Investigation note

Physical and chemical characteristics of the Palomero Toluqueño maize race

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Abstract

Accessions of the Palomero Toluqueño maize race do not have information on their capacity for expansion and the physicochemical properties of the grain related to this characteristic. Therefore, the objective of the present was to determine the relationship between the capacity of grain expansion and physical variables (hardness, density, hectoliter weight and thickness of pericarp) and chemical (content of total starch, amylose and amylopectin) in accessions of the Palomero Toluqueño maize race. 18 accessions of this race seven pre-improved materials were evaluated. The materials were cultivated in the spring-summer 2014 agricultural cycle in Montecillo, State of Mexico and Santa María Zacatepec, Puebla. As a witness, a commercial palomero of the brand ‘Valle Verde’ was used. The data of the variables evaluated were analyzed in a completely randomized design, comparison of means and correlation between the variables studied. The average hectolitre weight of the pre-improved materials exceeded by 3.9 kg hL^{-1} that of the accessions of Palomero Toluqueño. With respect to hardness, the pre-improved materials were statistically similar to the control. The Palomero Toluqueño breed and the pre-improved materials showed pericarp thickness less than 0.6 μm while the control showed 0.9 μm of the control. No statistical difference was observed in the chemical variables evaluated. The hectoliter weight and pericarp thickness were positively correlated with the volume of expansion, which will allow its use as indirect tests in the genetic improvement for the expansion capacity of the Palomero Toluqueño breed.

Keywords: amylose, hardness, hectoliter weight, pericarp, starch.

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The race of Palomero Toluqueño maize is part of the bursting races. Of this breed, 45 accessions have been sheltered in the different germplasm banks of Mexico, which have not been characterized by their expansion capacity, avoiding their potentiation for the production of popcorn.

The main quality variables considered in commercial pigeon pea include the shape of the rosette, the persistence of the pericarp (Ziegler, 2001), the volume of expansion and the proportion of unexploded grains (Soylu and Tekkana, 2007), which are influenced by factors such as: moisture of the grain (Gökmen, 2004), thickness and hardness of the pericarp (Hoseney *et al*., 1983), content of total starch, amylose and amylopectin (Borras *et al*., 2006; Sweley *et al*., 2012).

The expansion capacity of the native materials of the Palomero Toluqueño breed is lower than that of a commercial palomero maize, as demonstrated by the work done by Santacruz (2001) who reported expansion volumes of 1.62 $cm^3 g^{-1}$ in accessions of the Palomero Toluqueño breed, which contrast with the 38.87 $cm^3 g^{-1}$ obtained in a commercial palomero maize in North America. This difference is attributed to changes in both physical and chemical grain variables, induced by genetic improvement. The accessions of the Palomero Toluqueño maize race must be valued in their quality attributes to make popcorn, based on the quality criteria of commercial pigeon pea. In this context, the objective of the present study was to determine physical and chemical characteristics in accessions of the Palomero Toluqueño maize race and its relationship with the capacity of grain expansion. This information could be used as discriminant in the process of genetic improvement for grain trapping.

Genetic material

Twenty-six genotypes of the poplar maize race were evaluated; of them, 18 accessions belong to the race Palomero Toluqueño (APT), seven correspond to pre-improved materials of the work collection of the genetic improvement program of the College of Postgraduates (COLPOS), which are crosses between the race Palomero Toluqueño with Iowa Pop 12 derived from the Yellow Pearl of North America and a commercial witness of the brand 'Green Valley' (TC), belonging to the Yellow Pearl of North America. The selection of these 26 materials was for the purpose of having representativity of low, medium and high expansion volumes for the genealogical origins.

Location and handling of experiments

The experiments were established in the first-summer 2014 agricultural cycle in the towns of Montecillo, municipality of Texcoco, State of Mexico (19° 27' 54.8" North latitude and 98° 54' 20.5" West longitude, 2 250 masl) and Santa Maria Zacatepec, municipality of Juan C. Bonilla, Puebla (19° 7' 52" North latitude and 98° 21' 23" West longitude, 2 260 masl). The average accumulated precipitation for the agricultural cycle (from May to November) in the area adjacent to the experimental site was 548.2 and 780.6 mm, respectively (CONAGUA, 2016). A randomized complete block design with two repetitions was used, the experimental unit consisted of three rows of 5 m length with grooves of 0.8 m width with two plants each 50 cm, which produced a population density of 55 thousand plants ha^{-1} (Hernandez and Esquivel, 2004). The plantings were made on May 15 and 21, 2014 in Montecillo and Santa María Zacatepec, respectively. In both locations the crop was established under irrigation conditions. In Montecillo, the fertilization was with the formula 140-60-00, applying 60% of the N and all the P in the sowing and the rest of the N in the second weeding, while in Santa Maria Zacatepec the formula was 160-60-00 applying 30% N and all the P in the first weeding and the rest of the N in the second weeding. The harvest was made in November 2014.

Analysis of the physical and chemical characteristics of maize grain

The physical and chemical determinations of the grain were made in homogeneous samples obtained from each experimental unit harvested in each location. The variables of hectoliter weight (PHE), flotation index (IF), pericarp thickness (EP) and total starch content (ALM) were performed as described by Salinas and Vazquez (2006). The apparent amylose (AMI) was quantified by the method of Zhu *et al*. (2008), amylopectin (AMP) was determined by the difference between total starch and amylose (Salinas and Vazquez, 2006).

The optimal humidity to obtain the maximum volume of expansion is 13.5% (Gökmen, 2004), this humidity was obtained by placing a seed sample of each experimental unit in a controlled atmosphere chamber at 21 °C with 70% HR for seven days. The trapping was performed on 30 g of seed in Daewoo Model KOR-164H microwave ovens (127 V and 1 600 W) programmed at 70% power for 2:45 min. The volume was determined in a graduated cylindrical cylinder of 2 000 mL with 8.89 cm in diameter, expressing the value in $cm^3 g^{-1}$.

Statistical analysis

With the chemical and physical variables obtained, analysis of variance (Anava) was carried out for a completely random design, in SAS V.9.1 (SAS Institute, 2002), considering as random effects the materials and the locations of planting; in the variables with significant differences, mean comparisons were made with the Tukey test ($p \leq 0.05$). In order to study the relationships between the physical and chemical characteristics determined with the capacity for expansion, a correlation analysis was performed using the Corr procedure of SAS V.9.1 (SAS Institute, 2002).

Results. Analysis of variance for physicochemical characteristics

When the source of the ANOVA was the origin of the material, the PHE and EP showed highly significant differences ($p \leq 0.01$), the ALM and AMI had significant differences ($p \leq 0.05$) while the IF and AMP did not show significant differences. Using localities as a source, no significant differences were observed for the physical variables, however, they were highly significant for the chemical variables evaluated.

Physical characteristics of the seed

The highest PHE was presented in the TC grain (84.83 kg hL^{-1}), while the APT presented on average the lowest PHE (77.13 kg hL^{-1}). The PHE is directly related to the hardness of the grain, so the harder grain corresponds to the TC, which is confirmed by the value of IF that was considerably lower than that of the materials APT and COLPOS (Table 1). The lower the value of IF, the greater the hardness of the grain (Salinas *et al*., 1992). The materials of the

Palomero Toluqueño breed obtained the highest percentages of flotation index, while the COLPOS and commercial control materials were statistically equal in that same variable (Table 1). The observed values of hectoliter weight and flotation indices show that these are hard grain maize; however, this hardness is lower than that of the commercial palomero used as a control.

Table 1. Comparison of means of physical and chemical characteristics in groupings by volume, group of origin and localities of evaluation.

Physicochemical variables	By origin				By location		
	Pal. Toluqueño	COLPOS	Control	DSH	Santa Maria Zacatepec	Montecillo	DSH
Expansion volume range (cm^3 g^{-1})	1 a 6.33	5 a 8.33	19.33		3.59	3.87	
PHE (kg hL^{-1})	77.13 c	81.03 b	84.83 a	3.06	79.26 a	78.89 a	1.43
IF (%)	23.04 a	19.75 ab	4.5 b	17.9	20 a	21.87 a	6.76
EP (µm)	0.54 b	0.6 b	0.9 a	0.09	0.58 a	0.56 a	0.04
ALM (%)	60.84 a	64.17 a	62.19 a	6.8	60.04 b	64.56 a	2.43
AMI (%)	10.18 a	10.92 a	10.86 a	1.38	10.99 a	10.05 b	0.49
AMP (%)	50.66 a	53.26 a	51.33 a	7.22	49.05 b	54.52 a	2.49

Means with equal row letters are not statistically different (Tukey, 0.05). DSH= honest significant difference ($p \leq 0.05$).

The commercial control had a pericarp thickness of 0.9 µm, which is higher ($p \leq 0.05$) than that observed in the accessions of the Palomero Toluqueño breed and the pre-improved materials of COLPOS. Based on this difference it is possible to consider that, of the physical variables evaluated, the pericarp thickness is the one that has the greatest influence on the expansion capacity of the palomeros maizes. During the trapping process, the pericarp acts as a container for the pressure of the evaporated water, which makes it necessary for the poplar varieties to have a thick and resistant pericarp (Mohamed *et al*., 1993).

Chemical variables of the seed

In the chemical variables analyzed, there was no significant statistical difference between the materials evaluated and the commercial control (Table 1). The mean values of the starch, amylose and amylopectin content were in the range of values reported by Sweley *et al*. (2012) for commercial palomeros planted in different environments; however, they were lower than those reported by Park *et al*. (2000) in commercial hybrids. This difference is attributed to the modification in the technique proposed by Zhu *et al*. (2008) that was used in this investigation.

In Mexico, there are other races of maize that have the ability to burst, including Chapalote, which has a starch content greater than 70% with similar proportions of amylopectin and amylose (Vazquez *et al*., 2011). The similarities of materials evaluated in terms of their content of starch, amylose and amylopectin with the materials with greater volume of expansion are indicative that the genetic improvement for expansion capacity should prioritize physical characteristics such as pericarp thickness and decrease of the flotation index.

Correlation between the volume of expansion and the evaluated variables

With the exception of the hectoliter weight and the thickness of the pericarp, the rest of the variables did not show significant correlations with the volume of expansion (VE). Therefore, according to the correlations cited, as the hetolytric weight and the thickness of the pericarp increases, the volume of expansion increases. This result coincides with that described by Mohamed *et al*. (1993) in palomeros maizes burst in microwave oven (Table 2).

Table 2. Correlation coefficients between the volume of expansion and the physical and chemical characteristics of the grain.

	PHE	IF	EP	ALM	AMI	AMP
VE	0.61773*	-0.35777	0.67577*	0.06439	0.26249	0.01963
PHE		-0.04664	0.44477	0.23167	0.29576	0.18308
IF			-0.0838	-0.12446	-0.40938*	-0.05494
EP				0.077	0.40112*	0.00835
ALM					0.15177	0.98522**
AMI						-0.01979

A close ratio of 5:1 in volume of expansion was observed between the commercial control (Yellow Pearl of North America) and the Palomero Toluqueño breed, while the relation between the materials in process of improvement of the COLPOS vs the commercial control was 1:3 (Table 1). This difference did not occur in the chemical properties evaluated, which could be associated with no correlation between the chemical properties and the expansion capacity (Table 2). Once the content of starch and its components have been ruled out, it is possible that the protein content, fatty acids, fibers or sugars have the greatest influence on the expansion capacity of the Palomero Toluqueño breed and the COLPOS materials, agreement with Sweley *et al*. (2012), the chemical properties cited in advance along with starch, amylose and amylopectin have some kind of correlation with the ability to expand.

Conclusions

The physical variables analyzed showed greater variability than the chemical variables among the groups of genetic material analyzed. Of the physical variables, the hectoliter weight and the thickness of pericarp showed a greater association with the volume of expansion of the grain, allowing its use as selection criteria in the improvement of the palomeros maizes of Mexico.

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