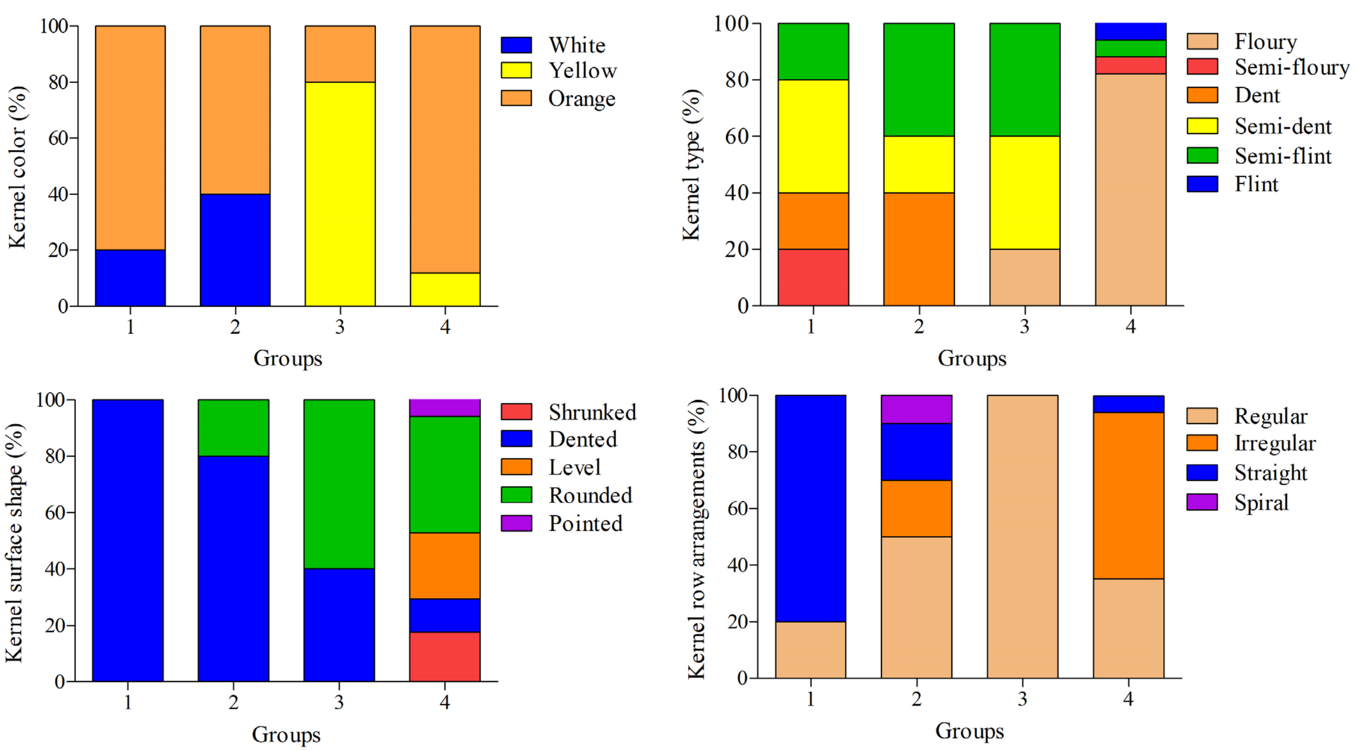

Figure 3. Discriminant qualitative characteristics in the morpho-agronomic characterization of the 37 native maize populations of the province of Manabí, grouped into the four groups of the dendrogram.

These characteristics are typical of the Candela race, of floury kernels found along the northwest coast of Ecuador. It is linked to the social and economic conditions of farmers and is generally used for family nutrition, through the preparation of typical gastronomic dishes of the sector, showing the importance it has in the farmer's diet (Pita *et al*., 2021; Fuentes *et al*., 2022).

Groups 1 and 3 were represented only by populations from two cantons. The populations of group 1 were collected in Jipijapa and Portoviejo while those corresponding to group 3 were collected in Pedernales and Paján (figure 2B), this shows that there is a group of farmers in these cantons who prefer hard types of maize (semi-dent and crystalline). Analuisa *et al*. (2020) mentioned that the productive and environmental conditions of Manabí are favorable for the cultivation of these types of maize.

Paján is considered the maize-growing region of the province of Manabí, probably farmers prefer to plant maize for commercialization, so they use hard maize; a similar case occurs in the San Vicente area of the Jipijapa canton, where it was determined that the production and commercialization of hard maize had an impact on the socioeconomic development of its inhabitants (Cañarte-Quimis *et al*., 2021). The same happened in the cantons of Pedernales and Paján in group 3, and in the case of floury maize within this same group, there are small producers who still have it (figure 3).

Maize production has had an impact on the social and economic development of Manabí for decades, increasing from 2007 to 2017 by 67.6 %; however, the crops were concentrated in the production of dry hard maize (Palacios-Cedeño *et al*., 2023). However, the use of commercial hard maize materials, usually hybrids, could be a challenge to the sustainability of genetic diversity, as it can lead to the loss of maize landraces. This is a problem that has arisen since the 60s when Timothy *et al*. (1963) reported the displacement of the Candela and Gallina races by commercial races such as the Tuxpeño and the Caribbean Yellow Flint. Tapia *et al*. (2015) identified that the Canguil, Chaucho, and Clavito races have ceased to be cultivated in some provinces of the Ecuadorian Sierra.

Qualitative characteristics were the most decisive for the grouping of the 37 maize populations harvested in the province of Manabí because they reduced the variability produced by environmental factors (Scheldeman and Van Zonneveld, 2010). According to Hortelano *et al*. (2008), kernel color is one of the most discriminating traits for grouping populations with wide morphological diversity, and together with the type of kernel, shape, and size of the ear were decisive in the selection practiced by farmers.

The quantitative variables ear height, panicle length, percentage of lodging, number of kernels per row, and biomass of the inflorescence rachis registered "D" indices of 0.75, showing themselves as discriminating variables in the formation of the groups (table 2). In contrast, the characteristics of leaf width, number of rows, ear diameter, the inflorescence rachis, length, and thickness of the kernel were found, which presented lower values (0.25) and lower discriminative power. Tapia *et al*. (2017) indicated that the characteristic ear length was the most discriminating with a "D" index of 0.66 according to the same statistical criterion, and in Torres *et al*. (2022) ear size and phenological variables had a greater influence on the formation of the groups.

Ear cover was not considered in the analysis because it was monomorphic in all populations. Using the χ^2 test, the type of kernel (χ^2 = 49.09***, P= 0.742, V= 0.64), kernel color (χ^2= 51.955***, P= 0.75, V=0.64), row arrangement *(*χ^2= 18.11*, P=0.56, V=0.39*)* and kernel surface shape *(*χ^2 = 20.52*, P=0.58, V=0.41) were the most discriminating (table 3). These results were similar to those reported by Tapia *et al*. (2017) finding that the variables kernel type (χ^2= 267.35**, P= 1.44, V=0.83*),* kernel surface shape (χ^2= 228.72**, P= 1.33, V=0.77*),* kernel color (χ^2= 48.72**, P= 0.62, V=0.36*)* and row arrangement (χ^2= 23.55**, P= 0.43, V=0.25*)* were the most discriminating in maize from the Sierra.

Table 3. Analysis of the discriminant value of the qualitative characteristics of the populations of native maize harvested in the province of Manabí, Ecuador.

Qualitative variables	Pearson's Chi-Square (X^2)	Pearson's Contingency Coefficient (P)	Cramér's Contingency Coefficient (V)
Stem color	4.62	0.322	0.24
Anthocyanin staining in adventitious roots	9.15	0.431	0.276
Pubescence on the margin of the sheath	5.953	0.36	0.386
Anthocyanin staining in the leaf sheath	4.923	0.331	0.248
Ear form	9.683	0.441	0.348
Kernel row arrangements	18.110*	0.558	0.388
Anthocyanin staining of the inflorescence rachis	5.634	0.351	0.265
Kernel Type	49.085***	0.742	0.64
Kernel color	51.955***	0.752	0.806
Kernel surface shape	20.517*	0.582	0.413

Significance level at 5 % (*) and 0.1 % (***)

These findings underscore the relevance of these native maize populations as an invaluable genetic reserve for preserving and exploiting this crop.

Conclusions

The province of Manabí registered a high morphological diversity of native maize, with the Candela, Cubano, Tuxpeño, Tusilla, and Uchima races, and the absence of the Chococeño race was reported in the samplings that have been carried out so far. The variables kernel type and color, arrangement of rows, kernel surface shape, ear height, panicle length, percentage of lodging, number of kernels per row, and biomass of the inflorescence rachis were mostly discriminating and allowed the formation of groups in native maize populations of the province of Manabí.

This study constitutes a contribution to the understanding of the diversity of native maize populations in Manabí, as an update of the previous findings reported decades earlier. In any case, in future research, it is necessary to carry out a greater sampling in the Manabi cantons that are poorly represented in this research, such as Tosagua and Chone, which could complement the results presented here.

Funding

This research was funded by the ECOTEC Technological University, Research Project CEDS_002: "Evaluation of the genetic diversity of native maize of the Ecuadorian coast using microsatellite molecular markers".

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