









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## Agronomic variability among hybrids of tomato plant with emphasis on the multivariate analysis

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### ABSTRACT

The tomato is one of the most economically, socially and nutritionally important vegetables, presenting high added value. The culture allows high profit for the producers, but it is a high risk activity due to, specially, the sensibility of some varieties to climate conditions as well as multiple plagues and diseases that attack the culture. Therefore, the search for new hybrids with more tolerance to biotic and abiotic factors is extremely important to attend to the demand of the culture's productive chain. The objective of this work was to demonstrate the importance of multivariate and univariate techniques in evaluating the level of similarity among hybrids of the tomato plant of the salad group with the purpose of diagnosing possible groups in relation to the variables analyzed. A total of 23 hybrids of tomato from the salad group were evaluated; of those, 9 were commercial hybrids and 14 were experimental hybrids. Throughout the conduction of the experiment, the productive characters of the culture were evaluated as well as the characteristics of the fruits and the agronomic characters of the plant. For the productive characters and the characteristics of the fruits, the multiple factor analysis was performed, and the averages were compared by the Scott-Knott test. For the agronomic characters of the plant, the exploratory data analysis was used with the correspondence analysis. The commercial hybrids studied present a high degree of similarity among them, with more than 77% of the materials with strong or high similarity with the other materials. Meanwhile, for the experimental hybrids, this result is seen in only 42.86% of the materials. The experimental hybrids 3124, 3139, and 3126 present higher divergence when compared to the other materials studied. They are, therefore, recommended to increase the genetic base of the tomato plant's breeding program.

**Keywords:** *Solanum lycopersicum*, plant breeding, similarity, correspondence analysis.

### RESUMO

#### Variabilidade agrônômica entre híbridos de tomateiro com ênfase na análise multivariada

O tomate é uma das hortaliças de maior importância econômica, social e nutricional, apresentando alto valor agregado. A cultura permite alto lucro para os produtores, mas é uma atividade de alto risco, devido principalmente, à sensibilidade de algumas variedades às condições climáticas e às múltiplas pragas e doenças que atacam a cultura. Portanto, a busca por novos híbridos com maior tolerância ao fator biótico e abiótico é de extrema importância para atender a demanda da cadeia produtiva da cultura. O objetivo deste trabalho foi demonstrar a importância das técnicas multivariadas e univariadas na avaliação do nível de similaridade entre híbridos do tomateiro do grupo salada com a finalidade de diagnosticar possíveis grupos em relação às variáveis analisadas. Foram avaliados 23 híbridos de tomate do grupo salada; sendo 9 híbridos comerciais e 14 híbridos experimentais. Ao longo da condução do experimento, foram avaliados os caracteres produtivos da cultura, assim como as características dos frutos e os caracteres agrônômicos da planta. Para os caracteres produtivos e as características dos frutos, foi realizada a análise multifatorial e as médias comparadas pelo teste de Scott-Knott. Para os caracteres agrônômicos da planta, utilizou-se a análise exploratória dos dados com a análise de correspondência. Os híbridos comerciais estudados apresentam alto grau de similaridade entre si, com mais de 77% dos materiais com forte ou alta similaridade com os demais materiais. Enquanto isso, para os híbridos experimentais, esse resultado é visto em apenas 42,86% dos materiais. Os híbridos experimentais 3124, 3139 e 3126 apresentam maior divergência quando comparados aos demais materiais estudados. São, portanto, recomendados para aumentar a base genética do programa de melhoramento do tomateiro.

**Palavras-chave:** *Solanum lycopersicum*, melhoramento de plantas, similaridade, análise de correspondência.

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The tomato (*Solanum lycopersicum*) is one of the major vegetables to be cultivated in the world. In Brazil the culture stands out for its significant contribution to the gross domestic product (GDP) (Deleo, 2020). In 2019,

almost 4 million tons were produced in an area of around 54,600 hectares (IBGE, 2019).

Despite the expressive Brazilian production, the high production cost and the logistical difficulties can harm

the sustainability of the culture. The production of tomato for consumption *in natura* has higher costs with skilled labor, and its cultural practices require a lot of time. Among the major varietal groups of table tomato placed in the

Brazilian market there are the Salad, the Italian, the Santa Cruz and the Cherry with a participation of 51.5%, 31.3%, 12.1%, and 5.1%, respectively (Nick *et al.*, 2018). The Salad group, focus of this work, has been experimentally explored in the search of better quality, productivity, and resistance to the main plagues and diseases.

In front of the socioeconomic importance of the culture for the country, the genetic breeding programs that deal with the tomato plant, both in private and public companies, aim at the development of genotypes adapted to the edaphoclimatic conditions in the different micro-regions of Brazil and at the resistance to the main diseases. The characterization and the analysis of the genetic diversity of the germplasm are fundamental steps for the success of the program since through these evaluations it is possible to identify the individuals that present genes of agronomic interest and, thus, insert them in breeding programs with genotypes already enhanced (Martins *et al.*, 2011).

In this context, the multivariate data analysis techniques are statistical tools that allow the access of information, exploring patterns and simplifying the structure of data sets. Thus, the objective of this work was to demonstrate the importance of multivariate and univariate techniques in evaluating the level of similarity among tomato hybrids of the salad group belonging to the company Hortec, through the productive characteristics of the plant and fruit, aiming at diagnosing possible groupings in relation to the variables analyzes.

## MATERIAL AND METHODS

The experiment was carried out in a randomized block design with 4 replications. A total of 23 hybrids of tomato from the indeterminate salad group were evaluated; of these, 9 were commercial hybrids available in the market [Compack (3100), Coronel (3101), Alambra (3102), Paronset (3103), Valerin (3104), Arendel (3105), Dylla (3106), Ômega (3107) and Paraty (3128)] that stand out for their productivity and/or resistance to the main crop diseases in the country and

14 experimental hybrids belonging to Hortec Sementes genetic breeding program (3124 to 3127, 3129, 3134, 3139 to 3146).

Seven plants were used in each portion with 0.70 m spacing between plants and 1.20 m between lines. The work was carried out in open field at CDTT/DAG/ESAL/UFLA (Centro de Desenvolvimento e Transferência de Tecnologia da Universidade Federal de Lavras) in Ijaci-MG (21°16'38''S, 44°91'67''W, 889 m altitude), in the period ranging from February to July 2020. The climate of the region, according to Koppen's climatic classification, is classified as Cwa (mesothermal), with dry winters and rainy summers (Álvares *et al.*, 2013).

The seedlings were produced in a nursery and after 34 days of seeding, seedlings were transplanted to the field, with the planting fertilization and the cover fertilization carried out following the recommendations from Nick *et al.* (2018), in addition to localized fertigation carried out weekly using soluble salts suitable for the culture. The application of insecticides, fungicides, and herbicides, as well as cultural treatments such as tutoring and pruning, were carried out according to the needs of the crop.

During the experiment, some evaluations considered important for the selection of new genotypes were carried out. The productive characters of the culture (productivity, number of commercial fruits, and number of waste fruits), the characteristics of the fruits [commercial classification according to EMATER PR (1997), diameter, and

length], and the agronomic characters of the plant [fruit picking, resistance to diseases, plant height, precocity, fruit vigor, fruit size, and fruit shape (Bittar *et al.*, 2012)] were evaluated through grades provided by 5 evaluators as shown in Table 1.

Harvests were weekly until the end of the crop cycle (seven weeks), evaluating all the parameters mentioned. We chose to work with the averages presented in each block since the multivariate technique employed in the analysis demands they are balances. Therefore, there were 4 replications for each hybrid in a total of 92 observations.

For the productive characters and the fruit characteristics, the multiple factor analysis was carried out, and the averages were compared by the Scott-Knott test at the level of 5% significance. For the agronomic characters of the plant, the exploratory data analysis was used with the correspondence analysis. The aim was to establish the association among the genotypes and the categorical variables in their levels.

The results of the analyzes were obtained through the development of scripts in the software R (R Core Team, 2020) for public use through the MVar pack version 2.1.3 (Ossani & Cirillo, 2020).

## RESULTS AND DISCUSSIONS

### Multiple factor analysis

The results described in Table 2 make evident that the analyzes can be applied in a two-dimensional space once the proportion of the variation explained in the first two components is

**Table 1.** Grades established from 1 to 5 for the different characteristics of salad indeterminate tomato plants and fruits. Lavras, UFLA, 2021.

Characteristics	Levels
Picking	1: very bad; 2: bad; 3: medium; 4: good; 5: very good
Resistance to diseases	1: very bad; 2: bad; 3: medium; 4: good; 5: very good
Plant height	1: very short; 2: short; 3: medium; 4: tall; 5: very tall
Precocity	1: very precocious; 2: precocious; 3: medium; 4: late; 5: very late
Plant vigor	1: very low; 2: low; 3: medium; 4: vigorous; 5: very vigorous
Fruit size	1: very small; 2: small; 3: medium; 4: big; 5: very big
Fruit shape	1: 3A; 2: 2A; 3: 1A; 4: special; 5: extra

70.93% of the total variation, in which the first and second components explain, respectively 36.44% and 34.49% of the total variation.

Taking into consideration the partial inertia of each hybrid, interpreted as the amount of variation returned in each component inherent to the global analysis, the results described in Table 2 corroborate with the claims related to a strong similarity among all the hybrids that have values over 0.9 in first component; high for values between 0.9 and 0.7; average for values between 0.7 and 0.5; low for values between 0.5 and 0.3; and weak for values under 0.3 (Souza *et al.*, 2019). It is possible to follow this same line of thought for the

second and third components. However, as every explanation is carried out in the first component, the other explanations are not necessary.

Following the specifications of the similarity, is it possible to note that 4.35% of the studied genotypes present weak similarity, 13.05% present low similarity, 26.08% present average similarity, 34.78% present high similarity, and 21.74% of the hybrids present strong similarity among them, as shown in Table 3.

These results demonstrate that the hybrids studied have high genetic diversity *per se*. The results described in Table 2 were used to generate Figure 1, so that the first component represents

the x-axis, the second the y-axis. Thus, the projections in the respective axes demonstrate the magnitudes of the similarities of the hybrids studied in the respective axes.

### Correspondence analysis

The Chi-square test was used to verify the dependence among the hybrids and the variables with 726 degrees of freedom and p-value: 1.00 E<sup>-9</sup>, at the level of significance of 5%. It was possible to verify that there is dependence among them, what indicates association among the hybrids and the variables.

The results described in Figure 2 make evident that the analyzes can be explained in a two-dimensional space once the proportion of the variation explained in the two first components is 50.42% of the sample variation.

The proximity of the points in the graph indicates their association. Thus, it is perceptible that the characteristics of high precocity and bad fruit picking (see Table 1) are associated with the 3142 hybrids, and both characteristics are also associated with the 3134 and 3129 hybrids alongside the characteristics low plant height and fruit size classified as special. The characteristics high plant height and fruit shape classified as 3A are associated with the Compact (3100) hybrid. The characteristic very good resistance to diseases is associated with the Paraty (3128) hybrid. Medium fruit picking and precocity are associated with the 3145 hybrids while the 3125 is associated with the characteristics very good picking and very big fruit size. Other associations can be made based on the distance of the points that represent the characteristics (blue) and the points that represent the hybrids (red).

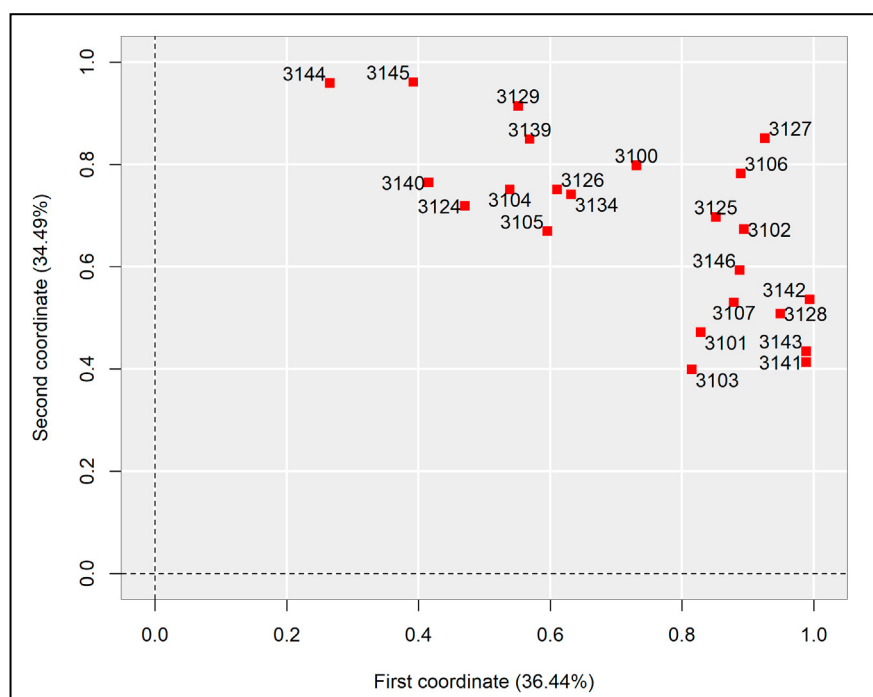
### Media test

The multiple factor analysis and the correspondence analysis complement the information presented by the univariate analysis through the Scott-Knott test (Tables 4 and 5). They might be a tool to help the breeders in strategies of material selection aiming at the success of the breeding program.

The media tests for the productive characters and for the fruit classification by size highlight the experimental

**Table 2.** Values referent to the computed inertia in the axes for the treatments formed by groups of variables. Lavras, UFLA, 2021.

Code	Components		
	1	2	3
3100	0.7310	0.7983	0.6285
3101	0.8286	0.4720	0.7669
3102	0.8940	0.6737	0.7818
3103	0.8150	0.3990	0.8140
3104	0.5386	0.7513	0.4089
3105	0.5959	0.6694	0.5404
3106	0.8895	0.7822	0.9810
3107	0.8790	0.5301	0.4948
3124	0.4703	0.7192	0.7016
3125	0.8515	0.6970	0.4353
3126	0.6107	0.7510	0.4877
3127	0.9261	0.8513	0.6404
3128	0.9495	0.5080	0.3208
3129	0.5514	0.9144	0.5275
3134	0.6316	0.7416	0.5191
3139	0.5688	0.8496	0.4364
3140	0.4155	0.7649	0.8881
3141	0.9886	0.4131	0.4254
3142	0.9940	0.5362	0.3206
3143	0.9886	0.4347	0.5870
3144	0.2655	0.9593	0.2817
3145	0.3922	0.9615	0.6030
3146	0.8876	0.5932	0.7016
Variance	16.6635	15.7712	13.2923
% variance	36.44	34.49	29.07
% accumulated	36.44	70.93	100.00



**Figure 1.** Inertia of the groups from the evaluation of 9 commercial hybrids and 14 experimental hybrids. Lavras, UFLA, 2021.

**Table 3.** Groups formed by hybrids by the degree of similarities. Lavras, UFLA, 2021.

Code	Components 1	Representativeness (%)	Similarity
3144	0.2655	4.35%	weak
3145	0.3922		
3140	0.4155	13.05	low
3124	0.4703		
3104	0.5386		
3129	0.5514		
3139	0.5688	26.08	moderate
3105	0.5959		
3126	0.6107		
3134	0.6316		
3100	0.7310		
3103	0.8150		
3101	0.8286		
3125	0.8515	34.78	high
3107	0.8790		
3146	0.8876		
3106	0.8895		
3102	0.8940		
3127	0.9261		
3128	0.9495		
3141	0.9886	21.74	strong
3143	0.9886		
3142	0.9940		

hybrids 3125 (average of 13.70 kg of fruits plant<sup>-1</sup>; 60.18 fruits per plant, and 57.94% of the fruits with classification 3A and 2A), 3124 (production average of 12.08 kg of fruits plant<sup>-1</sup>; with 46.64 fruits per plant and 37.96% of fruits classified as 3A), 3126 (average production of 11.57 kg of fruits plant<sup>-1</sup>; 55.89 fruits per plant, and 47.07% of the fruits with classification 3A and 2A), and 3139 (average production of 11.24 kg of fruits plant<sup>-1</sup>, 72.00 fruits per plant, and 60.81% of the fruits classified as 2A and 1A).

However, it is noteworthy that the univariate analyzes (Scott-Knott test) did not allow the explicit visualization of divergent groups, which makes the association of uni and multivariate techniques an important strategy to determine the genetic variability among tomato plant hybrids, as also cited by Araújo *et al.* (2016) and Maciel *et al.* (2018).

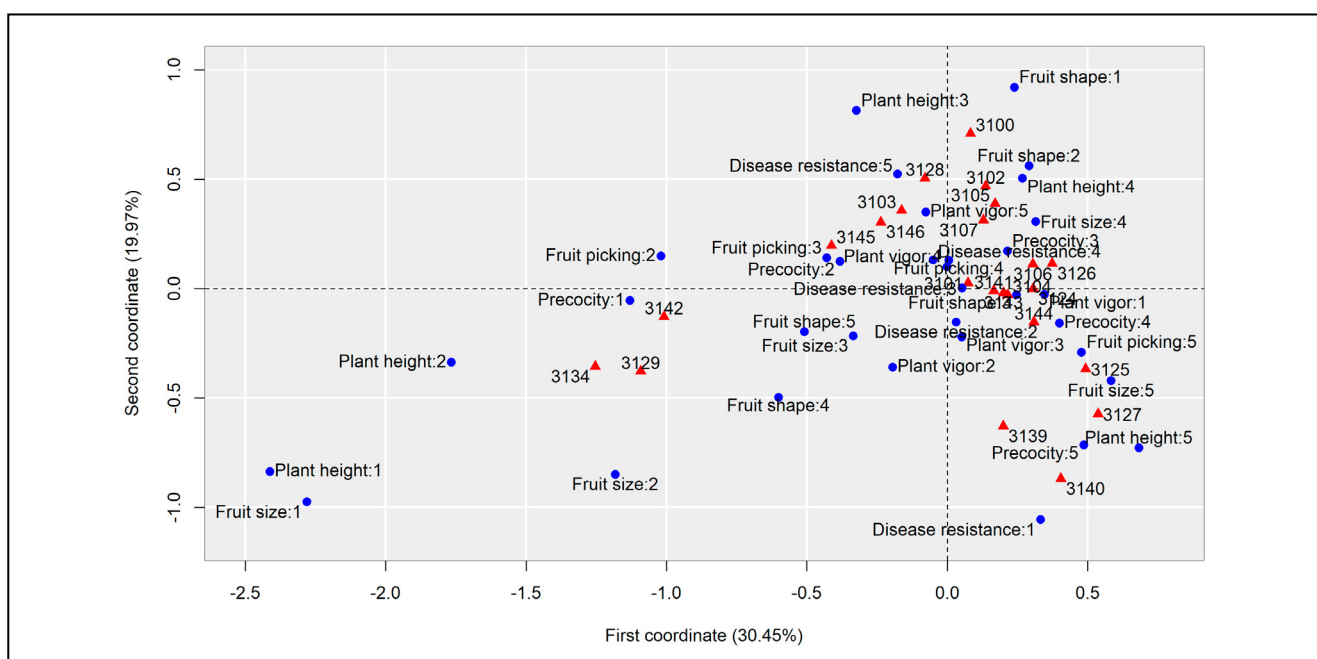
According to the similarity results (Table 2), the experimental hybrid 3124 (0.4703) present low similarity, and the experimental hybrids 3139 (0.5688) and 3126 (0.6107) have average similarity. Thus, these hybrids present higher divergence in relation to the other materials studied and with important characteristics. Therefore, their use as parents in the next breeding is advisable, aiming at increasing the genetic base of the breeding program. For Guar *et al.* (1978), the multivariate analysis may be employed as a powerful tool to estimate the genetic dissimilarity with the goal of helping in the choice of genetic constitutions that might result in better recombination.

In order to obtain superior populations, the improvers must evaluate, simultaneously, various characters to better infer on their relative superiority. The analysis of variable in isolation might not be enough since it does not take into consideration the existent correlations among them (Ledo *et al.*, 2003). Because it bases itself in only one or in a few characteristics, it culminates in less efficacy due to the importance of the simultaneous evaluation and interpretation of a possible maximum of characteristic involved in the productive system

**Table 4.** Productivity, number of commercial fruits and number of waste fruits in 23 hybrid tomato plants. Lavras, UFPA, 2021.

Code	Productivity		Number of commercial fruits (fruits/plant)	Waste (fruits/plant)
	(t/ha)	(kg/plant)		
3142	93.12 c	7.76 c	40.95 c	1.62 a
3134	101.64 c	8.47 c	43.39 c	3.92 c
3129	104.64 c	8.72 c	51.64 b	5.32 c
3141	108.00 c	9.00 c	40.04 c	2.10 a
3145	109.92 c	9.16 c	35.61 c	1.50 a
3146	111.72 b	9.31 b	35.89 c	1.07 a
3140	112.32 b	9.36 b	70.22 a	0.89 a
3143	113.52 b	9.46 b	39.18 c	2.04 a
3128	116.76 b	9.73 b	39.61 c	3.82 c
3103	117.72 b	9.81 b	53.68 b	1.72 a
3104	121.68 b	10.14 b	43.75 c	1.64 a
3127	123.12 b	10.26 b	43.32 c	2.93 b
3144	124.56 b	10.38 b	43.18 c	1.90 a
3139	134.88 a	11.24 a	72.00 a	2.04 a
3100	136.68 a	11.39 a	46.25 c	1.79 a
3126	138.84 a	11.57 a	55.89 b	3.04 b
3106	139.68 a	11.64 a	56.72 b	2.86 b
3124	144.96 a	12.08 a	46.64 c	2.79 b
3102	146.76 a	12.23 a	64.07 a	1.21 a
3105	148.32 a	12.36 a	61.89 b	4.18 c
3101	149.16 a	12.43 a	57.04 b	1.46 a
3107	149.64 a	12.47 a	55.25 b	2.14 a
3125	164.40 a	13.70 a	60.18 b	2.54 a
CV (%)	9.28		10.68	48.54

Averages followed by same letters in the column do not differ among themselves according to the Scott & Knott test, 5% probability.

**Figure 2.** Graphical representation of the association among evaluated genotypes and variables. Lavras, UFPA, 2021.

**Table 5.** Percentage of tomato fruits according to the size classes 3A (250 to 320 g), 2A (220 to 249 g), 1A (170 to 219 g), extra (140 to 169 g) and special (100 to 139 g). Lavras, UFLA, 2021.

Code	3A	2A	1A	Extra	Special
3142	15.45 d	24.33 b	38.48 a	20.18 b	1.55 d
3134	15.07 d	31.17 a	32.72 b	19.55 b	1.50 d
3129	4.17 e	18.96 b	40.05 a	32.94 a	3.88 c
3141	27.46 b	32.11 a	27.08 b	12.13 c	1.22 d
3145	38.63 a	28.18 a	24.47 b	7.93 d	0.79 d
3146	40.16 a	28.66 a	25.17b	5.65 d	0.37 d
3140	3.18 e	16.26 b	42.08 a	28.00 a	10.49 a
3143	33.58 a	29.23 a	27.86 b	8.45 d	0.88 d
3128	29.93 b	29.67 a	27.80 b	11.17 c	1.43 d
3103	12.68 d	29.38 a	30.65 b	20.74 b	6.57 b
3104	27.45 b	27.14 a	33.03 b	11.55 c	0.83 d
3127	34.37 a	27.02 a	25.50 b	12.11 c	0.95 d
3144	34.49 a	29.92 a	23.78 b	10.58 c	1.24 d
3139	1.80 e	20.72 b	40.09 a	28.65 a	8.75 a
3100	34.40 a	28.59 a	29.57 b	6.93 d	0.53 d
3126	19.86 c	27.21 a	30.44 b	19.61 b	2.89 c
3106	19.55 c	28.51 a	29.75 b	18.83 b	3.37 c
3124	37.96 a	29.96 a	22.86 b	8.44 d	0.80 d
3102	14.50 d	28.54 a	32.00 b	22.36 b	2.60 c
3105	21.73 c	30.90 a	30.07 b	16.07 c	1.23 d
3101	20.65 c	36.00 a	29.69 b	11.97 c	1.70 d
3107	19.14 c	37.67 a	31.25 b	10.44 c	1.51 d
3125	25.70 b	32.24 <sup>a</sup>	25.90 b	14.41 c	1.75 d
CV (%)	17.79	18.80	16.77	22.24	61.73

Averages followed by same letters in the column do not differ among themselves according to the Scott & Knott test, 5% probability.

(Maêda *et al.*, 2001). Meanwhile, the application of the multivariate analysis consists in a combination of multiple information inserted in the experimental unit in a way that the selection is based on a full set of important variables that discriminate the most promising materials (Maêda *et al.*, 2001).

Thus, the focus on promising hybrids can accelerate the steps within the genetic breeding program (Luz *et al.*, 2016). Therefore, the lower the degree of kinship between two parents, the greater the number of divergent loci and consequently lower genetic similarity between these individuals (Cruz *et al.*, 2014).

In front of the results presented in this experiment, it is possible to infer that the combination of the multivariate

techniques (multiple factor analysis and exploratory analysis) with the univariate analysis (media test) turns into a viable tool in tomato plants genetic breeding programs aiming at helping in the selection of promising genotypes. This study corroborates with the information presented in other researches with genetic diversity with the tomato culture that use classic strategies for the quantification of the distances among genotypes such as the generalized distance of Mahalanobis (Luz *et al.*, 2016; Figueiredo *et al.*, 2017; Maciel *et al.*, 2018), considered the most used in experiments with replications (Cruz *et al.*, 2014). This quantification of the genetic diversity may be carried out through molecular, morphological, and agronomic characters, among others. It

allows the selection of the best parents without the need for direct evaluation of its offspring (Faleiro, 2007).

The commercial hybrids studied present a high degree of similarity among themselves, with more than 77% of the materials [Compack (3100), Coronel (3101), Alambra (3102), Paronset (3103), Dylla (3106), Ômega (3107), and Paraty (3128)] with strong or high similarity. Meanwhile, for the experimental hybrids, this result is presented in only 42.86% of the materials (3125, 3127, 3141, 3142, 3143, and 3146). Therefore, these genotypes meet market demand and have characteristics similar to each other.

On the other hand, hybrids with less similarity can be interesting in terms



of increasing the genetic base of the tomato breeding program, in particular, this is the case of experimental hybrids 3124, 3126, and 3139, which show greater divergence with the other studied genotypes and they have interesting characteristics of their own, such as productivity and fruit classification.

The multivariate analysis and the study of the level of similarity between the genotypes are extremely important for the breeder's decision-making when choosing the different genotypes and the levels of divergence between them, seeking more heterosis in future combinations. This methodology has been used in genetic divergence studies with several vegetables, such as tomato (Maciel et al., 2018), carrot (Souza et al., 2021a), kale (Brito et al., 2021), strawberry (Souza et al., 2021b), among other species. The development of more work with this methodology is intended to improve the technique, aiming to help the success of genetic breeding programs.

## REFERENCES

- ÁLVARES, CA; STAPE, JL; SENTELHAS, PC; GONCALVES, JLM; SPAROVEK, G. 2013. Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22: 711-728.
- ARAÚJO, JC; TELHADO, SFP; SAKAI, RH; LEDO, CAS; MELO, PCT. 2016. Univariate and multivariate procedures for agronomic evaluation of organically grown tomato cultivars. *Horticultura Brasileira* 34: 374-380.
- BITTAR, CA; LUZ, JMQ; MENDES, LA; CARDOSO, RR. 2012. Desempenho de genótipos de tomate para processamento industrial. *Horticultura Brasileira*. 30: 4185-4192.
- BRITO, OG; ANDRADE JÚNIOR, VC; AZEVEDO, AM; DONATO, LMS; SILVA, AJM; OLIVEIRA, AMO. 2021. Genetic divergence between half-sibling progenies of kale using different multivariate approaches. *Horticultura Brasileira*. 39: 178-185.
- CRUZ, CD; CARNEIRO, PCS; REGAZZI, AJ. 2014. *Modelos biométricos aplicados ao melhoramento genético*. Viçosa: UFV. 668p.
- DELEO, JPB. 2020. Anuário hortifruti Brasil retrospectiva 2019 & perspectiva 2020. *Hortifruti Brasil*, 1: 28-30.
- EMATER-PR. 1997. *Manual técnico de olericultura*. Curitiba: EMATER-PR. 156 p.
- FALEIRO, FG. 2007. *Marcadores genético-moleculares aplicados a programas de conservação e uso de recursos genéticos*. Embrapa Cerrados. 102p.
- FIGUEIREDO, AST; RESENDE, JTV; SCHWARZ, K; MARODIN, JC; GALVÃO, AG; RESENDE, NCV. 2017. Genetic divergence among processing tomato hybrids and formation of new segregating populations. *Ciência e Agrotecnologia*, 41: 279-287.
- GUAR, PC; GUPTA, PK; KISHORE, H. 1978. Studies on genetic divergence of potato. *Euphytica* 27: 361-368.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. 2019. Levantamento sistemático da produção agrícola. Available At <https://sidra.ibge.gov.br/home/lspa/brasil>. Accessed January 9, 2020.
- LEDO, CADS; FERREIRA, DF; RAMALHO, MAP. 2003. Análise de variância multivariada para os cruzamentos dialélicos. *Ciência e Agrotecnologia*, 27: 1214-1221.
- LUZ, JMQ; BITTAR, CA; OLIVEIRA, RC; NASCIMENTO, AR; NOGUEIRA, APO. 2016. Desempenho e divergência genética de genótipos de tomate para processamento industrial. *Horticultura Brasileira* 34: 483-490.
- MACIEL, GM; FINZI, RR; CARVALHO, FJ; MARQUEZ, GR; CLEMENTE, AA. 2018. Agronomic performance and genetic dissimilarity among cherry tomato genotypes. *Horticultura Brasileira* 36: 167-172.
- MAÊDA, JM; PIRES, IE; BORGES, RCG; CRUZ, CD. 2001. Critérios de seleção uni e multivariados no melhoramento genético da *Virola surinamensis* Warb. *Floresta e Ambiente* 8: 61-69.
- MARTINS, FA; CARNEIRO, PCS; SILVA, DJH; CRUZ, CD; CARNEIRO, JES. 2011. Integração de dados em estudos de diversidade genética de tomateiro. *Pesquisa Agropecuária Brasileira*, 46: 1496-1502.
- NICK, C; SILVA, D; BORÉM, A. 2018. *Tomate: do plantio à colheita*. Editora UFV. Viçosa-MG, 237p.
- OSSANI, PC; CIRILLO, MA. 2020. MVar: Multivariate analysis. URL <<https://cran.r-project.org/web/packages/MVar/>>. R package version 2.1.3.
- R CORE TEAM. 2020. R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. URL <http://www.R-project.org>
- SOUZA, DC; AZEVEDO, MS; OSSANI, PC; FARIA, LP; MARQUES, WAA; NARITA, GA. 2021a. Variabilidade agrônômica entre genótipos comerciais e experimentais de cenoura com ênfase em análise multivariada. *Research, Society and Development*, 10: e173101321145.
- SOUZA, DC; OSSANI, PC; COSTA, AS; GUERRA, TS; ARAÚJO, AL; RESENDE, FV; RESENDE, LV. 2021b. Selection of experimental strawberry clones for fruit appearance attributes. *Pesquisa Agropecuária Brasileira*, 56: e02560.
- SOUZA, DC; OSSANI, PC; RESENDE, LV; CIRILLO, MA; SILVA, LFLS; XAVIER, JB. 2019. Variabilidade genética entre cultivares comerciais e híbridos experimentais de morangueiro com ênfase em análise de múltiplos fatores. *Magistra* 30: 48-59.