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PHOSPHORUS, POTASSIUM, ZINC, IRON, SODIUM, CALCIUM AND MAGNESIUM, CONTENTS AND THEIR VARIABILITY ANALYSIS IN CUBAN MAIZE ACCESSIONS

Contenido de fósforo, potasio, zinc, hierro, sodio, calcio y magnesio, análisis de su variabilidad en accesiones cubanas de maíz

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ABSTRACT. In our country, corn is cultivated since the time of the aborigines and it is a staple food in human nutrition, livestock and poultry; it is the second major cereal and has high preference of consumption by the population. In Cuba, there are six races of maize with a high morphoagronomic diversity, which has been extensively studied; however, diversity and nutritional characteristics of the plant is not known or varieties improved for this purpose have not been introduced. This work was carried out on a sample of 106 accessions, which included materials *in situ* and *ex situ* conserved. The aim of the study was to evaluate the degree of variability and morphoagronomic mineral content of these genotypes. The results allowed detect morphoagronomic variability in the accessions; also the phosphorus and calcium content was high while magnesium, potassium and sodium content was low, resulting in intermediate iron and zinc content in related to standards reported in the literature for this crop. The values of these elements in corn grain, are influenced by the concentrations present in soil or spiked through mineral fertilization, which can be variable depending on conditions. Therefore, it is recommended a deeper study on the variability of mineral concentrations elements in maize in Cuba.

Key words: phenotypic, nutritional value, variation, *Zea mays*

RESUMEN. En nuestro país, el maíz se cultiva desde la época de los aborígenes y constituye un alimento básico en la nutrición humana, del ganado y las aves; es el segundo cereal de importancia y tiene alta preferencia de consumo por la población. En Cuba, existen seis razas de maíz con una alta diversidad morfoagronómica, la cual ha sido ampliamente estudiada; sin embargo, no se conoce sobre la diversidad y características nutricionales del cultivo, ni se han introducido variedades mejoradas para este fin. El presente trabajo se realizó en una muestra de 106 accesiones, donde se incluyeron accesiones conservadas *in situ* y *ex situ*. El objetivo del estudio fue evaluar el grado de variabilidad morfoagronómica y el contenido de minerales de la colección. Los resultados obtenidos permitieron detectar la existencia de variabilidad morfoagronómica en la muestra; además, se demostró que el contenido de fósforo y calcio fue alto, mientras que el contenido de magnesio, potasio y sodio fue bajo, resultando el de hierro y zinc medio en comparación con los estándares informados en la literatura para este cultivo. Los valores de estos elementos, en el grano de maíz, son influenciados por las concentraciones presentes en el suelo o adicionadas a través de la fertilización mineral, por lo que pueden ser variables dependiendo de dichas condiciones, por tanto, se recomienda realizar un estudio más detallado sobre la variabilidad de las concentraciones de estos elementos en el maíz en Cuba.

Palabras clave: fenotípica, valor nutritivo, variabilidad, *Zea mays*

INTRODUCTION

The importance of cereals to the nutrition of millions of people around the world is widely recognized. Due to their relatively high intakes in developing countries, they cannot be considered only as a source of energy, but also supply proteins.

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Cereal grains have a low protein concentration and the quality of these is limited by the deficiency of two essential amino acids, lysine and tryptophan. A classic example of this is maize, since other cereals have equal but less obvious limitations (1).

The nutritive value of corn is very similar to that of other cereals, being somewhat higher than that of wheat and only slightly lower than that of rice (2). These three cereals are the most consumed in the world. The problem lies in the diet of maize, which is very deficient in the type of complementary foods necessary to improve the nutrients ingested with relatively large amounts of maize (1).

Throughout the world the interest of nutritionists and agronomists in the minor nutritional elements has risen (3). High levels of minerals and protein are generally considered to be indicators of high dietary quality of cereal products for humans and animals.This grain is widely consumed by the general population at two times of the ycob (spring and summer) and, in addition, because of the social programs carried out by the Cuban government, it is massively supplied and directed to specific populations of interest to the (Primary school, secondary, pre-university and university), children (day care center) and the sick (hospitals, polyclinics, etc.). It also reaches out to other institutions and work centers.

In Cuba, despite the existence of a wide variety of maize grown under low-input tropical conditions and consumed in one way or another by almost the entire population; there is no characterization of maize grown in terms of mineral content. Therefore, the evaluation of the content of the minerals in a sample of the corn diversity that is cultivated in our country, is important for the genetic improvement because it would be a new aspect to evaluate in the selection of the genotypes to be improved.

Due to this situation, this paper has as objectives to evaluate the morphoagronomic variability and the content of minerals like Zinc (Zn), Iron (Fe), Sodium (Na), Calcium (Ca), Phosphorus (P), Magnesium (Mg) and potassium (K) in 50 maize accessions

MATERIALS AND METHODS

Prospecting of accessions

Three maize prospections were carried out, collecting 0,5-1,0 kg of seed per entry. The main objective of the project was to collect maize diversity in each locality.

The first survey was carried out between November and December 1998, in the town of Catalina de Güines, Güines, La Habana, located in the western region of Cuba. This zone was selected because of the seed flow that occurs in the same area[A], where a large number of maize varieties enter and leave the local seed system each cob.

Subsequently, from April 15 to 21, 2002, the prospections were carried out in the Contramaestre municipality, Santiago de Cuba province, specifically in the town of Las Ventas de Casanova; In addition, it was collected in the Seed Company of the territory. This zone of the country was selected, due to the production of corn that has been made in the area for more than 50 cobs.

Finally, from April 19 to 24, 2003, corn prospecting was carried out in two provinces in the central area of the country: Villa Clara (municipalities: Corralillo, Ranchuelo and Remedios) and Sancti Spíritus (municipalities: Yaguajay and Taguasco). This zone of the country was selected for the references that had of the tradition in the planting of maize.

Morphoagronomic characterization

The work collection, made up of 106 accessions (Table I), consisted of 63 from the western region, of which 19 came from the Germplasm Bank of the Fundamental Research Institute for Tropical Agriculture (INIFAT), 21 from the Germoplasm Bank of the National Institute of Agricultural Sciences (INCA) collected by Acosta (2003) in La Palma, Pinar del Rio, 21 accessions collected in Catalina de Güines, one in San Antonio de los Baños (FELO variety) and another in Batabanó (Raúl Line) , 16 of which were collected in Santi Spíritus and eight in Villa Clara and 27 in the eastern region, of which 17 were collected in Sales de Casanova, Santiago de Cuba, six in the Company of Seeds of Santiago de Cuba , three in Holguin and one in Granma.

During 2003, 2004 and 2005 three evaluation cycles were carried out on the maize collection in the central area of INCA, located San José de las Lajas municipality, Havana province. In 2003, the planting took place on June 10; in 2004, on February 5th and in 2005, on November 11th. The same experimental area was used for each cycle and maize was part of a rotation system with beans or soybeans.

Sowings were carried out in plots of 5,0 m long, at a rate of six rows per plot, at a distance of 0,30 x 0,70 m, with a population of 115 plants per plot on a leached Ferralitic red soil (4); The soil characteristics are shown in Table II.

[A]Martínez, M. *Caracterización y evaluación participativa de maíz colectado en las localidades de Catalina de Güines, La Habana y Las Ventas de Casanova, Santiago de Cuba* [Tesis de Maestría], Instituto Nacional de Ciencias Agrícolas, La Habana, Cuba, 2003, 120 p.

Cultural attentions were made according to the Technical Instruction of the crop[B], except that no chemical fertilizer applications were made. A completely randomized design with three replicates was used at each planting.

A total of 10 plants per accession were evaluated according to the Manual for the Maize (*Zea mays* L.) Varietal Description (5), which was evaluated by a total of 17 morphoagronomic characters (Table III) .

The evaluations were carried out, selecting, in each plot, the plants of the center, to avoid the edge effect and to minimize the influence of cross-pollination.

Analysis of the variability of the collection studied

The statistical parameters average (X) and coefficient of variation (CV) of the general collection and the groups of accessions were determined for the number of grains per row, number of rows, mass of 100 seeds, cob length, diameter Mean of cob, number of grains per cob, stem diameter, upper cob height, plant length, incidence of *Spodoptera frugiperda* (Smith) and yield per plant. To determine these parameters the mean of the three cobs in each character was calculated.

[B] MINAGRI. *Instructivo Técnico del cultivo del maíz*, Dirección Nacional de Cultivos Varios, La Habana, Cuba, 1992

Table I. Distribution of the 106 accessions evaluated by region and locality

Region	Locality	Number of accessions
Western	Catalina de Güines, La Habana	21
	INIFAT	19
	La Palma, Pinar del Río	21
	San Antonio de los Baños, La Habana	1
	Batabanó, La Habana	1
	Sub-total	63
Central	Villa Clara	8
	Santi Spíritus	8
	Sub-total	16
Eastern	Holguín	3
	Granma	1
	Ventas de Casanova, Santiago de Cuba	17
	Seed company of Santiago de Cuba	6
	Sub-total	27
	Total	106

INIFAT=Instituto de Investigaciones Fundamentales en Agricultura Tropical

Table II. Physical-chemical characteristics of the soil where the sowing was carried out (4)

				Exchangeable cations (Cmol kg^{-1})				
Horizon	Depth (cm)	pH (H_20)	O.M (%)	Calcium	Magnesium	Sodium	Potassium	Sum
A1	0-19	7,34	3,67	16,3	2,1	0,2	0,9	19,5
B11	19-44	6,85	-	13,4	2,8	0,2	0,5	16,9
B12	44-60	6,72	2,00	9,5	1,5	0,2	0,3	11,5
B2t	60-100	5,77	1,12	8,3	1,0	0,2	0,2	9,7

O.M=organic matter

Table III. Characteristics evaluated, acronym, unit of measure and moment of evaluation in the 106 accessions studied in "ex situ" conditions

Nu.	Character	Acronym	Measurement unit	Moment of evaluation
1	Incidence of *Spodoptera frugiperda (Smith)*	ISF	Percentage (%)	3 moments*
2	Diameter of stem	DT	(mm)	Filling the grain
3	Height at the upper cob	AMS	(cm)	Filling the grain
4	Plant height	LP	(cm)	Filling the grain
5	Number of cob per plant	NMP	Unit	Filling the grain
6	Cob cover	CM	Value scale	After harvest
7	Color of grains	CG	Value scale	After harvest
8	Form of cob	FM	Value scale	After harvest
9	Disposition of rows	DH	Value scale	After harvest
10	Shape of the crown of the grains	FG	Value scale	After harvest
11	Number of grains per rows	NGH	Unit	After harvest
12	Number of rows	NH	Unit	After harvest
13	Cob length	LM	(mm)	After harvest
14	Medium diameter of cob	DMM	(mm)	After harvest
15	Number of grain per cob	NGM	Unit	After harvest
16	Mass of 100 seeds	M100S	(g)	After harvest
17	Yield per plant	R/P	kg	After harvest

Determination of mineral content

For the characterization, in April 2007, the collection of 50 maize accessions was planted in the central area of the National Institute of Agricultural Sciences, on a leached Ferralitic red soil (4). Sowing was done under the same methodological conditions as the previous experiment. A completely randomized design with no replicates was used.

The grains harvested in August 2007 were sun-dried and stored in plastic bottles in a room where the temperature is controlled by the use of an air conditioner and the humidity is regulated through two dehumidifiers. The mean temperature was ± 22 ^{0}C, and the relative humidity was ± 75. The evaluation was made to a representative sample of INCA's work collection, made up of 50 accessions (Table IV). They were selected using the stratified method with representation of the three regions (Western, Central and Eastern). The selection was made at random, and the sample was composed by 24 accessions from the western region (six from INIFAT, seven from La Palma and 11 from Catalina de Güines); 16 from the central region (eight from Villa Clara and eight from Sancti Spíritus) and 10 from the eastern region (seven from Casanova Sales, two from the Santiago de Cuba seed company and one from Manzanillo). In this way, it was guaranteed that the variations that in terms of climate, soil and cultivation conditions exist among the three zones were represented.

The 50 selected accessions, harvested in August 2007 at INCA, took a sample of 200 grams of seed by randomly selecting ten plants from the center of the plots of each of the accessions and mixed the seed of said plants, which were free of pathogens and without physical damage. To evaluate the nutritional quality of the sample, the following characteristics were determined: zinc content (Zn), iron (Fe), sodium (Na), calcium (Ca), phosphorus (P), magnesium (Mg) and potassium (K).

Samples (200 grams) were ground in a Tecator mill using a 0.5 mm stainless steel sieve, wrapped in commercial filter paper (10 x 11 cm) and degreased with 300 mL of hexane in a continuous Soxhlet extractor -type for six hours; then dried outdoors to remove excess hexane (6).

The determinations were made at the Higher Technical School of Rural Environment and Ethnology, belonging to the Polytechnic University of Valencia, Spain; using the protocols of the Ministry of Agriculture, Fisheries and Food of Spain (7).

Table IV. Code, name, donor and source of the 50 accessions evaluated

Nu.	Code	Name of accession	Donor	Procedence	Region
1	5	P 876 acb	INIFAT	INIFAT	Western
2	7	P 820 acb	INIFAT	INIFAT	Western
3	13	P 2284	INIFAT	INIFAT	Western
4	17	P 2089 act	INIFAT	INIFAT	Western
5	25	P 156	INIFAT	INIFAT	Western
6	35	P 3014 Tayuyo Rojo	INIFAT	INIFAT	Western
7	45	Criollo	Farmer	La Palma	Western
8	46	Criollo	Farmer	La Palma	Western
9	47	Criollo	Farmer	La Palma	Western
10	57	Criollo	Farmer	La Palma	Western
11	64	Criollo	Farmer	La Palma	Western
12	67	Criollo	Farmer	La Palma	Western
13	70	Criollo	Farmer	La Palma	Western
14	72	Criollo	Farmer	Catalina de Güines	Western
15	74	Criollo	Farmer	Catalina de Güines	Western
16	75	Criollo	Farmer	Catalina de Güines	Western
17	77	Criollo	Farmer	Catalina de Güines	Western
18	78	Criollo	Farmer	Catalina de Güines	Western
19	80	Criollo	Farmer	Catalina de Güines	Western
20	81	Criollo	Farmer	Catalina de Güines	Western
21	84	Criollo	Farmer	Catalina de Güines	Western
22	87	Criollo	Farmer	Catalina de Güines	Western
23	88	Criollo	Farmer	Catalina de Güines	Western
24	92	Criollo	Farmer	Catalina de Güines	Western
25	153	creole maize	Farmer	Corralillo	Central
26	158	Argentinean and purple maize	Farmer	Corralillo	Central
27	164	white and purple maize	Farmer	Corralillo	Central
28	169	red maize	Farmer	Corralillo	Central
29	185	creole maize of white straw	Farmer	Yaguajay	Central
30	188	creole maize	Farmer	Yaguajay	Central
31	191	white straw maize	Farmer	Yaguajay	Central
32	192	white maize	Farmer	Yaguajay	Central
33	193	argentinean and white maize, fat cob	Farmer	Remedios	Central
34	199	argentinean maize	Farmer	Camajuaní	Central
35	200	purple maize	Farmer	Camajuaní	Central
36	202	victoria maize	Farmer	Cabaiguán	Central
37	206	butter maizea (descendant of victory)	Farmer	Cabaiguán	Central
38	212	white and purple straw maize	Farmer	Ranchuelo	Central
39	215	argentinean maize and TGH	Farmer	Remedios	Central
40	219	galician maize	Farmer	Ranchuelo	Central
41	94	Criollo	Farmer	Manzanillo	Eastern
42	98	Canilla	Farmer	Ventas de Casanova	Eastern
43	99	Tayuyo Tusón	Farmer	Ventas de Casanova	Eastern
44	104	Tayuyo Diente Caballo	Farmer	Ventas de Casanova	Eastern
45	111	P 7928	Seed company	Seed company (Santiago de Cuba)	Eastern
46	112	Diente de Caballo	Farmer	Ventas de Casanova	Eastern
47	113	VST – 6	Seed company	Seed company (Santiago de Cuba)	Eastern
48	118	Tayuyo	Farmer	Ventas de Casanova	Eastern
49	134	Tusón	Farmer	Ventas de Casanova	Eastern
50	143	Tayuyo Blanco	Farmer	Ventas de Casanova	Eastern

INIFAT=Instituto de Investigaciones Fundamentales en Agricultura Tropical

After determination of zinc, iron, sodium, calcium, phosphorus, magnesium and potassium, the spectrophotometric determination of the phosphorus content, determination by photometry of sodium and potassium flame and determination by atomic absorption of calcium , Magnesium, iron, and zinc (7).

Study of the associations between morphoagronomic characters and mineral content

Pcobson's (r) bilateral correlations were determined between morphoagronomic characters and mineral content. These analyzes were performed using the statistical package SPSS, Version 11.5 (8).

The correlation coefficient (r)[C] ranges were used for the biological interpretation of the results. (Table V).

[C] Ortiz, R. *Características poblacionales y criterios de selección en las primeras etapas en caña de azúcar (Saccharum spp. híbridos)*. Tesis de Doctorado, Instituto Nacional de Ciencias Agrícolas, 1982, La Habana, Cuba.

Table V. Classification of correlation coefficients[C]

Classification	r value range
Weak	≤ 0,100
Moderate	0,101 – 0,300
Moderately strong	0,301 – 0,500
Strong	0,501- 0,700
Very strong	≥ 0,701

RESULTS AND DISCUSSION

Analysis of the variability of the collection under study

Table VI presents the mean values and coefficient of variation for the number of grains per row, number of rows, mass of 100 seeds, cob length, average cob diameter, number of grains per cob, stem diameter Spodoptera frugiperda (Smith) incidence and yield per plant, both in the general collection and in the three regions (western, central and eastern).

The incidence of Spodoptera frugiperda (Smith) was the most dispersive character in the whole collection with an average coefficient of variation (CV) of 27,15 %, as well as when discriminated by regions. In this regard, in the accessions of the western region the CV was 29,17 %, and in the eastern region 21,21 %.

The yield per plant showed high dispersion (CV> 25 %) in all the collections, being the character of greater variability in materials from the eastern and central regions, with coefficients of variation of 28,88 and 25,64 % respectively. The height at the upper cob showed high variability in the central region (20,40 %).

The lowest dispersion character in all the collections was the number of cobs per plant, with coefficients of variation lower than 5 % in all cases, because most of the plants had a cob.

Table VI. Mean and coefficient of variation for the quantitative traits in the general collection and in the three regions

		Character											
Collection	Statistician	NGH	NH	M1OOS	LM	DMM	NGM	DT	AMS	LP	NMP	ISF	R/P
General	Mean	31,77	13,35	31,12	15,36	4,49	423,58	1,51	1,26	2,47	1	64,19	0,13
	CV (%)	10,98	9,42	15,45	8,88	6,31	14,76	10,1	17,64	8,06	3,93	27,15	26,22
Westen	Mean	31,27	13,56	30,85	15,23	4,54	423,6	1,5	1,26	2,48	1	63,46	0,13
	CV (%)	10,12	10,56	15,42	9,17	6,3	15,47	9,19	16,15	7,5	4,93	29,17	25,06
Eastern	Mean	32,29	13,12	31,24	15,39	4,42	423,65	1,49	1,26	2,43	1	56,77	0,13
	CV (%)	12,55	6,95	16,14	9,35	5,78	14,11	9,74	19,04	7,62	1,81	21,21	28,88
Central	Mean	32,83	12,87	32	15,82	4,4	423,36	1,56	1,29	2,47	1	79,6	0,14
	CV (%)	10,13	5,53	14,08	6,03	6,25	12,96	12,85	20,4	10,37	1	11,72	25,64

CV = coefficient of variation, NGH=number of grains per row, NH=number of rows, M100S=mass of 100 seeds, LM=cob length, DMM=mean diameter of cob, NGM=number of grains per cob, DT=stem diameter, AMS=upper cob height, LP=plant length, NMP=number of cobs per plant, ISF=incidence of *Spodoptera frugiperda* (Smith) and R/P=yield per plant

The characteristics yield per plant, height at the upper cob, mass of 100 seeds, number of grains per cob and incidence of Spodoptera frugiperda (Smith), showed relatively high dispersion in all the collections, with CV percentages always higher than 25, 16, 14, 12,5 and 11 % respectively. Cuban corn has greater variation for the characteristics of the cob, therefore, they are important variables in the classification of the germplasm; however, height at the upper cob is a plant character, which showed variability in the evaluated collections. Therefore, it is recommended to evaluate its importance in the classification of Cuban germplasm (9).

When evaluating maize accessions in Mexico, lower values were obtained for the cob characters (10), in contrast to this work, when evaluating 25 accessions of maize from the Andean zone of Bolivia, a higher variability was found for the number of grains per rows (22,40 %), number of rows (14,27 %), mass of 100 seeds (24,62 %), cob length (15,53 %), mean cob diameter (12,12 %), stem diameter (13,35 %) and plant length (12,40 %) (11). The collections evaluated in Cuba show less variability than those evaluated in the Andean region; because this region is defined as a secondary center of corn diversification and therefore the variability of the characters is high.

The following coefficients of variation were found for the number of rows: CV = 4,9 %, for the mass of 100 seeds: CV = 10,0 %, for cob length: CV = 4,87 %, for cob height: CV = 7,78 % and for plant length: CV = 5,25 % (12). The dispersion found by these authors in the above-mentioned characters was lower than in the populations evaluated in this study, although the differences were not great, which is due to the fact that the varieties evaluated by these authors are hybrids and commercial varieties, so that, in general, they present greater homogeneity.

When evaluating local populations of maize in Mexico, the length of the cob had a CV of 13,7 %, the mean diameter of the cob of 8,7 %, the number of rows of 8,7 %, the number of grains per rows of 12,7 % and the mass of 100 seeds of 12,0 % (13, 14). The dispersion of the characters, number of grains per rows and number of rows was similar to that found in Cuban populations; while the variability of the mass of 100 seeds was lower, being in the length of the cob and average diameter of the upper stem in the local populations of Mexico.

When evaluating Cuban accessions of maize preserved both *ex situ* and *in situ*, it was found that the most variable characters were M100S, DT and NGH with coefficients of variation of 22,48; 18,44 and 15,57 % respectively, with NH being the least variable (CV = 8,22 %).

In general, the variability of the characters is considered moderate to moderately high, which is mainly due to the genotype - environment interaction, because the evaluations were carried out in three different cobs and at three different planting times, together, the origins plurality of the accessions that make up these collections, provoked a differentiated behavior. The less stable characters (ISF, AMS and M100S) are strongly influenced by the environment, which is the main cause of their variability.

Table VII shows the zinc, iron, sodium, calcium, phosphorus, magnesium and potassium contents evaluated in the 50 accessions studied.

The phosphorus content (P) in the grains of the accessions studied was between 205,64 and 375,72 mg per 100 g portion, the concentrations of this element being high (X = 295, 19 mg per 100 g) compared to those found in 1998 of 256 mg per 100 g portion (8). In 1991, phosphorus values were found in whole corn grains of 310,0 mg per 100 g sample portion (15).

Phosphorus levels in the grain range from 240 to 330 mg per 100 g portion (16). Some authors found concentrations of this mineral in corn kernels between 306,0 mg per 100 g portion and 368,0 mg per 100 g portion (17, 18). It should be noted that the concentration of phosphorus in maize grains is influenced by the inputs of phosphorus fertilizers to the soil (4).

The calcium content (Ca) ranged from 24,15 to 64,54 mg per 100 g portion of sample, these concentrations are high (X = 42, 99 mg per 100 g portion) compared to results of 30,80 mg/100 g of calcium in corn kernels (19). Some authors reported values of calcium in maize grain in the range of 24,0 to 39,0 mg per 100 g portion (18). Low concentrations of this mineral were found in corn kernels, reporting levels of 12,9 and 14,7 mg per 100 g portion (17). Calcium favors the production of some products derived from maize for human consumption (19), constituting an added value.

[D] Fernández, L. *Identificación de razas de maíz (Zea mays L.) presentes en el germoplasma cubano*. Tesis de Doctorado, Instituto de Investigaciones Fundamentales en Agricultura Tropical (INIFAT), 2009, La Habana, Cuba, 100 p.

Table VII. Content of zinc, iron, sodium, calcium, phosphorus, magnesium and potassium determined in the 50 accessions

Códe	Zn (mg per portion of 100 g)	Fe (mg per portion of 100 g)	Na (mg per portion of 100 g)	Ca (mg per portion of 100 g)	P (mg per portion of 100 g)	Mg (mg per portion of 100 g)	K (mg per portion of 100 g)
5	1,98	0,91	25,93	29,45	279,07	59,29	279,78
7	2,22	3,91	28,73	46,39	309,56	60,87	206,12
13	2,01	1,20	27,90	33,61	276,20	56,51	307,64
17	1,87	0,83	26,40	33,43	283,87	49,80	254,58
25	2,55	3,67	32,00	52,40	358,95	64,71	236,29
35	2,32	1,57	28,32	55,73	296,91	49,62	211,81
45	2,68	1,12	34,75	57,88	265,09	46,76	255,33
46	1,80	0,71	28,54	49,33	250,64	41,00	223,35
47	2,06	0,93	27,38	38,88	281,81	72,10	210,80
57	2,28	1,09	29,00	39,05	330,91	60,75	249,90
64	2,38	1,31	27,16	34,76	302,35	48,01	209,11
67	2,52	1,02	26,04	28,28	319,68	58,75	258,80
70	1,52	0,79	24,18	24,15	208,76	34,55	160,08
72	1,90	0,89	33,57	51,33	242,36	65,77	236,01
74	2,80	0,71	24,57	45,72	241,82	43,35	186,34
75	2,31	0,88	26,40	47,59	269,40	48,80	209,35
77	2,15	1,16	26,00	45,18	285,87	49,61	197,31
78	2,23	0,99	25,99	30,86	262,36	47,68	183,79
80	2,59	1,27	27,85	36,54	371,53	61,37	283,28
81	3,02	0,82	26,82	39,91	245,64	43,52	112,45
84	2,06	1,03	24,75	28,98	279,23	58,36	212,13
87	2,05	0,85	27,86	40,34	285,14	56,38	187,10
88	2,27	0,96	23,86	44,85	275,49	62,47	207,90
92	2,25	1,31	29,02	47,03	294,81	51,39	188,10
153	4,55	1,57	31,01	42,57	356,31	61,02	270,74
158	2,66	1,56	30,59	64,54	375,72	66,83	260,13
164	2,30	1,12	27,86	32,04	303,81	47,42	264,40
169	1,40	0,84	27,82	29,98	234,25	60,39	229,91
185	3,32	1,41	64,34	51,94	314,90	61,72	235,15
188	1,94	0,71	25,62	47,77	268,54	56,74	211,09
191	2,18	0,72	28,60	31,15	270,07	69,85	203,81
192	2,36	0,78	28,29	30,61	292,74	46,43	186,00
193	2,87	0,98	28,59	47,88	209,24	57,26	179,16
199	1,51	0,96	26,17	41,94	205,64	52,47	161,47
200	2,64	1,89	31,27	51,19	365,52	61,76	299,60
202	2,30	2,33	26,99	32,94	297,56	55,94	179,94
206	2,13	0,40	52,94	56,95	290,65	47,04	175,76
212	2,07	1,06	26,44	32,94	297,12	48,87	212,87
215	2,30	1,01	27,04	49,56	354,08	58,60	212,81
219	5,69	2,03	31,28	61,61	345,40	84,06	208,72
94	2,32	1,03	29,74	35,01	314,84	64,05	206,41
98	2,57	1,83	26,91	45,69	352,37	57,27	235,65
99	5,01	1,35	23,51	51,65	363,59	46,18	226,70
104	2,53	1,45	33,24	56,90	348,77	50,68	174,54
111	2,45	1,65	30,39	44,82	367,18	67,15	328,61
112	2,34	1,48	30,57	48,53	321,77	56,48	212,17
113	1,95	0,69	26,21	29,47	268,89	50,19	137,65
118	2,06	1,12	27,33	33,91	262,60	38,83	137,27
134	2,60	2,21	26,44	41,23	314,78	45,87	186,96
143	2,00	1,04	63,55	42,89	292,58	66,59	161,20
Media	2,36	1,27	29,73	42,99	295,19	57,33	214,36
Min.	1,40	0,40	22,38	24,15	205,64	34,55	112,45
Máx.	5,69	3,91	64,34	64,54	375,72	88,37	328,61

Zn=zinc, Fe=iron, Na=sodium, Ca=calcium, P=phosphorus, Mg=magnesium, K=potassium, Min=minimum and Max=maximum

The high contents of this element are also influenced to the high contents (4) present in the soil where the corn accessions were cultivated, therefore, it is necessary to study in other conditions or soil types the accumulation of calcium in the corn grain in Cuba.

In contrast, the magnesium (Mg) contents fluctuated between 34, 55 and 88, 37 mg per 100 g portion of sample, with a mean X=57,33 mg per 100 g portion; being inferior to that found in 2008 by Vázquez-Carrillo *et al*. (18), who reported concentrations of this mineral in maize grains between 99,0 mg/100 g and 281,0 mg/100 g. In addition, in 2005 magnesium contents were found between 106 and 126 mg per 100 g portion (17). The low magnesium contents could be influenced by the contents of this nutrient in the soil.

Potassium (K) levels ranged from 112, 45 and 328,61 mg per 100 g portion of sample in the Cuban accessions evaluated; (X = 214,36 mg per 100 g portion) compared to those obtained in 2005, which found potassium concentrations in the grain of tropical maize varieties in the range of 357,0 mg/100g to 396, 0 mg/100 g (16). When evaluating mineral concentration in dry period, authors found values of 340,0 to 360,0 mg per 100 g portion (20).

The concentrations of sodium (Na) in the 50 accessions evaluated were in the range of 22, 38 to 64,34 mg per 100 g sample, with a mean of 29, 73 mg/100g. These concentrations are low in relation to what was reported in 2009 by Puga *et al*. (17), who, when evaluating the effects of the nitrogen fertilizer application on the mineral composition of maize grains, found sodium values between 59,92 and 133,8 mg per 100 g portion of sample.

Iron levels (Fe) were in the range of 0,40 to 3,91 mg per 100 g sample, with an average of 1,27 mg per 100 g serving, coinciding with the average standards (19).

Zinc concentrations in the evaluated accessions had a mean of 2,36 mg/100 g) and ranged from 1,40 to 5,69 mg per 100 g portion; results that coincide with those obtained when evaluating the mineral composition of tropical maize found concentrations ranging from 2,18 to 2,40 mg per 100 g portion (21).

In summary, in this work the phosphorus and calcium content was high, while the content of magnesium, potassium and sodium was low, and the intermediate iron and zinc content in comparison with the standards reported in the literature for this crop. The values of these elements in the corn grain are influenced by the concentrations present in the soil or added through mineral fertilization (19), so that these concentrations can be variable. Therefore, it is recommended to carry out a study on the variability of the concentrations of these elements in maize grown in Cuba.

Table 8 shows the Pcobson (r) correlations between the morphoagronomic characters and the mineral contents evaluated in the group consisting of 50 accessions to which the nutritional quality of the grain was evaluated.

From the biological point of view, the correlations that were presented among these characters were in the categories of moderate (0,101-0,300) and moderately strong (0,301-0,500), reason why the importance of these correlations was smaller than those that occur among the morphoagronomic characters.

In general, there were no significant correlations among the characters evaluated, only a positive and significant correlation was observed between the number of rows and the sodium content, in essence, an increase in the number of rows, for this group of accessions, constitutes a possible increase in sodium content.

Table VIII. Phenotypic correlations of morphoagronomic characters and mineral contents evaluated

	NGH	NH	M100S	LM	DMM	NGM	DT	AMS	LP	NMP	ISF
Zn	0,302(*)	0,063	0,078	0,169	0,06	0,278	-0,242	-0,01	-0,114	-0,01	0,111
Fe	-0,062	-0,032	-0,298(*)	-0,196	-0,24	-0,056	0,032	-0,084	0,021	0,209	0,199
Na	0,14	0,367(**)	0,101	0,285(*)	-0,24	0,248	0,185	0,09	-0,016	0,015	0,027
Ca	0,21	0,161	-0,052	0,173	-0,16	0,231	-0,1	-0,244	-,319(*)	0,290(*)	0,189
P	0,272	0,07	-0,063	0,133	-0,02	0,263	-0,234	-0,013	-0,12	0,063	0,216
Mg	0,031	0,155	-0,043	0,086	-0,07	0,081	-0,036	-0,026	-0,016	0,023	0,23
K	-0,175	-0,052	-0,139	-0,128	0,023	-0,166	-0,01	-,302(*)	-0,114	0,149	0,26

**=(p≤0.01), *=(p≤0.05). Zn = zinc, Fe = iron, Na = sodium, Ca = calcium, P = phosphorus, Mg = magnesium and K = potassium

CONCLUSIONS

- The maize collection evaluated showed morphoagronomic variability; due to the difference between genotypes and the plurality of origins, management and environmental conditions in which this crop is developed in Cuba.
- There were no significant correlations among the evaluated characters.
- The content of phosphorus and calcium was high, while the content of magnesium, potassium and sodium was low, the iron and zinc content being intermediate among the standard values for the culture.

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