

FIGUEIREDO AST; RESENDE JTV; FARIA MV; PAULA JT; RIZZARDI DA; MEERT L. 2016. Agronomic evaluation and combining ability of tomato inbred lines selected for the industrial segment. *Horticultura Brasileira* 34: 086-092. DOI - <http://dx.doi.org/10.1590/S0102-053620160000100013>

Agronomic evaluation and combining ability of tomato inbred lines selected for the industrial segment

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ABSTRACT

This study carried out agronomic evaluation and estimated the combining ability of tomato lines for the industrial segment, aiming to elect promising genotypes for breeding and to find simple hybrids with superior traits. Randomized-blocks design was used with 57 treatments (45 experimental hybrids, 10 lines and 2 checks treatments) with 3 replications. A complete diallel among 10 tomato lines for processing was used. Evaluated traits were: fruit total (YT) and commercial production (YC), pulp yield (YP), fruit average mass (MM) and total soluble solids content (TSS). Diallel crosses allowed synthesizing experimental hybrids with superior traits when compared to commercial hybrids. Non-additive effects prevailed over the expression of YT, YC, YP and TSS, whereas additive effects prevailed for MM. Lines RVT-08, RVT-05 and RVT-10 are most appropriate for intrapopulation breeding. Experimental hybrids RVT-08 x RVT-09, RVT-07 x RVT-10 and RVT-08 x RVT-10 were pointed as the experimental genotypes with the best performance, surpassing the commercial genotypes for the traits evaluated.

Keywords: *Solanum lycopersicum*, diallel analysis, industrial processing.

RESUMO

Capacidade combinatória de linhagens de tomateiro de crescimento determinado para processamento industrial

O presente trabalho teve como objetivo avaliar o desempenho agrônomico e estimar a capacidade combinatória de linhagens de tomateiro industrial visando eleger genótipos promissores para o melhoramento e encontrar híbridos simples superiores. O delineamento utilizado foi blocos casualizados com 57 tratamentos (45 híbridos experimentais, 10 linhagens e 2 testemunhas), em três repetições. Utilizou-se um dialelo completo entre 10 linhagens de tomateiro industrial. Foram avaliados a produtividade total (PT) e comercial (PC) de frutos, rendimento de polpa (RP), massa média dos frutos (MM) e teor total de sólidos solúveis (TSS). Os cruzamentos dialélicos propiciaram a formação de híbridos experimentais superiores aos híbridos comerciais. Os efeitos não aditivos predominaram sobre a expressão das características PT, PC, RP e TSS enquanto que para a MM houve a predominância de efeitos aditivos. As linhagens RVT-08, RVT-05 e RVT-10 são as mais apropriadas para o melhoramento intrapopulacional. Os híbridos experimentais RVT-08 x RVT-09, RVT-07 x RVT-10 e RVT-08 x RVT-10 se destacaram como os genótipos experimentais de melhor desempenho do experimento, superando as testemunhas comerciais para as características avaliadas.

Palavras chave: *Solanum lycopersicum*, análise dialélica, processamento industrial.

(Recebido para publicação em 16 de maio de 2014; aceito em 9 de setembro de 2015)

(Received on May 16, 2014; accepted on September 9, 2015)

Tomato (*Solanum lycopersicum*) is the second most important vegetable crop in Brazil and worldwide, grown in nearly all over the Brazilian territory. This fact is due to social and economic importance of the crop, as well as its nutraceutical benefits (Gameiro *et al.*, 2007).

Tomato fruits can be intended both for fresh consumption and for industrial processing, producing value-added derivatives. Industrial tomato production has held a prominent position in Brazilian agribusiness. In 2011, Brazil

produced 1.81 million tons of tomatoes for the industrial segment, achieving the fifth position in the ranking of the world's largest producers (Boiteux *et al.*, 2012).

The use of hybrids is the main reason, which led Brazil to reach this position (Aragão *et al.*, 2004; Boiteux *et al.*, 2012). Generally, hybrids are more productive than lines and open-pollinated populations, due to a more effective exploitation of genetic effects (Maluf, 2001). Thus, the use of hybrids in tomato crop is reasonable considering

the several advantages provided to producers and consumers, mainly: higher productivity, earliness, quality of fruits and possibility to match resistance to pests and diseases in the same genotype (Aragão *et al.*, 2004; Santos *et al.*, 2011; Schwarz *et al.*, 2013).

Tomato is an autogamous species and its genetic base became narrow along the process of domestication, preventing intrapopulation breeding strategies to provide satisfactory genetic gains in crop breeding (Amaral Júnior *et al.*, 1997, 1999; Souza *et al.*, 2012).

In this sense, the recombination of the genetic variability is an excellent alternative for obtaining plants with superior genetic merit (Maciel *et al.*, 2010; Souza *et al.*, 2012).

One of the most used methodologies in breeding programs, including for tomato, are diallel crosses (Maluf, 2001). Diallels are a type of genetic design which provides the breeder information on genetic parameters such as prevailing gene action, combination aptitude of parents, heterosis as well as the best breeding strategies to be adopted (Cruz *et al.*, 2012; Souza *et al.*, 2012). The authors found several studies on the use of diallel crosses in tomato, for various characteristics such as fruit productivity (Amaral Júnior *et al.*, 1997, 1999; Souza *et al.*, 2012), pest resistance (Maciel *et al.*, 2010) and disease resistance (Elsayed *et al.*, 2012), post-harvest (Resende *et al.*, 2000; Akhtar & Hazra, 2013).

Most research works with industrial tomato breeding in Brazil are linked to public education and research institutions, which do not have enough financial resources to launch cultivars regularly. However, most of the commercial hybrids of tomato available to Brazilian producers are obtained from other countries where this fruit is grown. These hybrids are introduced into an experimental network and the most adapted and stable ones end up being registered and sold in the domestic seed market (Aragão *et al.*, 2004). Thus, more studies in order to obtain germplasm adapted to Brazilian growing conditions and which produces high quality raw material for the fruit processing agribusiness, are necessary. The goal of this work was to estimate combining ability of industrial tomato lines, aiming to elect potential genotypes for breeding programs and find superior simple hybrids of tomato intended to industrial segment.

MATERIAL AND METHODS

The experiment was carried out in the experimental field of the “Núcleo de Pesquisa em Hortaliças (Research Center for Vegetable Crops) of the

Universidade Estadual do Centro-Oeste (UNICENTRO) (State University of the Central-Western Paraná), in Guarapuava, Paraná State, Brazil. The soil in the experimental field is classified as Distrofic Brown Oxisol and the local climate is characterized as subtropical and humid (Cfb) without definite dry season and mild hot summers and harsh winters, according to Köppen classification.

The experiment consisted of a complete diallel among 10 lines of industrial tomato selected by UNICENTRO. In total, 57 genotypes of tomato with industrial aptitude (45 single hybrids of the diallel, 10 lines and 2 checks) were evaluated. Randomized blocks were used, with three replications. The description of lines and checks is presented in Table 1. Each experimental unit consisted of two contiguous plant rows, with eight plants in each one, grown at 1.20 m between lines and 0.35 between plants. Two plants of each end of the plot were used as border lines, totaling an area of 5.46 m².

Genotypes were sown in trays of 200 cells following seedling transplanting to the field (± 30 days). During the crop cycle, three fertilization operations were carried out (at planting, at flowering and at full fructification) based on soil chemical analysis and on nutritional requirements of the crop. The irrigation system used was sprinkler, operated according to the necessity of the plants. Pest and disease control was carried out through insecticide (acephate, triflururon and thiamethoxam) and fungicides applications (copper oxychloride, metalaxyl-M, mancozeb and chlorothalonil), weekly, using recommended doses for the crop.

After 85 DAT of seedlings, four harvests were carried out, in which weight and total number of harvested fruits in each plot was calculated. The fruits were classified as marketable (regular/small defects) and unmarketable fruits (serious defects) according to the standards of the Ministério da Agricultura (Ministry of Agriculture), Decree 553/1995 (BRASIL, 1995). Afterwards, total (YT) and commercial yield (YC) of the fruits (kg/ha) and

average mass of fruits (MM) were calculated. In the third harvest, eight fruits of each plot were collected in order to verify the soluble solids content (TSS). These fruits were sanitized and then homogenized. Afterwards, total soluble solids content (SS, °Brix) was measured, using a bench digital refractometer (model PAL-1).

Pulp yield (YP) of the genotypes was calculated according to Giordano *et al.* (2000), using the expression $YP = [(YT * 0.95) * TSS] / 28$, in which YP is the total yield of the fruits (t/ha) and TSS is the soluble solids content (°Brix). The authors considered pulp concentration at 28°Brix as reference for calculation.

After verifying homogeneity and normality of errors through Bartlett and Lilliefors test ($p < 0.05$) respectively, the authors proceeded to the analysis of variance for randomized blocks, with the unfolding of the degree of freedom of treatment into effects of lines, experimental hybrids, commercial hybrids and contrasts of means between “lines vs hybrids” and “experimental hybrids vs commercial hybrids” (Cruz *et al.*, 2012). After analysis of variance, the means of treatments were grouped through the Scott Knott test ($p < 0.05$).

For diallel analysis, the sum of squares of treatments were unfolded into estimates of general (GCA) and specific aptitude for combination (SCA), according to the Method II (parents and F₁ hybrids), Model 1 (fixed effect for genotype), according to Griffing (1956). The mathematic model adopted follows $Y_{ij} = m + g_i + g_j + s_{ij} + e_{ij}$ in which Y_{ij} = value of hybrid combination ($i \neq j$); m = general average; g_i and g_j = estimates of general aptitude for combination of the parents i^{th} and j^{th} , respectively; s_{ij} = estimates of specific aptitude for combination of the parents i and j and e_{ij} = average experimental error. The genetic analyses were carried out using statistical software Genes (Cruz, 2013).

RESULTS AND DISCUSSION

Results of the analysis of variance and of the diallel are reported in Table 2. Commercial hybrids and lines did not show significant effects on

Table 1. Agronomic and morphological characteristics of genitor lines and commercial hybrids (características agrônômicas e morfológicas das linhagens genitoras e híbridos comerciais utilizados no experimento). Guarapuava, UNICENTRO, 2012.

Genotype	Crop cycle (days)	Leaf index (%)	Fruit flesh (mm)	Fruit format	Fruit color	Growth habit	JT
RVT-01	122	95	8.47	Al	Ama	Det	x
RVT-02	120	53	7.29	Al	Cl	Det	x
RVT-03	124	71	8.53	Al	Cl	Det	x
RVT-04	120	57	9.99	Al	Int	Det	x
RVT-05	121	55	7.34	Al	Cl	Det	x
RVT-06	121	66	8.83	Al	Int	Det	x
RVT-07	119	34	8.97	Al	Cl	Det	x
RVT-08	121	60	7.97	Al	Cl	Det	x
RVT-09	123	82	6.61	Red	Int	Det	x
RVT-10	121	43	8.22	Al	Int	Det	x
AP-529	120	53	4.99	Per	Cl	Det	x
Tinto	120	67	4.51	Al	Int	Det	x

Al: long fruit (fruto alongado); Red: round fruit (fruto redondo); Per: pyriform fruit (fruto periforme); Amr: yellow fruit (fruto amarelo); Cl: bright fruit (fruto claro); Int: Intense red fruit (fruto vermelho intenso); Det: determined (determinado); JT: jointless; X= Presence of jointless.

YC whereas experimental hybrids influenced significantly ($p < 0.05$) all variables studied in the experiment (Table 2). These results prove that diallel crosses among lines allowed the generation of genetic variability, being possible to select the best tomato hybrids for processing. Although the genetic basis of tomato crop is narrow, due to inbreeding and domestication during evolution (Amaral Júnior *et al.*, 1999) obtaining variability by recombining genotypes is possible, enabling to obtain high-performance hybrids (Aragão *et al.*, 2004; Santos *et al.*, 2011, Andrade *et al.*, 2014).

Contrast among the means of “lines vs other genotypes” presented negative and significant estimates ($p < 0.05$) for variables YT, YC, YP and MM, demonstrating the superiority of experimental hybrids over their parental lines (Table 2). Only TSS presented positive and significant contrast estimates, showing that on average, the lines showed higher TSS compared to other genotypes studied (Table 2).

Contrast among experimental hybrids vs commercial hybrids showed positive and significant estimates ($p < 0.05$) for YT, YC, YP and TSS demonstrating the average superiority of experimental hybrids over the means of their parental lines (Table 2). These results are of great

importance and enable studies which allow the recombination of existing germplasm aiming to find superior hybrids which maximize genetic effects such as heterosis. Other studies confirm the possibility of obtaining promising experimental genotypes of tomato for industrial segment (Aragão *et al.*, 2004) and fresh consumption (Maciel *et al.*, 2010) by recombination of elite genotypes.

For MM, the contrast among experimental hybrids vs commercial hybrids presented negative and significant estimates ($p < 0.05$), showing the inferiority of experimental hybrids compared to commercial hybrids for MM (Table 2). This statement is proven by the performance of hybrid Tinto, which presented the highest MM of the experiment (104.40 g/fruit) not being grouped with any other genotype. Schwarz *et al.* (2013) also proved the superiority of this hybrid with respect to MM, this being considered one of the genotypes with the highest MM in their study.

General combining ability (GCA) is a consequence of the behavior of a given parent for crosses in which it took part in, reflecting the effect of additive genes (Griffing, 1956). High and absolute values of GCA are present in genotypes whose favorable allele frequency is higher or lower than the

average frequency of favorable alleles at all other parents of the diallel (Cruz *et al.*, 2012). Specific combining ability (SCA) is the deviation of a hybrid in relation to the expected based on GCA of their parents, reflecting the non-additive gene action (Cruz *et al.*, 2012).

In relation to the diallel, mean square of GCA and SCA were significant for all traits showing that both additive and non-additive genes are important on genetic control of these traits. Pádua *et al.* (2010) used tomato lines from different genetic backgrounds and observed significant estimates of GCA and SCA for fruit production, and attributed these results to genetic divergence between the parents. Results similar to this study can be found in other studies (Souza *et al.*, 2012; Saleem *et al.*, 2013).

Relationship between quadratic components of GCA and SCA indicates which genetic effect is predominant in the character expression (Cruz *et al.*, 2012). When GCA is higher than SCA, additive-effect genes are predominant in the character expression, so intrapopulation breeding strategies are the best option. However, when SCA is higher than GCA, non-additive genes are predominant and interpopulation breeding strategies, which explore the effects of dominance, overdominance and epistasis are most appropriate.

Table 2. Summary of ANOVA (experiment and diallel) with estimates of mean square for the characteristics evaluated in 57 genotypes of tomato for industrial segment (resumo da ANOVA do experimento e do diallelo, com as estimativas de quadrado médio para as características avaliadas em 57 genótipos de tomateiro industrial). Guarapuava, UNICENTRO, 2012.

Variation source	DF	MS				
		YT	YC	YP	MM	TSS
Treatment	(56)	321,016,802*	247,197,032*	8,589,666*	320.40*	0.3511*
Experimental hybrids (HE)	44	228,197,609*	167,524,509*	7,622,908*	227.61*	0.3419*
Inbred lines (Lin)	9	197,896,613*	165,011,778*	3,858,102*	336.48*	0.3175*
Commercial hybrids (HC)	1	172,772,843*	86,499,153 ^{NS}	2,817,377*	3479.56*	0.6016*
Lin vs HE + HC	1	5,358,084,808.8* (-14,717,45)**	4,242,193,718* (-13,095.53)	92,008,972* (-1,928.60)	280.61* (-3.36)	0.4294* (0.1317)
HE vs HC	1	451,601,217* (8,866.34)	658,108,797* (10,703.25)	16,059,453* (1,671.98)	1,147.50* (-14.13)	0.7269* (0.3537)
Block	2	17,990,557	16,672,591	235,665.15	374.80	0.0478
Error	112	22,951,369	23,290,157	498,498	40.25	0.0098
Total	170	-	-	-	-	-
Mean	-	57.86	52.06	8.12	66.21	4.14
CV (%)	-	8.28	9.27	8.69	9.58	2.39
Diallel ANOVA						
Treatment	(54)	322,489,380*	247,471,773*	8,752,080*	244.9*	0.3381*
GCA (\hat{g}_i)	9	328,025,332*	226,750,329*	11,477,603*	1.081*	0.4671
SCA (\hat{s}_{ij})	45	321,382,189*	251,616,062*	8,206,975*	77.6*	0.3123
Error	108	23,349,135	23,723,696	508,580	37.15	0.0101
Mean	-	58.08	52.35	8.15	6.70	4.16
CV (%)	-	8.31	9.30	8.74	9.27	2.42
Quadratic components						
GCA (\hat{g}_i)	-	8,463,227	5,639,628	304,695	29.00	0.00012
SCA (\hat{s}_{ij})	-	99,344,351	75,964,121	566,131	13.49	0.00147

*Significant by F test ($p < 0.05$) {significativo pelo teste de F ($p < 0,05$)}; **Estimates of contrasts (Estimativas de contrastes).

For variables YT, YC, YP and TSS the quadratic component of SCA was higher than GCA, showing that non-additive genes predominated in the control of these characteristics (Table 2). Other studies show the predominance of non-additive effects in control of YT, YC and TSS and according to these studies, the search for superior hybrids is the best breeding strategy to be adopted (Shende *et al.*, 2012; Souza *et al.*, 2012; Saleem *et al.*, 2013). Other studies report non-additive action being involved in the genetic control of some traits in tomato. Amaral Junior *et al.* (1999) observed that YT in tomato is controlled by the genes with partial dominance whereas TSS is controlled by the overdominant effect. On the other hand Singh *et al.* (1999) reported that

TSS in industrial tomato is controlled by complete dominance genes.

For MM, GCA was higher than SCA, and additive genes are predominant in its expression (Table 2). Thus, intrapopulational breeding strategies such as selecting plants with higher frequency of alleles which favors the increase of MM seems to be the most recommended strategy. Garg *et al.* (2008), Pádúa *et al.* (2010) and Saleem *et al.* (2013) reported that additive gene actions are predominant in the expression of a higher MM corroborating the results of this work. Amaral Junior *et al.* (1999) reported that a higher MM is controlled by some genes, whose recessive alleles contribute to the increase of this trait.

In relation to GCA estimates, lines

RVT-08 and RVT-05 figured as the parents with the highest estimates for YT, YC and YP traits (Table 3). These lines contributed positively to the superiority of hybrids in which they participated as parents, due to the presence of favorable alleles for improving these traits. The range of estimates of GCA for the traits YT, YC and YP was 9.80 t/ha, 8.43 t/ha and 1.87 t/ha respectively, corresponding to an average of 17% of YT and YC and 23% of YP, highlighting the possibility of satisfactory genetic gain only with the choice of suitable parents.

In the current literature, aptitude for combination studies in tomato genotypes in relation to YP was not found. However, in this study, the authors observed that non-additive

Table 3. Estimates of general aptitude for combination (GCA) for agronomic and post-harvest characteristics, referring to industrial tomato lines, used as genitors in a complete diallel {estimativas de capacidade geral de combinação (GCA) para características agrônomicas e de pós-colheita, referente a linhagens de tomateiro industrial, utilizadas como genitoras em um dialelo completo}. Guarapuava, UNICENTRO, 2012.

Inbred lines	YT	YC (t/ha)	YP	MM (g/fruit)	TSS (°Brix)
RVT-01	-4.78	-4.80	-0.84	9.20	-0.070
RVT-02	-1.35	-0.55	-0.93	-4.47	0.025
RVT-03	0.67	-0.49	0.18	3.20	0.021
RVT-04	-2.89	-1.90	-0.62	0.74	-0.130
RVT-05	3.85	3.63	0.66	-3.70	0.020
RVT-06	-2.43	-1.79	-0.45	5.88	-0.073
RVT-07	1.33	1.89	0.02	-1.18	-0.128
RVT-08	5.02	2.89	0.94	-1.61	0.232
RVT-09	-0.18	-0.63	-0.17	-9.93	-0.030
RVT-10	0.76	0.77	0.38	1.85	0.131
SD (\hat{g}_i)	0.76	0.77	0.11	0.96	0.016
SD ($\hat{g}_i - \hat{g}_j$)	1.13	1.14	0.16	1.43	0.024

genes are predominant in control of fruit production and pulp yield, facilitating the tomato breeding for this trait, since these strategies can be adopted for both traits, the search for productive hybrids with excellent pulp yield being the most recommended strategy.

Line RVT-01 obtained the lowest estimate of GCA for YT, YC and YP (Table 3). This line should be avoided in breeding programs which search for genotypes with high YP, YT and YC, since it reduced genotypic value of these traits in crosses in which it took part as parent (Table 3). However, RVT-01 was the line with the highest GCA for MM highlighting the presence of favorable alleles for improving this trait (Table 3).

For TSS, only line RVT-08 stood out for GCA (0.232°Brix), contributing for increasing TSS in hybrids in which this line was parent (Table 3). Line RVT-08 stood out as one of the parents with the highest estimate of GCA for YT, YC, YP and TSS, this being a consequence of the presence of favorable alleles in this genotype, which makes it indispensable in breeding programs which aims to improve these traits.

The ideal hybrid according to breeding is that one which presents concomitantly a high estimate of SCA and that, at least, one of its parents shows high estimate of GCA (Cruz *et al.*,

2012). Estimates of SCA close to zero show that the hybrid behaved close to the expected considering the GCA of their parents. Usually, effects of SCA do not contribute satisfactorily to autogamous breeding, including tomatoes. However, finding transgressive genotypes, which may be selected for their greater genetic merit due to the accumulation of favorable alleles, may be found in populations obtained from hybrids with high SCA and, at least, one of the parents expressing high GCA (Saleem *et al.*, 2013).

For YT, the best hybrids according to SCA were RVT-08 x RVT-09 and RVT-05 x RVD-10 due to their high SCA (Table 4) and for presenting parents RVT-08 and RVT-05 which obtained the two highest GCA for this trait (Table 3). The grouping of means showed formation of five different groups for YT, joining the hybrids RVT-08 x RVT-09 (84.37 t/ha) and RVT-07 x RVT-10 (80.37 t/ha) as the most productive genotypes of the experiment, differing statistically from other genotypes, including the commercial hybrids Tinto and AP-529 (Table 4). The lowest yield of tomato fruits was observed in lines RVT-01 (35.17 t/ha), RVT-02 (40.13 t/ha) and RVT-09 (40.35 t/ha), which did not differ statistically (Table 4).

Considering tomato for industrial

segment, results for YT have been ranged from 14 t/ha to 124.31 t/ha, the edaphoclimatic conditions and the genotypic constitution of plants being primarily responsible for this wide range (Aragão *et al.*, 2004; Seleguini *et al.*, 2007; Galvão *et al.*, 2013). Schwarz *et al.* (2013), studying tomato hybrids in the South Central region of Parana observed that the production ranged from 37.18 t/ha to 112.52 t/ha, corroborating the productivities obtained in this work, which ranged from 35.17 t/ha (RVT-01) to 84.37 t/ha (RVT-53) (Table 4). These same authors reported values for YT for hybrids AP-529 (42.40 t/ha) and Tinto (68.75 t/ha) quite close to those found in this work for these same hybrids (Table 4).

YC is a very important trait for tomato cultivars for dual purpose market, in which the fruits are intended both for fresh consumption and for industrial processing, depending on price and market fluctuations (Schwarz *et al.*, 2013). The best hybrids for YC according to SCA were: RVT-07 x RVT-10, RVT-05 x RVT-06 and RVT-08 x RVT-09 since they showed the highest estimates of SCA of the experiment and concomitantly at least one of their parents (RVT-05, RVT-08 and RVT-07) were good general combiners (Table 3). With respect to yield, the best genotypes were RVT-07 x RVT-10 (77.05 t/ha) and RVT-02 x RVT-03 (70.65 t/ha) being the most recommended hybrids for decumbent (not tutored) tomato crop aiming to dual purpose fruit production (Table 3).

The success of an industrial tomato hybrid is directly related to fruit YP, being one of the main traits to be observed when choosing a cultivar (Giordano *et al.*, 2000). Thus, based on estimates of SCA, the best hybrids for YP were RVT-01 x RVT-05 and RVT-08 x RVT-09 (Table 4), as they showed concomitantly positive estimates for SCA and at least one of the parents (RVT-08 and RVT-05) were considered good combiners according to GCA observed (Table 3). With respect to YP, formation of five groups with similar yield was observed. Hybrid RVT-07 x RVT-10 presented the highest YP of the experiment, 12.66 t/ha being grouped

Table 4. Specific aptitude for combination (SCA) and average values of 57 genotypes (10 lines, 45 experimental hybrids and 2 commercial hybrids) of tomato for industrial segment considering agronomic and post harvest traits {capacidade específica de combinação (SCA) e valores médios de 57 genótipos (10 linhagens, 45 híbridos experimentais e 2 híbridos comerciais) de tomateiro com aptidão industrial para características agrônômicas e pós colheita}. Guarapuava, UNICENTRO, 2012.

Genotype	YT(t/ha)		YC (t/ha)		YP (t/ha)		MM (g/fruit)		TSS (°Brix)	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
RVT-01	35.17 f*	-	29.20 e	-	4.85 e	-	80.78 c	-	4.06 f	-
RVT-02	40.13 f	-	37.94 e	-	5.76 e	-	56.34 d	-	4.25 e	-
RVT-03	55.82 d	-	49.62 d	-	7.76 c	-	74.23 c	-	4.10 e	-
RVT-04	38.53 d	-	37.57 e	-	5.36 e	-	67.96 c	-	4.11 e	-
RVT-05	48.43 d	-	45.38 d	-	6.83 d	-	56.71 d	-	4.16 e	-
RVT-06	43.15 d	-	38.70 e	-	5.93 e	-	74.22 c	-	4.08 f	-
RVT-07	60.80 c	-	54.73 c	-	7.91 c	-	57.35 d	-	3.85 g	-
RVT-08	50.75 d	-	45.03 d	-	8.02 c	-	57.54 d	-	4.90 a	-
RVT-09	40.35 f	-	35.93 e	-	5.84 e	-	46.46 d	-	4.26 e	-
RVT-10	43.90 e	-	38.48 e	-	6.99 d	-	63.14 d	-	4.76 a	-
01 x 02	55.25 d	3.31	52.83 c	5.84	7.50 c	0.29	77.53 c	7.10	4.03 f	-0.08
01 x 03	62.19 c	8.21	49.33 d	1.29	8.79 c	1.30	88.34 b	10.24	4.21 e	0.10
01 x 04	45.76 e	-4.63	40.52 e	-5.12	6.47 d	-0.21	69.75 c	-5.90	4.20 e	0.23
01 x 05	71.86 b	14.71	63.93 b	12.75	11.54 a	3.57	65.72 d	-5.46	4.71 b	0.61
01 x 06	56.80 c	5.94	51.05 c	5.30	7.58 c	0.72	88.10 b	7.30	3.95 f	-0.06
01 x 07	55.03 d	0.40	50.23 d	0.79	7.03 d	-0.29	77.30 c	3.57	3.76 g	-0.19
01 x 08	60.80 c	2.48	53.58 c	3.14	7.79 c	-1.25	75.00 c	1.70	3.86 g	-0.45
01 x 09	52.47 d	-0.63	51.50 c	4.59	7.00 d	-0.12	59.94 d	-5.02	3.96 f	-0.91
01 x 10	50.92 d	-3.13	46.77 d	-1.54	6.91 d	-0.78	69.94 c	-6.86	4.08 f	-0.14
02 x 03	77.11 b	19.70	70.65 a	18.37	11.77a	3.53	60.68 d	-3.73	4.50 c	0.29
02 x 04	59.73 c	5.90	55.64 c	5.75	7.49 c	0.06	60.40 d	-1.56	3.70 g	-0.35
02 x 05	56.65 c	2.30	52.61 c	-2.81	7.25 c	-1.46	54.19 d	-3.32	3.57 h	-0.62
02 x 06	56.60 c	-3.29	52.34 c	2.35	8.32 c	0.72	60.61 d	-6.49	4.38 d	0.26
02 x 07	52.36 d	-5.70	47.26 d	-6.42	8.34 c	0.27	55.20 d	-4.83	4.70 b	0.64
02 x 08	61.14 c	-0.60	54.52 c	-0.15	9.89 b	0.88	62.79 d	3.18	4.80 a	0.38
02 x 09	62.73 c	6.18	53.07 c	1.91	8.29 c	0.41	59.92 d	8.63	3.95 f	-0.20
02 x 10	60.79 c	3.29	54.30 c	1.73	8.10 c	-0.33	64.95 d	1.83	3.93 f	-0.38
03 x 04	57.73 c	1.87	53.33 c	2.39	7.51 c	-0.19	67.68 c	-1.95	3.83 g	-0.22
03 x 05	61.87 c	-0.73	55.83 c	-0.65	8.39 c	-0.59	59.88 d	-5.29	4.16 e	-0.03
03 x 06	53.10 d	-3.21	47.75 d	-3.29	6.96 d	-0.90	72.49 c	-2.28	3.86 g	-0.23
03 x 07	46.03 e	-14.0	42.82 d	-11.9	6.03 e	-2.30	71.77 c	4.07	3.86 g	-0.18
03 x 08	65.97 c	2.19	59.72 c	-3.98	10.37b	1.09	66.56 d	-0.71	4.63 b	0.21
03 x 09	50.75 d	-7.89	46.14 d	-6.05	7.79 c	-0.36	57.73 d	-1.22	4.53 c	0.37
03 x 10	60.58 c	1.06	56.91 c	3.30	8.63 c	-0.08	67.38 c	-3.40	4.20 e	-0.11
04 x 05	59.91 c	0.88	54.76 c	0.67	8.39 c	0.20	68.92 c	6.18	4.13 e	0.07
04 x 06	51.68 d	-1.07	48.81 d	0.15	7.54 c	0.47	69.21 c	-3.12	4.30 d	0.34
04 x 07	56.32 c	-0.19	50.53 d	-1.80	6.37 d	-1.17	59.81 d	-5.44	3.33 i	-0.57
04 x 08	70.76 b	10.55	61.69 b	8.35	9.36 b	0.88	63.01 d	-1.80	3.90 g	-0.36
04 x 09	58.47 c	3.47	52.14 c	2.33	8.07 c	0.71	59.58 d	3.07	4.06 f	0.07
04 x 10	66.65 c	10.70	60.42 c	9.19	10.19b	2.28	77.36 c	9.02	4.50 c	0.33
05 x 06	73.46 b	13.96	68.23 b	14.03	10.00b	1.69	71.93 c	4.06	4.03 f	-0.07
05 x 07	66.00 c	2.73	59.11 c	1.22	10.00b	1.17	61.86 d	1.06	4.46 c	0.41
05 x 08	76.40 b	9.08	63.14 b	4.22	11.09a	1.33	65.46 d	5.08	4.30 d	-0.11
05 x 09	60.71 c	-1.03	56.30 c	0.95	8.25 c	-0.38	48.21 d	-3.84	4.00 f	-0.15
05 x 10	61.73 c	-0.96	54.79 c	-1.97	8.93 b	-0.26	68.56 c	4.67	4.26 e	-0.04
06 x 07	64.62 c	7.63	58.60 c	6.14	8.68 c	0.97	80.91 c	10.50	3.96 f	0.01
06 x 08	61.02 c	0.345	56.47 c	3.02	9.52 b	0.88	71.27 c	1.30	4.60 b	0.28
06 x 09	58.57 c	3.08	52.44 c	2.52	7.34 c	-0.17	55.75 d	-5.89	3.70 g	-0.35
06 x 10	47.03 e	-9.38	41.18 e	-10.1	6.27 d	-1.80	74.58 c	1.11	3.93 f	-0.28
07 x 08	50.92 d	-13.5	45.85 d	-11.2	6.80 d	-2.31	62.80 d	-0.09	3.93 f	-0.33
07 x 09	62.00 c	2.77	57.66 c	4.05	8.06 c	0.07	56.90 d	2.33	3.83 g	-0.17
07 x 10	80.37 a	19.84	77.05 a	22.03	12.66a	4.13	67.19 c	0.77	4.66 b	0.50
08 x 09	84.37 a	21.44	67.91 b	13.30	11.74a	2.81	52.31 d	-1.82	4.65 b	0.28
08 x 10	66.64 c	2.77	57.57 c	1.56	9.19 b	-0.28	68.98 c	3.00	4.06 f	-0.45
09 x 10	65.90 c	7.24	59.14 c	6.65	9.31 b	0.95	60.15 d	2.49	4.16 e	-0.09
AP-529	44.37 e	-	40.31 e	-	6.17 e	-	56.24 d	-	4.10 e	-
Tinto	59.55 c	-	47.90 d	-	7.54 c	-	104.4 a	-	3.46 h	-
SD S _{ij}	2.25		2.32		0.37		3.24		0.053	
SD S _{ij} - S _{ik}	3.22		3.80		0.55		4.76		0.078	
SD S _{ij} - S _{kl}	3.60		3.63		0.53		4.54		0.075	

*Means followed by the same letter belong to the same group, according to Scott Knott group ($p < 0,05$) {médias seguidas pela mesma letra pertencem ao mesmo grupo, de acordo com teste de agrupamento Scott Knott ($p < 0,05$)}.

with other hybrids RVT-02 x RVT-03, RVT-08 x RVT-09, RVT-01 x RVT-05 and RVT-05 x RVT-08 (Table 4).

For MM, the hybrids which showed the highest estimates of SCA and concomitantly at least one of the parents with good estimate of GCA were: RVT-01 x RVT-03, RVT-01 x RVT-06 and RVT-01 x RVT-02 (Table 4). All the hybrids previously mentioned showed in common the parent RVT-01 due to being the same line with the highest GCA for MM of the diallel (Table 3). For this experiment, no experimental hybrid exceeded the check hybrid Tinto, which presented the highest MM of the experiment (104.40 g/fruit) not being grouped with any other genotype (Table 4).

TSS influences directly the flavor and the yield of tomato pulp; and the price paid for the raw material is directly related to TSS (Giordano *et al.*, 2000). According to SCA, the best industrial tomato hybrids considering TSS were: RVT-02 x RVT-08, RVT-03 x RVT-08, RVT-06 x RVT-08 and RVT-08 x RVT-09 due to presenting high estimates of SCA and concomitantly the parent RVT-08, as it also showed high estimate of GCA (Table 3). The means grouping test joined genotypes in nine different groups (Table 4). Line RVT-08 showed the highest value for TSS in the experiment (4.90) being grouped with the hybrid RVT-02 X RVT-08 (4.80°Brix) and the line RVT-10 (4.76°Brix) (Table 4).

This way, the authors concluded that diallel crosses have led to the formation of superior experimental hybrids, in comparison to the checks used in the experiment, the following simple hybrids being highlighted RVT-08 x RVT-09, RVT-07 x RVT-10 and RVT-08 x RVT-10 which exceeded the commercial hybrids in relation to fruit productivity and pulp yield. Regarding the control of gene expression, the authors concluded that non-additive genes predominated for controlling YT, YC, YP and TSS traits, whereas additive genes predominated for MM. Parents RVT-08, RVT-05 and RVT-10 are the most appropriate for intrapopulation breeding.

ACKNOWLEDGEMENT

CAPEs for financial support, FINEP, NUPH and UNICENTRO.

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