Article

Morphological and agronomic diversity of seven corn races from the state of Chiapas

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Abstract

The centers of origin and genetic diversity of corn are located in Mexico, in the state of Chiapas is one of the areas with greater diversity and great social roots towards this crop. Several previous studies of this diversity have been carried out, which have had the limitation that they include a small number of representative populations of the reported races. The objective of this study was to analyze the morphological and agronomic diversity of 42 accessions belonging to seven of the main corn races grown in the state of Chiapas. Field evaluations were established under random complete block designs with two repetitions, in this way, they were sown in warm, semi-warm and temperate zones, under rainfed conditions in the spring-summer cycle of 2018. The analyses of variance detected significant differences between accessions in 79.1% of the variables analyzed and, through the principal component analysis, three groups were formed: group I was compactly integrated by populations of the Zapalote Grande race, with a greater morphological similarity between their accessions, group II with the Comiteco and Tehua races, with morphological amplitude between their populations and group III with the Olotón, Negrito, Negro de Chimaltenago and Motozinteco races, grouped by their phenological cycle and plant size. The groupings observed were consistent with those obtained in the cluster analysis, which reflects consistency in the associations and confirms the identity of the corn races previously reported for the state of Chiapas, they also confirm the complexity of the corn germplasm of that area, finding a wide variation and interrelations between the different populations and races.

Keywords: *Zea mays* L., Chiapas, multivariate analysis, phenotypic characterization.

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Introduction

Some of the centers of origin and diversification of corn are located in Mexico, a megadiverse country in which the orographic, environmental, cultural systems and interaction between them constitute the main drivers of this diversity (Muñoz *et al*., 2009). In corn, these conditions, together with the type of cross-pollination that characterizes it, have led to a wide morphological variation, which has led to adaptation to particular environmental and ecological conditions of each region. In this panorama of variation, the state of Chiapas has one of the areas with the greatest genetic diversity of corn in Mexico (Muñoz, 2003; Perales and Hernández, 2005) represented by the Chiapas-Oaxaca-Guatemala region (Kato *et al*., 2009).

Efforts to understand and study the magnitude of morphological and adaptive diversity in the varied environments have focused classification in the race category, such as those made by Wellhausen *et al*. (1951); Goodman and Paterniani (1969); Sánchez *et al*. (1993). These pioneering studies are based on the use of morphological variables, product of the phenotypic expression of the materials evaluated for their own recognition, description and racial classification. Castillo (1993) mentions that it is necessary to know in detail the variation that exists between and within populations in order to design methods of exploitation and classification of the diversity of native corns.

Studies carried out in the analysis of agronomic and morphological diversity in native corns of races cultivated in the state of Chiapas have used a reduced number of representative populations for each race, such as those reported by Doebley *et al*. (1985); Sánchez and Goodman (1992); Sánchez *et al*. (2000), who used two to four accessions per race, among which are the Olotón, Comiteco, Motozinteco, Negro de Chimaltenango, Negrito, Tehua, Tepecintle and Zapalote Grande races.

In other studies such as those proposed by Perales *et al*. (2005); Benz *et al*. (2007), who addressed in their studies a small sample of races cultivated in Chiapas or, reference has been made to studies of corn with respect to social, historical and cultural processes (Bellon and Brush, 1994; Keleman *et al*., 2009), which makes it necessary to deepen with research works on the analysis of diversity to propose strategies for the conservation and use of this genetic diversity. Corn is the most important cultivated species in Chiapas; however, characterization works to generate knowledge that values morphological and agronomic diversity have been scarce.

These previous studies provide a vision that can be complemented by the diversity existing within each of the races and on appropriate characters for the systematization of the diversity, specifically of native corns from Chiapas, under the hypothesis that there is a wide morphological and agronomic variation intrapopulation and between races cultivated in Chiapas, which can be used in an improvement program by recurrent selection, the objective of this research work consisted of analyzing the morphological and agronomic diversity of a sample of accessions of seven corn races present in the state of Chiapas.

Materials and methods

Genetic material

Forty-two representative accessions of seven corn races from the state of Chiapas were used (Table 1). The seed used came from the germplasm banks of the International Maize and Wheat Improvement Center (CIMMYT, for its acronym in Spanish), the Chapingo Autonomous University (UACH, for its acronym in Spanish), the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish) and the College of Postgraduates (CP).

Table 1. Races and number of populations characterized in six localities of the state of Chiapas.

Race	Places of evaluation	Abbreviation	No. of accessions
Zapalote Grande	Villaflores and Ocozocoautla	Z	16
Comiteco	Teopisca and Comitán	C	7
Tehua	Teopisca and Comitán	T	4
Olotón	Rancho Nuevo and Mitzitón	O	8
Motozinteco	Rancho Nuevo and Mitzitón	M	4
Negrito	Rancho Nuevo and Mitzitón	B	2
Negro de Chimaltenango	Rancho Nuevo and Mitzitón	N	1

Experimental sites

The evaluations were established under rainfed conditions in the spring-summer (SS) agricultural cycle of 2018 in six localities: San Ramón University Center for Technology Transfer of the Autonomous University of Chiapas in the municipality of Villaflores 16º 15’ north latitude, 93º 15’ west longitude and 535 masl, in the Central Chiapas Experimental Field of INIFAP in Ocozocoautla de Espinosa 16º 28’ north latitude, 93º 46’ west longitude and 810 masl, both localities considered in warm zone, Rancho Nuevo 16º 39.82’ north latitude, 92º 32.51’ west longitude and 2 459 masl and Mitzitón 16º 37.92’ north latitude, 92º 32.53’ west longitude and 2 446 masl, municipalities of San Cristóbal de las Casas of temperate zone, as well as in the Auxiliary Field of INIFAP in the municipality of Teopisca 16º 32’ north latitude, 92º 28’ west longitude and 1 779 masl and Laguna Larga, municipality of Comitán 16º 24.90’ north latitude, 92º 15.27’ west longitude and 1 994 masl, corresponding to semi-warm zone. The georeferencing of the places was carried out using a GPS model eTrex Vista® (Garmin LTD, Saitama, Japan). The distribution of accessions for their evaluation at the different sites is indicated in Table 1, which was based on their racial classification, assigning the races in their agroecological zone of adaptation.

Experimental design and unit

Experimental designs in random complete blocks with two repetitions were used at the six evaluation sites. The experimental unit consisted of two furrows 5 m long and 0.8 m wide, with 11 bushes per furrow and two plants per bush, which represent a population density of 55 000 plants ha^{-1}.

Conduction of experiments and agronomic management

The experiments were established on the following dates: February 12, 2018, in Ocozocoautla, June 3 in Mitzitón and Rancho Nuevo, June 4 in Teopisca and Laguna Larga and June 18 in Villaflores. Most of the sowings were carried out under rainfed conditions, except for that of Ocozocoautla, which was under an irrigation regime; sowing was carried out by depositing 3 seeds every 50 cm, adding granular insecticide Pounce® (3-Phenoxybenzyl (1RS)-cis, trans-(2,2-dichlorovinil)-2,2-dimethyl cyclopropane carboxylate) in doses of 20 kg ha^{-1}.

Later, when the plants were approximately 25 cm tall, a thinning was carried out to leave two plants per bush. The fertilization formula 90-46-21 was used, which was applied in two fractions, 50% of N and all the P and K in the first application at 34 days and the rest of N in the second application at 63 days after planting. Weed control was performed with applications of Atrazine 90% in doses of 1.5 kg ha^{-1} at the time of sowing and two applications of glyphosate and 2-4-D in doses of 3.3 and 2 L ha^{-1}, 20 and 45 days after the plants emerged.

Foliage pest control was carried out with sprays of Lambdacyhalothrin 5% in doses of 0.26 L ha^{-1} at 29 days and a second application at 58 days after sowing and with the insecticide Pounce® in doses of 5 kg ha^{-1} aimed at the bud of the plants. The harvest of the experiments was carried out on June 28, 2018, in Ocozocoautla, on October 1 in Villaflores, on December 3 in Teopisca, on January 9, 2019, in Laguna Larga and on January 10, 2018, in Mitzitón and Rancho Nuevo.

Recorded variables

In each experimental plot, five plants with full competence were selected, to which phenological variables of plant, tassel, ear and grain were measured according to the IBPGR descriptor (IBPGR, 1991), in addition, six additional variables were generated through ratios between them. The phenological variables recorded were days to female flowering (DFF) and days to male flowering (DMF) counted from sowing to the day when 50% of the plants emitted receptive stigmas and pollen, respectively, as well as floral asynchrony (FA), considered as the difference between the two.

During vegetative development, the following variables were measured: number of suckers per plant (NSP); plant height (PH) measured in cm from the level of the ground to the tip of the tassel, and ear height (EH) in cm to the insertion node of the main ear, as well as the ratio between the two (PER); length (PLL) and width (PLW) of the leaf of the main ear recorded in cm; number of leaves above the ear (LAE) and total number of leaves of the plant (TNL).

After flowering, the following tassels measurements were recorded in cm: total length (TTL) from the upper node to the tip of the central branch; branched section length (BSL), as the distance from the first to the last primary branch; length of the central branch of the tassel (LCB), measured from the insertion point of the upper primary branch to the tip of the tassel; peduncle length (PL), from the insertion node of the tassel into the plant to the insertion point of the lower primary branch; the number of primary branches (NPB) was counted and the ratio between the branched section length and total tassel length (TBSR) was determined.

After harvesting, five ears were selected from each experimental unit, which were measured: diameter (ED), recorded in the middle part; length (EL) from base to tip, the distance from the insertion node of the peduncle to the base of the ear was considered as ear peduncle length (EPL) and cob diameter (COD) in the middle part; these variables were recorded in cm, in addition to the number of rows per ear (NRE) and the ratio between the diameter and length of the ear (EDLR).

Ten grains of each of the five ears were randomly obtained and measured: width (GW), length (GL) and thickness (GT) in cm to obtain their average; likewise, 100 grains from each experimental unit were randomly obtained and their weight in g (W100G) and their volume (V100G) in cm^3 were recorded. The percentage of shelling (SHEL) was also determined by the ratio of grain weight to the weight of the ear multiplied by 100 and the following ratios were estimated: width over length (GWLR), grain thickness over length (GTLR) and weight over volume of 100 grains (GWVR).

Statistical analysis

A combined analysis of variance across localities within each climate zone was performed. A principal component analysis was performed using the matrix of correlations between the variables. With the values of the first two principal components, a scatter plot of the populations was created. A cluster analysis was also performed with data standardized to the normal distribution (0, 1), using Euclidean distances and the unweighted pair-group method with arithmetic mean (UPGMA). To define the number of population groups in the dendrogram, the Pseudo F index was used. These analyses were performed using the statistical packages SAS® V.9.0 (SAS Institute, 2002) and NTSYSpc® V.2.21 (Rohlf, 2009).

Results and discussion

Analysis of variance

According to the combined analysis of variance applied by climatic zone, which included 16 populations in warm zone, 11 populations in semi-warm zone and 15 in temperate zone. Significant statistical differences between the genotypes were detected in most of the variables analyzed, corresponding to 50% of variables with significance in the warm zone, 84% in the semi-warm zone and 81% in the temperate zone (Table 2), which indicates the existence of diversity among the populations representing the studied races.

Table 2. Mean squares of the combined analysis of variance across localities within agroclimatic zones of Chiapas.

Var	Warm zone				Semi-warm zone				Temperate zone			
	Genotype	Locality	G × L	Error	Genotype	Locality	G × L	Error	Genotype	Locality	G × L	Error
DFF	63.24**	2058.68**	8.5*	2.5	298.84**	44.3*	65.76**	10.22	699.98**	1.06ns	136.85*	40.76
DMF	64.83**	1494.22**	6.75*	3.05	285.16**	4.92ns	51.25**	6.73	887.63**	21.12ns	112.68*	34.56
FA	1.25ns	36.12**	0.62ns	1.86	7.47ns	14.01ns	6.97ns	3.87	11.98ns	80.85*	15ns	10.76
NSP	0.02ns	0ns	0.004ns	0.01	0ns	0ns	0ns	0	0.01*	0.002ns	0.003ns	0.006

Var	Warm zone				Semi-warm zone				Temperate zone			
	Genotype	Locality	G × L	Error	Genotype	Locality	G × L	Error	Genotype	Locality	G × L	Error
PH	1108.1**	74061.2**	259.5ns	158.3	4662.1**	140233.8**	528.1ns	346.4	2348.2*	106983.9**	1498.2*	769.2
EH	876.26**	9103.5**	202.55*	90.53	3139**	76316.5**	320.38ns	183	1094.5**	59806.1**	566.61*	230.5
PER	0.007**	0.09**	0.002ns	0.002	0.012**	0.16**	0.003*	0.001	0.01ns	0.33**	0.01ns	0.008
TNL	7.3ns	103.2ns	0.85ns	0.69	2751.2ns	47010.2**	2763.2ns	2281	11.08**	93.38**	7.61**	0.82
LAE	0.82**	38.72**	0.19ns	0.13	0.85**	2.58**	0.17ns	0.11	2.34**	0.24ns	0.66*	0.21
PLL	45.82ns	124.29ns	30.92ns	22.29	100.39ns	2331.6**	33.14ns	51.01	132.46*	11387.92**	135.46*	57.89
PLW	0.87*	33.62**	0.21ns	0.3	2.4**	32.01**	0.99*	0.24	1.14ns	61.97**	1.51*	0.64
TTL	21.43*	5023.36**	8.23ns	8.61	44.69*	25.76ns	12.53ns	14.52	26.82ns	555**	25.44ns	14.43
PL	9.24ns	0.98ns	6.93ns	5.18	25.26**	60.95*	7.1ns	3.67	63.53**	2.84ns	12.21*	5.62
LCB	7.17ns	50.16*	8.61ns	4.88	31.72*	79.26*	4.31ns	6.19	30.01*	9.22ns	16.17ns	10.7
BSL	5.58ns	0.06ns	1.5ns	1.51	12.84*	210.4**	2.8ns	4.11	7.92*	276.12**	8.1*	3.54
NPB	26.33ns	251.62*	22.88ns	24.69	41.08**	97.48*	11.47ns	5.9	20.38*	544.5**	7.4ns	5.74
TBSR	0.002*	0.21**	0.001*	0.001	0.007*	0.11**	0.002ns	0.001	0.008ns	0.08*	0.005ns	0.005
EL	8.99**	1.53ns	1.34ns	1.01	17.59**	344.32**	8.59*	2.24	14.2ns	6.53ns	13.31ns	1.24
ED	0.09ns	7.54**	0.05ns	0.05	0.62**	38.15**	0.32*	0.07	1.08**	6.58**	1.03**	0.04
NRE	1.76*	0.06ns	0.71ns	0.54	7.03**	289.88**	6.61*	0.97	5.21*	14.1*	2.48ns	1.49
EPL	3.82ns	68.83**	2.17ns	2.68	8.64*	215.95**	1.81ns	3.22	6.08*	94.38**	4.79ns	2.61
COD	0.17**	0.4**	0.03ns	0.01	0.18*	5.14**	0.1ns	0.03	0.25**	0.003ns	0.07*	0.02
EDLR	0.007*	0.08**	0.002ns	0.002	0.008**	0.01*	0.006*	0.001	0.02**	0.1**	0.01*	0.003
GL	0.6ns	0.05ns	0.3ns	0.31	4.96**	116.31**	1.22*	0.43	0.97**	6.04**	0.54*	0.15
GW	0.33ns	1.78ns	0.1ns	0.15	5.44**	28.58**	0.87*	0.34	0.63**	0.01ns	0.69**	0.07
GT	0.34ns	0.3ns	0.09ns	0.14	1.54*	5.82**	1.07*	0.25	0.55**	0.53*	0.31**	0.05
SHEL	13.04ns	85.8*	14.99ns	22.64	221.72**	6077.11**	125.22*	28.3	242.99**	30.91ns	130.33*	50.52
W100G	21.3ns	11.68ns	15.62ns	12.28	160.44**	6784.79**	53.23*	16.82	87.64**	40.57*	38.83*	9.5
V100G	37.16*	53.38ns	30.91ns	18.08	679.63**	9972.26**	88.72*	35.79	91.44*	699.3**	63.6ns	31.89
GWLR	0.005*	0.01*	0.002ns	0.002	0.04**	0.12**	0.01*	0.002	0.005**	0.08**	0.004**	0.001
GTLR	0.004*	0.002ns	0.001ns	0.002	0.02*	0.02*	0.01*	0.004	0.007**	0.004*	0.007**	0.001
GWVR	0.003ns	0.02ns	0.004ns	0.003	0.15ns	0.04ns	0.12ns	0.007	0.02*	0.07*	0.01ns	0.007

*= $p \leq 0.05$, **= $p \leq 0.01$; ns= not significant; Var= variable; DFF= days to female flowering=; DMF= days to male flowering; FA= floral asynchrony; NSP= number of suckers per plant; PH= plant height; EH= ear height; PER= height of plant and ear ratio ; TNL= total number of leaves; LAE= leaves above the ear; PLL= plant leaf length; PLW= plant leaf width; TTL= total tassel length; PL= peduncle length; LCB= length of the central branch of the tassel: BSL= branched section length; NPB= number of primary branches; TBSR= branched section and length ratio; EL= ear length; ED= ear diameter; NRE= number of rows per ear; EPL= ear peduncle length; COD= cob diameter; EDLR= ear diameter and length ratio; GL= grain length, GW= grain width; GT= grain thickness; SHEL= percentage of shelling; W100G= weight of 100 grains; V100G= volume of 100 grains; GWLR= grain width and length ratio; GTLR= grain thickness and length ratio; GWVR= grain weight and volume ratio.

Also in the present study, significant differences ($p \leq 0.05$ and 0.01) were observed between localities in 18 variables in the warm zone, 28 in the semi-warm zone and 22 in the temperate zone, of the 32 variables recorded. The interaction genotype × environment was significant ($p \leq 0.05$ and 0.01) in 13, 50 and 63% of the variables recorded for the warm, semi-warm and temperate zone, respectively, these results show the influence of other factors such as the environment on the differential behavior exhibited by the populations in morphological characters molded with the criteria of the farmers.

Principal component analysis

Considering the 32 variables recorded, which have been used in different studies of genetic diversity of native corn for their usefulness in differentiating populations (Vega-Álvarez *et al*., 2017; Linares-Holguín *et al*., 2019), the principal component analysis was carried out (Table 3), in which the first six components explained 80% of the total variation observed. The first principal component contributed 40.6% of the total variation, the second 18.4% and components 3 to 6 accounted for 22.7% (Table 3).

Table 3. Vectors, eigenvalues and proportion of variance explained by the first two principal components (PC) in 42 populations of seven races of corn from the state of Chiapas.

Variables	PC1	PC2
Days to female flowering (DFF)	-0.232	0.181
Days to male flowering (DMF)	-0.232	0.176
Floral asynchrony (FA)	-0.176	0.201
Number of suckers per plant (NSP)	0.047	0.02
Plant height (PH)	0.13	0.338
Ear height (EH)	0.212	0.225
Height of plant and ear ratio (PER)	0.219	-0.037
Total number of leaves (TNL)	0.048	0.296
Leaves above the ear (LAE)	0.074	0.154
Plant leaf length (PLL)	0.248	0.045
Plant leaf width (PLW)	0.124	0.258
Total tassel length (TTL)	0.249	-0.084
Peduncle length (PL)	0.058	0.077
Length of the central branch of the tassel (LCB)	0.037	0.104
Branched section length (BSL)	0.216	0.193
Number of primary branches (NPB)	0.183	0.13
Branched section and length ratio (TBSR)	0.055	0.321
Ear length (EL)	0.162	0.265
Ear diameter (ED)	0.216	-0.074
Number of rows per ear (NRE)	0.097	-0.147
Ear peduncle length (EPL)	0.196	-0.132

Variables	PC1	PC2
Cob diameter (COD)	0.208	-0.015
Ear diameter and length ratio (EDLR)	-0.105	-0.245
Grain length (GL)	0.252	-0.098
Grain width (GW)	0.231	-0.004
Grain thickness (GT)	-0.16	0.212
Percentage of shelling (SHEL)	0.126	-0.284
Weight of 100 grains (W100G)	0.224	0.077
Volume of 100 grains (V100G)	0.233	0.083
Grain width and length ratio (GWLR)	-0.132	0.154
Grain thickness and length ratio (GTLR)	-0.237	0.143
Grain weight and volume ratio (GWVR)	-0.056	0.04
Eigenvalue	12.99	5.88
Variance explained (%)	40.61	18.38

The original variables of greatest contribution to the definition of variability in the first principal component were: PH, TBSR, TNL, SHEL, EL, PLW, EDLR, EH, GT, FA, BSL, DFF and DMF, while the variables GL, TTL, PLL, GTLR, V100G, DMF, DFF, GW, W100G, PER, BSL, ED and EH contributed most to the definition of the variation of component 2.

The high proportion explained with a low number of components allows an efficient interpretation of the variation (Pla, 1986; León *et al*., 2008), in this way, through a scatter plot built with the first two principal components (Figure 1), it was possible to observe the populations of the Zapalote Grande, Motozinteco, Olotón and Negrito races, which showed greater morpho-agronomic differentiation, being integrated into three groups. Group I, located in quadrant IV, was integrated with the populations of the Zapalote Grande race, which indicates that they have a marked morphological identity, which is mainly determined by the variables: DFF (61.5), DMF (59.1), PH (195.9 cm), EH (109.1 cm), PER (0.6), LAE (5.1), PLW (8.2 cm), TTL (44.1), TBSR (0.3), EL (11.6), NRE (11.4), COD (2.4), EDLR (0.4).

In this group, plants of low size and short phenological cycle are distinguished, which contrasts with what was reported by Sánchez and Goodman (1992), who reported heights of 250 to 320 cm and 85 to 105 days to flowering in the same race, these authors cataloged this race within the group of tropical toothed that are grown in the regions of medium and low elevation of Chiapas. Sánchez *et al*. (2000) mention that this race adapts mainly to low elevations and generally shows plants of low size, Ortega (2007) added that they correspond to a subgroup of short cycle, which coincides with the results of the present study.

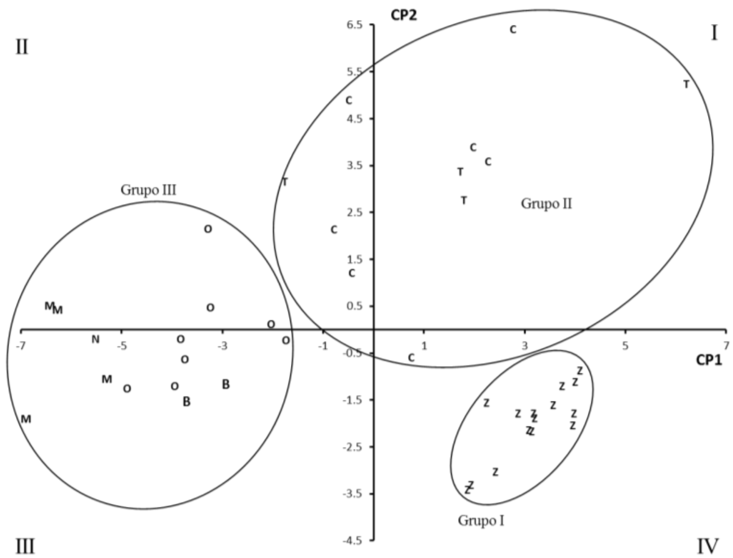

Figure 1. Dispersion of 42 populations of corn from the state of Chiapas based on the first two principal components, built with 19 morphological variables. Races (C: Comiteco, M: Motozinteco, B: Negrito, N: Negro de Chimaltenango, O: Olotón, T: Tehua, Z: Zapalote Grande).

Group II was integrated by populations of the Comiteco and Tehua races, which dispersed in quadrants I, II and IV. The populations of these races were characterized by having intermediate flowerings (109.9 and 104.4 days), plants with 270.8 and 266.8 cm in height, tassels with 37.2 and 36.1 and ears of 15.8 and 14.4 cm, similar values reported by Wellhausen *et al*. (1951) for the description of these races. The dispersion of the populations of these races, represented in the plot, is probably the product of movement between niches and constant gene flow between them, since they are populations cultivated by producers in the adjacent semi-warm areas, where the exchange of seeds between farmers is common.

In this regard, Perales and Hernández (2005) report that the diversity of morphological characters is greater in some regions of rapid transition between temperate and warm climates. In the study conducted by Reif *et al*. (2006), the Olotón, Comiteco, Tehua and Zapalote Grande races were close, probably because they share genetic characteristics in common and in this case, the geographical origin, although there is also the possibility of proximity by probability, being a study where only one accession per race was included; Doebley *et al*. (1985) found that the Olotón, Comiteco, Tehua and Zapalote Grande races did not fall in well-defined groups.

Group III, made up of populations of the Olotón, Negrito, Negro de Chimaltenango and Motozinteco races, was located between quadrants II and III, the populations had characteristics in common, such as late flowerings (DFF 143.7 and DMF 138.8), greater than those reported by Wellhausen *et al*. (1951), plant and ear heights with 180 and 76.6 cm, 30.2 cm in tassel length, 9.8 primary branches in the tassel, ears with 9.3 cm in length and 3.2 cm in diameter and grains with 8.4, 7.8 and 4.9 mm in length, width and thickness, respectively. These populations are part of the group that Sánchez *et al*. (2000) classified as late maturity, which also shows agreement with what was reported by Ortega (2007), in the variables plant height and ear length, and lower than that reported by Sánchez and Goodman (1992) with 320 to 380 and 18 to 22 cm respectively, the expression of these characters was affected by a long drought period (approximately 25 days) during their development.

Cluster analysis

The groupings observed through the principal component analysis were consistent with those of the cluster analysis based on the data of all the populations and variables evaluated, which reflects consistency in the associations, manifesting a continuum with respect to the diversity of agroclimatic zones of the state of Chiapas, such as precocity and agronomic characteristics (Sánchez *et al*., 1993; Sánchez *et al*., 2000). Of the diversity of populations that were analyzed, the dendrogram allowed differentiating four groups at a Euclidean distance of 7.8 units, according to the Pseudo F statistic (Figure 2).

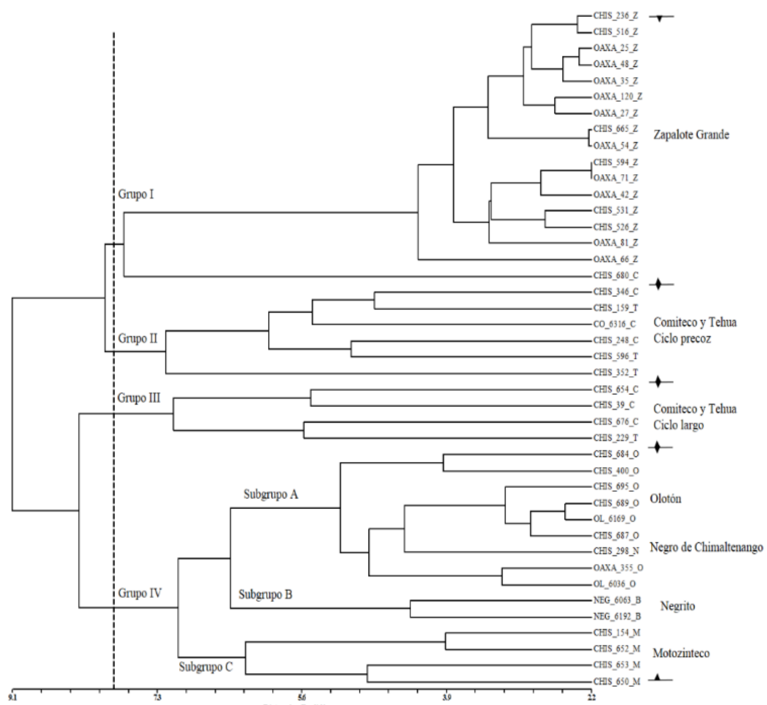

Figure 2. Dendrogram of 42 accessions of corn from the state of Chiapas, built by UPGMA with Euclidean distances derived from 32 morphological and agronomic variables.

The early and small ear populations were grouped at the top of the dendrogram, followed by the intermediate populations and at the bottom the populations of long cycle, large ear and bulging base, which agrees with what Ortega (2007) exposed. In Group I, the short-cycle populations cultivated in the warm zone, corresponding to the Zapalote Grande race, were agglomerated. The evaluated populations of the Comiteco and Tehua races were distributed mostly in two groups, group II that included the earliest (101 DFF) and group III that included those that had long cycles (up to 123 days to female flowering), only one accession of the Comiteco race was located in group I.

It is known that the corns grown by farmers are in a dynamic of constant change oriented by preferences and interests at the level of the family nucleus of farmers and the environmental conditions of the ecological niche, influence of ethnic diversity, adaptability (Muñoz, 2003), movement of seeds among farmers that guides the distribution of corn populations beyond their primary habitat (Brush and Perales, 2007), promoting a scenario of genetic erosion. Currently, according to Perales and Hernández (2005); Brush and Perales (2007), the Comiteco race has a wide distribution that ranges from 900 to 2 500 masl, in contrast to what was reported by Wellhausen *et al*. (1951), with an amplitude of 1 000 to 1 500 masl.

In group IV, three subgroups corresponding to populations of the temperate zone of long cycle were observed: subgroup A, made up of populations of the Olotón race, with plants of 146 DFF and 140 DMF, few suckers per plant (average of 0.08) with cob diameters of 2.03 cm and Negro de Chimaltenango, with female and male flowering of 158 and 152 days, respectively, the populations of both races had heights that ranged from 162 to 193 cm. Subgroup B concentrated populations of the Negrito race with 120 DFF and 114 DMF, with plant heights within the same range as the previous ones, greater number of total leaves (13.7) and cob diameter (2.5), and subgroup C, composed with populations of the Motozinteco race with very late flowerings (156 DFF and 152 DMF), greater number of leaves above the ear (5.5) and a large grain length (8.37 mm).

According to the results, there is genetic variability in the set of populations that represent each of the races of the state of Chiapas and their complexity is conjugated at the morphological level between different types classified as races previously, in such a way that some populations are grouped with others of races of common origin, since they share characteristics.

Conclusions

Wide phenotypic diversity was observed among the evaluated populations corresponding to seven corn races from the state of Chiapas. The prehistoric mestizo race Zapalote Grande is the most defined in the groupings, it has plants of early cycle and ears of intermediate size, characteristics of corns of warm zone. The groupings presented by the principal component analysis and the cluster analysis are congruent, which reflects consistency in the associations using all the variables evaluated.

The cluster analysis showed the Comiteco and Tehua races divided into two groups differentiated by the flowering period. The Olotón, Negrito, Negro de Chimaltenango and Motozinteco races agglomerated forming the group of late corns from the temperate zone. The amplitude of dispersion of these populations, as well as their grouping in the cluster analysis indicate that it is necessary to deepen this type of studies in these races, with an even greater number of accessions or with molecular markers. The associations confirm the complexity of the corn germplasm from that area, with its variation, groupings and interrelationships between the different populations. This knowledge can be applied to propose a better design of programs for the conservation, management and use of the genetic diversity of corn races from the state of Chiapas.

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