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YIELD STABILITY OF RAINFED NATIVE MAIZE IN THE OAXACAN MIXTEC REGION

Leodegario Osorio-Alcalá
Sitio Experimental Mixteca Oaxaqueña, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias
Santo Domingo Yanhuitlan, Oaxaca

Jesús Martínez-Sánchez
Campo Experimental Centro de Chiapas, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias
Ocozocoautla, Chiapas
https://orcid.org/0000-0002-0214-5153

Luis Eduardo García-Mayoral
Campo Experimental Valles Centrales de Oaxaca, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias
Villa de Etla, Oaxaca
https://orcid.org/0000-0001-7073-9482

Abstract: The state of Oaxaca is considered an important center of maize (*Zea mays* L.) diversification; at least 35 breeds have been identified as a consequence of the selection process carried out by producers in different environments. The objective of the research was to evaluate the grain yield of native maize populations in rainfed environments in the Mixteca Alta region of Oaxaca, in order to identify the most stable in yield. Eighteen native maize populations were evaluated in five contrasting environments under a randomized complete block design. A combined analysis of variance was performed. Subsequently, for grain yield, the site regression model (SREG) was applied to study the genotype-by-environment interaction. Stability analysis was done using the GGE biplot. Based on the stability analysis of the 18 native maize varieties evaluated in five rainfed environments, populations 16 (Yanhuitlán), 14 (Jazmín) and 17 (Jaltepec) stood out for their grain yield, with yields of 5.5, 5.49 and 5.7 t ha^{-1}, respectively. These results reflect the yield potential of native maize and its adaptation to the environmental conditions of the region; in addition, it is widely accepted by producers.
Keywords: Zea mays, adaptability, populations.

INTRODUCTION

Mexico is the center of origin of corn; at least 60 breeds have been identified from which diverse types of corn have been generated as a consequence of the selection process carried out by producers in diverse environments ranging from sea level to 3,000 meters above sea level. Native maize is a source of germplasm for the generation of improved open-pollinated varieties and hybrids. Oaxaca is considered one of most important genetic reservoirs of maize in Mexico and the world, concentrating 35 maize races, which represents 54% of those reported for the entire country Aragón-Cuevas *et al.*

Native corn has several attributes such as greater tolerance to pests, diseases, drought, in addition to the various nutraceutical properties of the grain that contribute to a better, healthier and more nutritious diet Fernández *et al.* Given the effect of climate change there is an increase in temperature and it is associated with longer periods of drought, native materials possess genes that favor better development of these materials, compared to improved varieties (hybrids), therefore, it is essential their conservation, production and improvement Turrent *et al.*, (2016).

The challenge for breeders is to identify native maize with high grain yield and stable behavior contrasting environments; this is the first step to implement a breeding program that includes superior populations of native maize diversity Martinez *et al.*, (2016); Martinez *et al.*, (2018). There are different methodologies to optimize selection, highlighting techniques that combine analysis of variance and principal components such as AMMI and SREG models, among others Yan *et al.*, (2007); Lozano *et al.*, (2015), which have proven to be effective for modeling genotype environment interaction in native maize Arellano *et al.*, (2014). The objective of the research was to evaluate the grain yield of 18 native maize populations in five rainfed environments in the Mixteca Alta region of Oaxaca, in order to identify the most stable populations in yield and use them for future genetic improvement programs that in the medium term could be released as varieties and contribute to improve the production of native maize.

MATERIALS AND METHODS

In 2015, a collection of 18 populations of native maize was made in various communities of the Mixteca Alta region comprising the Nochixtlán Valley, Teposcolula and Coixtlahuaca, where a semi-dry temperate climate with summer rains predominates. These populations were evaluated in five environments during 2015 to 2017, all under rainfed conditions Table 1). Experimental Site 2015 (SE 15), Experimental Site 2016 (SE 16), Tiltepec 2016 (Tilt 16), Yanhuitlán 2017 (Yanh 17) and Experimental Site 2017 (SE 17)

Of the 18 populations studied in the five environments (years and locations), 16 were white-grained, one was yellow-grained and one was blue-grained. The greatest diversity was with white-grain corn (Table 2). A randomized block experimental design with three replications was used, the total plot size was 4 furrows of 5 meters in length and separated by 0.75 meters (15 m²). The useful plot was two central furrows (7.5 m²).

No. Population	*Genotype origin and identification*	*Grain color*
1	Yucuita Creole	White
2	Criollo Chachoapam wide	White
3	Coyotepec Creole	White
4	Soyaltepec Creole	White
5	Nativitas Creole	White
6	Creole Suchixtlahuaca	Blue
7	Coixtlahuaca Creole	White
8	Tejupan Creole	White
9	Tiltepec Creole	White
10	Creole San Juan Teposcolula	White
11	Creole Teposcolula	White
12	San Pedro Añañe Creole	White
13	Tecomatlan Creole	White
14	Creole El Jazmín Yanhuitlán	White
15	Creole San Antonio Nduayaco	White
16	Criollo Santo Domingo Yanhuitlán (witness)	White
17	Jaltepec Creole	White
18	Yucuita Creole	Yellow

Table 2. Origin and kernel color of native maize populations evaluated in five contrasting environments.

Agronomic management and variables recorded. In the five environments, planting was done manually, placing 2 seeds per bush separated at 0.25 m and in furrows 0.75 m apart. When plant emergence occurred, only one plant was left every 0.25 m, to achieve a population density of 53,333 plants per hectare.

Fertilization. A total fertilization dose of 100-80-60 (NPK) was used, using Urea (40-00-00 NPK) as a source of nitrogen, diammonium phosphate (18-46-00 NPK) as a source of phosphorus, and potassium, potassium chloride (0-0-60 NPK) as a source of potassium. Phosphorus and potassium were applied at sowing, nitrogen was divided into three applications, 50 units at sowing, 25 at V4 and another 25 units of nitrogen at V7. Weed control was carried out by applying Atrazine 1.5 kg/ha in pre-emergence, and those that emerged later were controlled manually. The seed was treated with Alectus (Bifenthrin + Imidacloprid) to prevent damage from soil pests, and for foliage pests karate (cypermethrin) was applied at a dose of 0.25 l/ha.

The following variables were recorded: days to male flowering (FM), days to female flowering (FF), physiological maturity (MF), plant height (AP), ear height (AM), grain yield (RG), ear length (LM), diameter (DM), number of rows per ear (NHPM), number of grains per row (NGPH) and number of grains per ear (NGPM).

Statistical analysis. For vegetative, phenological variables and yield components, the statistical analysis was performed using a combined analysis of variance, for the comparison of means between populations and locations the Tukey's test of means at 0.05 probability was applied, the interaction genotype environment and grain yield stability was modeled with site regression method (SREG), according to the principles described by Frutos *et al.*, (2014). Analyses of variance were solved with the SAS system (SAS, 2000) while for the SREG model the GEA-R program Pacheco *et al.*, (2015) was used.

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Location	Location	Altitude masl	Year	Sowing date	Precipitation (mm)
Mixteca Experimental Site (2015)	17° 30' 29" LN 97° 21' 28" LW	2138	2015	June 11	343.5
Mixtec Experimental Site (2016)	17° 30' 29" LN 97° 21' 28" LW	2138	2016	June 6	428.7
Santa María Tiltepec (2016)	17° 27' 51" LN 97° 20' 56" LW	2162	2016	June 9	382.7
Mixtec Experimental Site (2017)	17° 30' 29" LN 97° 21' 28" LW	2138	2017	June 8	796.5
Santo Domingo Yanhuitlán (2017)	17° 31' 26" LN 97° 20' 56" LW	2144	2017	June 23rd	783.7

Table 1. Evaluation environments of native maize populations evaluated under rainfed conditions in the Mixteca of Oaxaca

F.V	A	REP(A)	P	P*A	X	C.V
FM	247.7**	6.3 ns	201.2**	8.9**	84.5	2.4
FF	1230.5*	3.8 ns	195.2**	7.4**	86.2	2.3
MF	4325.6**	30.9**	174.8**	28.4**	170.2	3
LM	134.4**	0.3 ns	5.1**	1.0*	12.6	6.7
DM	1.7**	.06 ns	0.5**	.05 ns	4.6	4.2
NH	15.4**	0.6 ns	23.3**	1.0**	12.5	5.6
NGPH	286.0**	9.9**	19.3**	5.8*	25.6	7.7
NGPM	98849.9**	1884.6 ns	17806.2**	1839.9**	321.5	10
AP	2144.7**	210.7ns	1055.0**	272. 0ns	241.4	6.5
AM	19367.2**	74.9ns	10129.7**	152.3ns	141.8	9.4

Table 3. Mean squares and statistical significance of agronomic traits of native maize populations evaluated in 5 environments of the Mixteca Alta, Oaxaca.

A = Environment, Rep = Repetitions, P = Populations, P*A = Interaction populations by environments, X = Mean, C. V = Coefficient of variation (%), FM = Days to male flowering (DDS), FF = Days to female flowering (DDS), MF = Physiological maturity (DDS), LM = Ear length (cm), DM = Ear diameter, NH = Number of rows, NGPH = Number of grains per row, NGPM = Number of grains per ear, AP = Plant height (cm), AM = Ear height (cm).

Variety	FM	FF	MF	AP	AM
1	88.8 cab	89.5 cab	173.9 cab	230.8 cdb	129.1 d
2	86.5 ced	88.1 cd	174.9 ab	245.8 cadb	142.4 cdb
3	**78.7 i**	**80.6 h**	167.1 gef	231.5 cdb	134.0 cd
4	82.8 gf	85.9 of	171.3 cadb	232.1 cdb	129.2 d
5	81.2 igh	83.1 gfh	167.7 gedf	229.3 cd	138.8 cdb
6	81.3 igh	83.5 gfe	166.7 gf	234.1 cdb	138.6 cdb
7	82.4 gh	83.9 fe	167.7 gedf	240.0 cadb	133.8 cd
8	87.0 cedb	88.7 cb	173.1 cab	243.2 cadb	139.6 cdb
9	85.9 e	87.9 cd	171.0 cedb	245.6 cadb	143.0 cdb
10	85.9 ed	87.7 cd	170.4 cedf	247.5 cab	154.2 ab
11	88.5 cadb	89.5 cab	172.5 cab	251.4 ab	165.5 a
12	89.3 ab	91.1 ab	175.0 a	**257.5 a**	149.6 cab
13	86.9 cedb	88.9 cb	171.4 cadb	248.8 ab	147.4 cab
14	**78.9 i**	**80.7 h**	**164.6 g**	226.6 cd	131.9 d
15	80.1 ih	82.3 gfh	**164.6 g**	240.0 cadb	139.9 cdb
16	80.6 igh	81.3 gh	**166.5 g**	246.7 cadb	140.3 cdb
17	85.3 ef	87.1 cd	170.8 ced	247.6 cab	142.3 cdb
18	90.0 a	91.6 a	173.7 cab	243.0 cadb	140.6 cdb
DSH	2.6	2.5	3.9	20.2	17.2

Mean agronomic traits of native maize populations of the Mixteca alta, average of five environments under rainfed conditions.

AP = plant height (cm), AM = ear height (cm), FM = days to male flowering (DDS), FF = days to female flowering (DDS), MF = physiological maturity (DDS).

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RESULTS AND DISCUSSION

In the analysis of variance, significant differences were detected (P< ;0.01) for all variables between environments and populations, in the interaction populations by environments there was no statistical significance (P> ;0.05) in the variables ear diameter, plant height and ear height (Table 3). These results can be considered as indicators of genetic diversity among populations, that there was environmental variation and that phenology and yield components behaved differently across environments. The coefficients of variation were below 10%, which indicates good environmental control and the precision of the experimental technique used, giving statistical reliability to information.

Among native maize populations, significant differences were observed for days to female flowering ranging from 79 to 90; male flowering from 81 to 92 and physiological maturity from 165 to 175 days; plant height from 229 to 258 cm; ear height from 129 to 166 cm; ear length from 11.5 to 13.6 cm; number of rows from 10.5 to 14.6; number of kernels per row from 23.4 to 27.4 and number of kernels per ear from 267 to 368 (Tables 4 and 5). The days to flowering of these varieties are considered late compared to those reported by Martínez *et al*. (2017), for native maize populations of warm climate in the state of Chiapas and less than those reported for populations of Chalqueño blue maize from the Central Highlands of Mexico Arellano *et al*. (2014)

In terms of earliness at male and female flowering, populations 3 and 14 from Coyotepec and el Jazmín stood out, with 78 and 80 days to male and female flowering, respectively, while treatment 18 from Yucuita was latest with 90 days to flowering. At physiological maturity, the earliest materials matured between 164 and 166 days, with treatments 14 (el Jazmín), 15 (Nduayaco) and 16 (Yanhuitlán) standing out again. Jaltepec maize matured at 170.8 days.

Regarding plant height among native maize (Table 4) there is genetic variability, one of the main characteristics that distinguishes the native materials is their greater plant height with respect to the improved ones. Treatment 12 (Añañe) and 11 (Teposcolula) had the highest PA in the five environments with values of 257.5 and 251.4 cm, respectively; while 14 (Jazmín) and 5 (Nativitas) had the lowest PA and MA with 226.6 and 229.3 cm, respectively.

The smaller plant height of some native maize gives them the advantage of greater resistance to lodging during grain filling in the event of torrential rains, in addition to facilitating manual harvesting, especially with self-consumption producers. This advantage is found in populations 14 and 5; the opposite occurs with populations 12 and 11. Of course, the materials with higher PA also preferred by producers because they produce a greater amount of forage that is used to feed their livestock, so each material has its advantages for both grain and forage production, which is why they are cultivated by producers Aragón-Cuevas *et al.*

Knowledge of the phenological and morphological variables of native corn is essential to identify valuable materials that can be used as a source of germplasm in breeding programs, and to obtain open-pollinated varieties and even hybrids. Those with greater earliness and lower plant height may be the most suitable for cultivation in environments with drought problems, due to their lower water demand, with respect to materials with greater vegetative cycle and plant height that may demand greater amounts of water and nutrients, but be used for forage production Turrent *et al*., (2016).

Yield components. Genetic variability was found among native maize populations in yield components, which is indicative that a breeding program can be implemented with the best maize, and agrees with Pecina-Martínez *et al*. (2011) in the sense that native maize populations provide genetic diversity and outstanding agronomic traits that can be exploited in the improvement of grain production.

Variety	LM	DM	NH	NGPH	NGPM
1	13.1 ab	4.8 cb	12.7 fde	25.6 cadbe	326.4 cedb
2	11.9 cde	4.7 dceb	10.3 h	27.4 a	283.2 gf
3	12.6 cadb	4.6 dce	11.7 g	24.8 cdbe	289.8 gef
4	13.1 ab	4.8 dcb	11.5 g	25.3 cadbe	291.4 gef
5	13.0 cab	4.7 dceb	13.6 cdb	25.9 cadbe	352.8 cab
6	11.5 e	4.5 faith	12.8 of	23.4 of	299.2 gedf
7	13.2 ab	4.9 ab	11.9 fge	24.6 cde	292.9 gef
8	12.8 cadb	4.8 dcb	12.1 fge	24.3 of	294.6 gef
9	11.7 of	4.3 f	13.5 cdb	27.3 ab	368.4 a
10	13.6 a	4.8 cb	14.1 cab	25.7 cadbe	363.9 ab
11	12.8 cadb	4.7 dceb	13.3 cd	27.0 cab	360.3ab
12	12.4 cdbe	5.1 a	14.6 a	24.0 of	352.5 cab
13	12.2 cdbe	4.7 dceb	13.4 cd	25.3 cadbe	339.3 cadb
14	13.2 ab	4.6 dce	11.6 g	26.5 cadb	308.6 edf
15	12.2 cdbe	4.5 faith	14.3 ab	26.5 cadb	380.0 a
16	12.3 cdbe	4.7 dceb	12.0 fge	24.9 cadbe	303.3 gedf
17	13.2 ab	4.7 dceb	11.8 fg	26.4 cadb	313.2cedf
18	12.6 cadbe	4.6 of	10.5 h	25.4 cadbe	266.8 g
DSH	1.1	0.3	0.9	2.6	41.5

Yield component means of native maize populations from the Mixteca, average of five environments under rainfed conditions.

LM = ear length (cm), DM = ear diameter, NH = number of rows, NGPH = number of kernels per row, NGPM = number of kernels per ear.

In LM, treatments 10 (San Juan Teposcolula), 1 (Yucuita), 4 (Soyaltepec), 14 (Jazmín) and 17 (Jaltepec) stood out with values that fluctuated between 13.1 and 13.6 cm; while those with the lowest LM were: 6 (Suchixtlahuaca) and 9 (Tiltepec) with an average of 11.6 cm. Genetic variability was also observed for NH, highlighting treatments 12 (Añañe) and 15 (Nduayaco) with average values of 14.6 and 14.3; on the contrary, treatments 18 (Yucuita) and 2 (Chachoapan) had 10.5 and 10.3 rows, respectively.

In the NGPM, treatments 15 (Nduayaco) and 9 (Tiltepec) stood out with 380 and 368.4 grains, statistically superior to other materials. Treatments 14 (Jazmín) and 17 (Jaltepec) reported 308.6 and 313.2 NGPM, respectively. In this aspect, as pointed out by Hernández and De León Castillo (2021), yield components are important variables indirect selection for productivity; in maize, yield is correlated with ear length, hectoliter weight and grain size.

Table 6 shows the analysis of variance for grain yield and the Gollob test used to obtain the statistical significance of the components of the SREG model. For grain yield there were significant differences between environments, populations and the P*A interaction; the first two components are significant (P< ;0.01) and together explain 84.7% of the interaction; these results allow a reliable interpretation of the genotype environment interaction, since an acceptable value for this is a proportion greater than 75%, Martinez *et al*., (2016). The significant interaction indicates that creole varieties behave differently under environmental variations and, consequently, there are varieties that are good for some environments but do not respond favorably in others. Genotype-environment interaction was observed, which indicates that the materials have different responses to the environments where they were evaluated, mainly due to the amount and distribution of rainfall crop development. The maize that show a better response to environments with less precipitation would be the most important for producers, because it would allow them to face drought problems in the face of the effects of climate change.

Source of variation	Sum of squares	Percentage of sum of squares	Squares media
Environments	693.6	81.6	173.4**
Populations	57.1	6.7	3.4**
P * A	98.9	11.6	1.5**
PC1	71.6	45.9	3.6**
PC2	60.5	38.8	3.4**
PC3	11.9	7.6	0.7
PC4	9.3	6.0	0.7
PC5	2.6	1.7	0.2

Table 6. Statistical significance of grain yield (t ha^{-1}) and Gollob's test used to obtain the significance of the SREG model components for the 18 native maize populations evaluated in five environments.

P * A = Interaction Populations by environments.

Response of native corn in different rainfed environments. Table 7 shows the yield of the 18 native maize varieties, the grain yield ranged from 4 to 5.7 t ha^{-1}, with a mean of 4.87 t ha^{-1}, eight populations exceeded the mean yield. In the first group of significance were 10 populations with yields that ranged from 4.77 t ha^{-1} (Trat 2) to 5.71 t ha^{-1} (Trat 14); while those with the lowest yields were treatments 6 and 9 with 4.0 and 4.17 t ha^{-1}, respectively. These yields are outstanding because commercially an average of between 1.1 and 1.5 t ha^{-1} is obtained with native maize grown in the different communities. These results show that there is good genetic potential for native maize to exceed 4 t ha^{-1}, only agronomic practices such as population density, nutrition and timely control of pests and weeds need to be improved.

Treatments 17 (Jaltepec) and 14 (Jasmine) were the highest yielding populations across environments, yielding on average 5.49 and 5.71 t ha^{-1}, respectively, but as seen in Table 7, Jasmine has a potential higher than 7.5 t ha^{-1} and Jaltepec at 8.5 t ha^{-1}, as observed in SE15 (Experimental Site 2015).

The highest rainfall recorded during the crop cycle of native maize was presented in the Mixteca Oaxaqueña Experimental Site (SE) during 2017 where 796.5 mm were recorded, similar to what occurred in Yanhuitlán during the same year with 783.7 mm, but there was not an adequate distribution, therefore, the highest yields were not presented either. On the contrary, the lowest rainfall occurred in the SE during 2015 with 343.5 mm and in Tiltepec 2016 with 382.7 mm with an adequate distribution during the critical stages of the crop.

These results are in agreement with those reported by (Barrales *et al.*, 1984), who point out that yield is associated not only with the quantity, but also with the distribution of water during the female flowering period, which is a stage very sensitive to moisture deficit.

For the Mixteca Alta region and other similar areas, early-cycle varieties that escape the lack of water that generally occurs at the end of the cycle and that can affect late materials during grain filling are of interest, as also pointed out by (Ángeles-Gaspar *et al.,* 2010) and (Conceição dos Santos *et al.*, 2019), that earliness is an outstanding characteristic of native materials to tolerate drought, with respect to improved varieties.

Genotype-environment interaction. The interaction of native maize populations with environments (Figure 1), in SE15 varieties 17, 18, 16, 7, 2 and 12 exceeded 8 t ha^{-1} inferring that these varieties respond well in years with favorable environments, in SE16 populations 14 and 1 were the highest yielding (6.9 t ha^{-1}), but did not present statistical differences with the rest of the populations according to the DSH (α=0.05), in SE17 populations 4 and 14 had the highest average yield maintaining outstanding yields for the Mixteca Alta region of Oaxaca which is characterized by its erratic and irregular rainfall distribution, as occurred during 2017 which was a very wet year with 796.5 mm but not necessarily the highest yields were obtained.

Genotype	Environments					Average
	SE15 (343 mm)	SE16 (428 mm)	SE17 (796 mm)	Tilt16 (382 mm)	YAN17 (783 mm)	
1	6.97	**6.96**	5.18	4.13	2.07	5.06 abcd
2	8.13	6.41	3.17	3.83	2.30	4.77 abcde
3	6.05	5.64	4.28	4.07	3.12	4.63 bcde
4	7.09	6.82	**6.31**	4.26	3.07	5.51 ab
5	7.80	6.38	4.08	**4.56**	2.83	5.13abc
6	5.69	5.44	3.45	3.13	2.45	4.03 e
7	8.14	6.08	3.75	4.48	2.75	5.04 abcd
8	6.40	6.28	3.90	4.12	3.07	4.76 bcde
9	5.91	5.41	3.52	3.50	2.53	4.17 of
10	6.40	6.60	2.94	3.82	2.84	4.52 cde
11	5.45	6.75	3.73	3.51	2.73	4.43 cde
12	8.13	6.04	2.53	4.01	2.24	4.59 bcde
13	7.44	5.70	4.64	4.05	2.55	4.88 abcde
14	7.59	**6.99**	5.56	4.69	**3.74**	5.71 a
15	5.94	5.77	4.89	3.65	2.75	4.60 bcde
16	**8.42**	5.85	5.35	4.13	**3.87**	5.52 ab
17	**8.99**	6.61	4.16	4.16	3.54	5.49 ab
18	**8.94**	6.36	3.03	4.06	1.76	4.83 abcde
Average	7.19 a	6.23 b	4.14 c	4.01 c	2.79 d	4.87
DSH (α=0.05)	2.77	2.18	2.32	1.5	2.38	

Table 7. Average grain yield (t ha^{-1}) of 18 native maize populations evaluated in five environments in the Oaxacan Mixteca

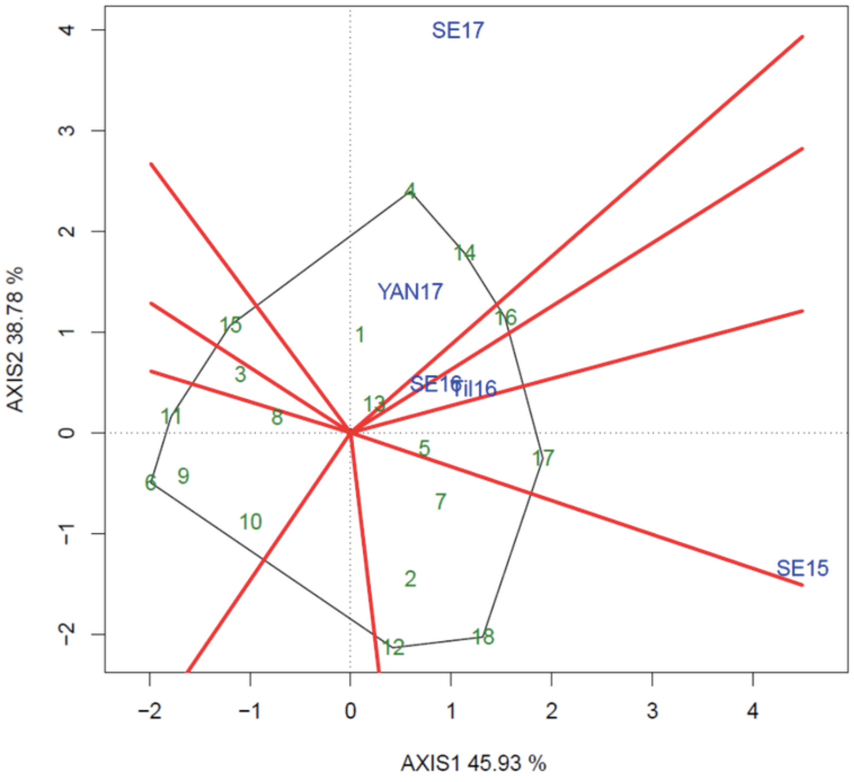
E15 = Mixteca Oaxaqueña Experimental Site (2015); SE16 = Mixteca Oaxaqueña Experimental Site (2016); Mixteca Oaxaqueña Experimental Site (2017); Tiltepec (2016); Santo Domingo Yanhuitlán (2017).

In Tiltepec during the Spring-Summer 2016 cycle and with a rainfall of 382 mm population 14 had the highest yield (4.69 t ha^{-1}) probably due to its shorter vegetative cycle which is an advantage in environments with prolonged droughts as occurs in the area, finally in Yanhuitlán (2017) population 16 recorded the highest yield (3.87 t ha^{-1}), although there were no statistical differences between populations (Table 7).

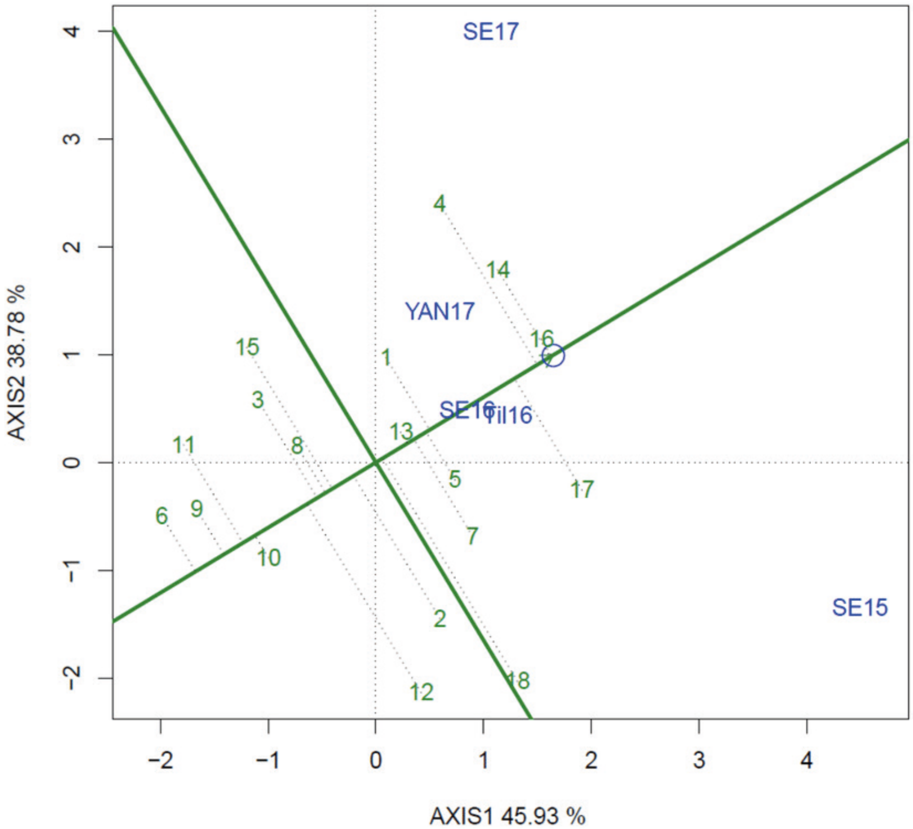
The graphical description of the who-won--where pattern of the SREG model confirms the relationship between varieties and environments described above, confirming the accuracy of this model (Figure 1).

The yield of the populations versus their stability is represented in the GGE biplot in Figure 2, the line with an arrow passing through the origin of the biplot (abscissa axis) indicates the average yield of the populations. It is observed that populations 16, 14, 4 and 17 were the highest yielding. The stability of the populations is represented perpendicularly (ordinate axis), longer vectors indicate greater interaction, population 16 had high yield and stability, according to the criteria described by (Frutos *et al.*, 2014).

With these results, very valuable populations have been identified, such as 16, 14 and 17, because they responded favorably in drought environments, showing that they have genes that provide tolerance to water stress; these maize can be an alternative to implement a breeding program that can lead to an improved variety for the region. In the research conducted by (Avendaño *et al.,* 2005), they found that the improved varieties of corn Zacatecas 58 and Cafime original tolerant to drought, new materials were generated by the stratified mass selection method selected under drought environments,



Distribution pattern of 18 native maize populations evaluated in five environments of the Oaxacan Mixteca.



Average yield versus stability of 18 native maize populations evaluated in the Mixteca Alta of Oaxaca.

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it was found that they contained greater accumulation of proline in the cytoplasm, may be related to their tolerance to drought.

The evaluation of diversity in native maize is important for the development of strategies for the conservation, characterization and use of germplasm in genetic improvement, given its potential as a source of new, exotic and favorable traits (González *et al.,* 2013).

It is desirable to incorporate germplasm with good performance through environments in conservation and genetic improvement programs for the agroecological conditions of the Mixteca Alta of Oaxaca, one of the regions with the lowest maize yields in the state of Oaxaca, and to face the problems of drought, populations with drought tolerance, precocious and complement with agronomic practices that conserve more moisture in the soil should be used.

CONCLUSIONS

Genetic variability was identified among the various native maize species for grain yield across environments, reflecting the possibility of using the best populations in a genetic improvement program to help reduce the effects of drought in the region and similar areas.

Based on the stability analysis of the 18 native maize varieties evaluated in five rainfed environments, the populations 16 (Yanhuitlán), 14 (Jazmín) and 17 (Jaltepec) stand out for their grain yield, with yields of 5.5, 5.49 and 5.7 t ha^{-1}, respectively. These results reflect the yield potential of native maize and its adaptation to the environmental conditions of the region; and above all, they are accepted by producers.

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