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Exploring the breeding potential of Mexican tomato landraces

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ABSTRACT

General (GCA) and specific (SCA) combining ability are parameters that provide insight into the genetic value of lines utilized in plant breeding programs based on hybridization. The aim of this study was to estimate the GCA for yield of ten S_5 lines derived from Mexican tomato landraces and four testers S_5 derived from commercial varieties, as well as to estimate the SCA of forty hybrids obtained under the line × tester mating design. The traits evaluated were fruit yield and six of its yield components. The lines with the greater GCA effects for yield were LOR82, LOR91 and LOR111, with values of 240, 208, and 99, respectively, being higher than those obtained by most of the testers, which suggested that those native lines have important alleles. In the highest-yielding crosses participated at least one line with high positive GCA effects. In contrast, in crosses with the lowest yield, at least one parent or both exhibited negative GCA. All this results indicated that the best or worst hybrids are not necessary obtained from parents having a high or low GCA, respectively. Valuable germplasm with high yield potential was identified to be used in the generation of hybrid or open-pollinated varieties in tomato breeding programs.

1. Introduction

For any breeding program, the selection of parental germplasm is one of the most important decisions to be taken by breeders, and knowing the combining ability of parents improves the efficiency of the breeding program (Gutiérrez et al., 2004).

General (GCA) and specific combining ability (SCA) values let us estimate the breeding potential of a set of studied lines under hybrid combinations, since the *per se* evaluation of the lines is not a reliable parameter. General combining ability is defined as the mean performance of one line under hybrid combinations, whereas specific combining ability are those cases in which certain specific hybrid combinations express good performances in relation to that observed on their parents (Sprague and Tatum, 1942). Based on these definitions, Cockerham (1963) related the GCA with the genetic additive effects and the SCA with the dominance and epistatic effects. SCA and GCA were introduced by Sprague and Tatum (1942), and such concepts were used as a base by Griffing (1956) to develop four diallel designs, which are frequently used for the estimation of GCA and SCA (De la Cruz et al., 2010).

To date, there are many genetic designs to estimate combining ability; however, the most common genetic designs are the diallel mating and line × tester designs (Lobato-Ortiz et al., 2010). Davis (1927) and Lobato-Ortiz et al. (2010) indicated that since 1920–1930, the estimation of GCA on maize inbred lines consisted on the evaluation of all possible $n(n-1)/2$ direct crosses; however, this procedure require too many human and material resources when the number of parental lines is high. In 1932, this situation allowed Davis to develop and introduce the line × tester design (Hallauer et al., 2010). Basically, this mating design is an extension of the topcross design and involves the hybridization of n lines with more than one tester (Singh and Chaudhary, 1985). The tester utilized could be a population with broad or narrow genetic base as well as a low-yielding line (Hallauer and López, 1979). This evaluation allows selecting the best parents in a series of crosses and identifies specific combinations with above-average performance of the lines, which could help to develop breeding programs based on reciprocal recurrent selection or hybridization (De la Cruz et al., 2010).

A recent research has demonstrated that tomato domestication was a two step-process; a first domestication in South America

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and a second step in Mesoamerica (Blanca et al., 2015). Mexico is considered as part of Mesoamerica, thus a broad range of genetic variation regarding fruit colors, shapes and sizes is observed in several Mexican regions (Bonilla-Barrientos et al., 2014). In tomato, various experiments have examined the combining ability of lines from different countries (El-Gabrya et al., 2014; Kumar et al., 2013; Andrade et al., 2014; Kalloo et al., 1974; Govindarasu et al., 1981); however, the exploration of genetic potential in Mexican landraces by GCA and SCA estimations has been limited. Using molecular markers, Sim et al. (2011) studied the genetic structure of 70 landraces including 28 processing varieties, 19 fresh-market varieties, 19 vintage varieties and 4 Latin American landraces. They detected an extensive genetic diversity into the four groups identified by Bayesian analysis. Marín-Montes et al. (2016) investigated the genetic diversity of 55 tomato landraces from the south-central region of Mexico, and found a broad allelic variation among populations, suggesting these populations have important alleles which can be utilized into tomato breeding programs. All these previous studies examined the genetic diversity of Mexican landraces, however, their breeding potential has not been elucidated. Once the genetic potential is known, significant progress regarding the exploitation of these materials in the breeding programs will be observed. Therefore, in the present research, we studied the genetic potential of 10 native lines under hybrid combinations with four lines derived from elite material. The objectives were: (1) to know the breeding potential of the 10 native lines based on the general and specific combining ability for yield and its components, and (2) to identify elite lines or superior hybrids, which can be used as a source of genes for developing hybrids and synthetic varieties of tomato.

2. Material and methods

2.1. Genetic material and agronomic management

A total of fifty-five materials, including forty hybrids, four testers derived from Saladette type tomato, ten native lines and the commercial hybrid 'El Cid' as check, were evaluated during the spring-summer season of 2014 (Table 1). Four testers labeled as R, C, L and T were obtained from the commercial varieties 'Reserva', 'Cuauhtémoc', 'Loreto' and 'Tuss-2008', respectively, while the native lines were derived from landraces. Both testers and lines were obtained using the pedigree method for increased yield and fruit quality during 2010–2013. All crosses were obtained using the line × tester mating design where the four commercial lines were used as males and the ten native lines as females. The studied populations were planted in a randomized complete block design with 3 replications and each experimental unit comprised 10 plants. The study was conducted under greenhouse conditions and was localized on the experimental field at Colegio de Postgraduados (19°30′ and 98° 53′).

During the harvest period, two harvests were set at 120 and 144 days after planting. A total of four irrigations per day were applied and the fertilization was performed using the nutrient solution proposed by Steiner (1984). Pest control was carried out applying Captan®, Ridomil gold®, Interguzan®, Beleaf®, Ampligo®, Confídor® and New leverage®.

2.2. Data collection

At the end of the growing season, a total of six yield components and yield per plant were collected. Total number of fruits (TNF) and yield per plant (YL) in grams (g), were evaluated counting and weighting, respectively, the number of produced fruits in each plant. Average fruit weight (AFW) in grams (g), was calculated by averaging the total weight of 5 fruits per plant. Firmness (F) in newtons (N), was measured on the fruit equatorial zone using a texturemeter FOR CEFIVE Model FDV-30. Number of flowers for the third truss (NF) was counted as the total number of flowers localized on the third truss, whereas number of trusses per plant (NTP) was measured as the total number of trusses that each plant had at 144 days after planting. Finally, the days to flowering (DF) were calculated as the days from transplanting to the first flower open in third truss.

2.3. Data analyses

The analysis of combining ability was conducted according to the model used by Fan et al. (2009). SAS macro code was used to estimate the GCA effects for each parent as well as the SCA effects for each cross. The analysis of variance for combining ability was performed using the PROC ANOVA statement in SAS software version 9.0 (SAS Institute, 2002). Thus, the following statistical model was used for data analysis:

$$Y_{ijl} = \mu + l_i + p_j + s_{ij} + b_l + e_{ijl}$$

where Y_{ijl} is the observed value, μ is the population mean, l_i is the GCA effect of line i, p_j is the GCA effect of parent j, s_{ij} is the SCA effect of the hybrid ij, b_l is the blocks effect and e_{ijl} is the residual effect.

Finally, correlation analysis was performed in SAS version 9.0 (SAS Institute, 2002) using the PROC CORR statement.

3. Results and discussion

3.1. Analysis of variance and gene action

Analysis of variance for GCA showed significant variation among the crosses, testers, lines and line × tester interaction effects (Table 2). These results provided evidence of the presence of a wide genetic variability among lines, testers, and hybrids. In addition, such results also indicated that GCA effects of tester and lines were significantly different for all traits. Regarding the hybrids, the analysis of variance detected significance among the F_1 progeny for all variables, which indicated that the mean performance of each hybrid combination was significantly different for all traits. Such results are in harmony with the findings of Yadav et al. (2013), who evaluated ten lines, three testers and their 30 F_1 hybrids. They detected significant difference among the GCA and SCA effects produced by lines and hybrids, respectively.

From the estimations of genetic variances, the σ^2_{GCA} was higher than σ^2_{SCA} for most of the traits, suggesting that the additive gene effects played a major role on the inheritance and variability of the traits than the non-additive gene effects. These results were supported by the ratio of $\sigma^2_{GCA}/\sigma^2_{SCA}$, which was greater than one, and by the degree of dominance being less than one. A similar result was reported by Kumaravel et al. (2003), who found that additive effects played an important role in controlling the total number of fruits and yield.

For average fruit weight, firmness and days to flowering for the third truss, the σ^2_{SCA} values were higher than those found for σ^2_{GCA}. These results indicated that dominance appeared to be more important than the additive gene action on the inheritance of these traits. These results are in agreement with the findings of El-Gabrya et al. (2014) since they obtained a higher value of general combining ability variance than that observed on the specific combining ability variance for the average fruit weight.