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Univariate and multivariate procedures for agronomic evaluation of organically grown tomato cultivars

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ABSTRACT

Tomato is one of the most important crops, the worldwide production in 2012 reached 161.8 million tons. Considering the lack of agronomic information on already available cultivars as well as on the varieties under development by breeding programs for organic systems, the objectives of this work were determine the yield components of 14 tomato cultivars in the organic system, through univariate and multivariate analysis. The experimental design was randomized blocks with six replications and five plants per plot. Evaluations consisted of total, marketable and non-marketable yield and number of marketable fruits per plant, in 2010. We carried out analysis of variance, using test F 5%. The effect of cultivar was fixed and the block effect was random. Then, means were ranked according to Scott-Knott 5%. Differences among cultivars were significant for total yield, number of marketable fruits per plant and marketable yield. The mean for total yield among cultivars was 51 t/ha and for marketable yield was 41 t/ha. Cultivars IAC 1 and Santa Clara were the least dissimilar (0.38). On the other hand, cultivars HTV 0601 and IAC 3 were the most dissimilar (10.63). The score dispersion graph showed two distinct groups. The second group contained cultivars HTV 0601, Granadero, Bari and Netuno, which stood out in the evaluation for the organic production system, presenting the highest total yield, marketable yield and number of marketable fruits per plant. Multivariate analysis was effective in identifying clusters of cultivars.

Keywords: *Solanum lycopersicum*, varietal segmentation, yield.

RESUMO

Procedimentos uni e multivariados na análise de desempenho agronômico de tomate sob cultivo orgânico

O tomateiro é uma das culturas de maior importância, cuja produção mundial, em 2012, atingiu 161,8 milhões de toneladas. Devido à carência de informações sobre o comportamento agronômico das cultivares disponíveis, e de novas cultivares ainda em desenvolvimento pelos programas de melhoramento genético, conduzidas em sistema orgânico de produção, os objetivos do trabalho foram determinar, quantitativamente, por meio de técnicas de análise uni e multivariadas, as características produtivas de 14 cultivares de tomate de mesa em sistema orgânico de produção. O delineamento experimental foi de blocos casualizados com seis repetições e cinco plantas úteis por parcela. Avaliou-se a produtividade total, comercial, não-comercial e número de frutos comerciais por planta, em 2010. Os dados foram submetidos à análise de variância pelo teste F a 5% de probabilidade, considerando o efeito da cultivar como fixo e os efeitos de bloco como aleatórios. Houve efeito significativo entre as cultivares para a produtividade total, comercial e o número total de frutos comerciais por planta. As produtividades médias, total e comercial, foram 51 e 41 t/ha, respectivamente. As cultivares IAC 1 e Santa Clara apresentaram a menor magnitude de distância (0,38). Por outro lado, as cultivares HTV 0601 e IAC 3 apresentaram a maior magnitude de distância (10,63). No dendrograma de dissimilaridade, houve a formação de dois grupos. No segundo grupo, percebe-se o agrupamento das cultivares HTV 0601, Granadero, Bari e Netuno, que se destacaram no cultivo sob sistema orgânico, apresentando os maiores valores de produtividade total e comercial e número de frutos comerciais por planta. A análise multivariada foi eficiente na identificação de agrupamentos das cultivares.

Palavras-chave: *Solanum lycopersicum*, segmentação varietal, produtividade.

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Tomato (*Solanum lycopersicum*) is one of the most important crops worldwide, grown in a number of places with distinct latitudes, under contrasting technical levels. Tomato is considered a functional food, due to its excellent vitamin and mineral supply, besides the presence of lycopene, a carotenoid pigment which provides the red color to the fruits, presenting antioxidant properties (Alvarenga, 2004).

In 2012, the world production of tomato, both for fresh market and for industry, reached 161.8 million tons in a cultivated area of 4.8 million hectares, yielding 33.7 t/ha (FAO, 2014).

The area under organic cultivation worldwide reached 37 million hectares in 2010. The area corresponding to organic vegetables, specifically, grew 34%, from 2004 to 2010. The United States accounts for the largest area of organic vegetables, with 63.3 thousand hectares. Brazil has the third largest area, 31 thousand hectares (Willer & Kilcher, 2012). Organic production deserves a great research effort, since it has been growing rapidly and accounts for a relatively small area worldwide.

The techniques proposed for organic systems, which allow a reduction in use of environmentally-damaging inputs, can benefit also the conventional agriculture, as an alternative to reduce costs and environmental impact.

Even considering large government incentive programs, technical difficulties in the field restrict the organic production development. The lack of agronomic information on already available cultivars, as well as on cultivars under development by breeding programs for organic systems, is one of the obstacles.

In order to evaluate certain traits, the use of univariate associated with multivariate techniques is advantageous, mainly to address a heterogeneous set of individuals, as it allows to quantify the existing diversity, making possible the identification of distinct genotypes, and to explain the relationship between the parameters analyzed (Souza & Queiroz, 2004). Information on genetic distance between individuals in a population of interest is crucial for a breeding program, as it allows germplasm ranking as well as a more efficient sampling (Nienhuis *et al*., 1993).

Considering (1) agronomic distinction of genotypes is possible when they are cultivated in the same production system and (2) the organic systems lack information, this research aimed to evaluate agronomic traits of 14 tomato genotypes for fresh consumption under organic production, using uni and multivariate techniques.

MATERIAL AND METHODS

Location, installation and conduction of the experiment

The experiment was carried out in Piracicaba, São Paulo State, Brazil (22º49'21"S, 47º45'24"W, 546 m elevation), from March to September, 2010, in Typic Haplufalf soil, on a slightly hilly terrain owned by an organic farmer certified by the Organização Internacional Agropecuária (International Agricultural Organization).

Soil sample was used to determine chemical traits and particle size, presenting results for 0-20 cm: pH ($CaCl_2$ 1.0 mol/L)= 5.1; 9.0 mg/dm^3 P; 1.8 mmol$_c$/dm^3 K; 36 mmol$_c$/dm^3 Ca; 19 mmol$_c$/dm^3 Mg; 22 mmol$_c$/dm^3 H+Al; 2 mmol$_c$/dm^3 Al; sum of bases equivalent to 57 mmol$_c$/dm^3; CEC 79 mmol$_c$/dm^3; 72% base saturation; 3% aluminium saturation; 3 mg/dm^3 S (SO_4); 0.5 mg/dm^3 Cu; 64 mg/dm^3 Fe; 0.9 mg/dm^3 Zn; 17.6 mg/dm^3 Mn; 0.15 mg/dm^3 B; 129 g/kg clay; 11 g/kg silt; 310 g/kg coarse sand (2.0-0.21 mm) and 550 g/kg fine sand (0.210-0.053 mm).

The local climate is Cwa (according to Köppen) characterized as tropical altitude, humid summer and dry winter, the average temperature being, in the hottest month, higher than 22°C.

The experiment was arranged in randomized blocks design, with 14 treatments and six replications. The research was carried out under field conditions with ten plants per plot, five plants being evaluated (useful plants), in 11 harvests. The spacing used was 1.20 m between lines and 0.35 m between plants in a row, forming an experimental plot with 4.20 m^2 total area, totaling 840 plants, 420 being useful plants. Population was 23,809 plants/ha.

From the 14 cultivars studied (IAC 1, IAC 2, IAC 3, IAC 4, IAC 5, IAC 6, Avalon, HTV 0601, Netuno, Débora Victory, Granadero, Pizzadoro, Bari and Santa Clara), six were experimental cultivars from the Instituto Agronômico (IAC) (Campinas Agronomic Institute) breeding program, three of them belonging to the Italian group (IAC 3, IAC 4, IAC 6) and three belonging to the Santa Cruz group (IAC 1, IAC 2 and IAC 5). Eight other cultivars were also used. Four of them of Italian group (Netuno, Granadero, Pizzadoro and Bari) and four of Santa Cruz group (Avalon, HTV 0601, Débora Victory and Santa Clara). With exception of 'IAC 2', 'IAC 4' and 'Santa Clara', which are open-pollinated cultivars, all the other cultivars are hybrids.

Seedlings were grown in polystyrene trays with 128 cells, using substrate containing organic compost and vermiculite, under aphid-proof screenhouse with plastic covering. The organic compost was produced on site with the use of organic poultry house litter and mowing grass (*Brachiaria* sp.). Sowing was carried out in March, 2010. Transplanting to the field was carried out at the four-to-five definite leaf stage.

The experimental field had been cultivated with perennial *Brachiaria decumbens* not grazed for over six years. The tillage consisted of harrowing followed by rotary hoe, taking into account the ideal point of moisture for tillage. Soil correction, planting fertilization and top dressing were carried out according to the soil analysis and the recommendations for tomato crop, applied considering the crop development stage, according to Alvarenga (2004), following the law for organic agriculture.

Planting fertilization consisted of 1.08 t/ha gypsum; 974 kg/ha P_2O_5, through 6.09 t/ha Yoorin Master 1® (16% P_2O_5); 40 kg/ha N, through 40 t/ha organic compost (1% N); 80 kg/ha K_2O through 160 kg/ha potassium sulfate (50% K_2O); 9 kg/ha magnesium, through magnesium sulphate (9% Mg). Then, top dressing application was carried out. The authors used organic poultry house litter with 3% N, Yoorin Master 1® 16% P_2O_5, and potassium sulfate (50% K_2O): at 15 days (18 kg/ha N; 63 kg/ha P_2O_5 and 36 kg/ha K_2O), at 30 days (45 kg/ha N and 45 kg/ha K_2O), at 45 and 60 days (60 kg/ha N and 60 kg/ha K_2O), at 75 days (45 kg/ha N and 90 kg/ha K_2O), at 90 days (57 kg/ha N and 113 kg/ha K_2O), at 105 days (57 kg/ha N and 113 kg/ha K_2O) and at 120 days (57 kg/ha N and 113 kg/ha K_2O). Foliar fertilization with micronutrients was also carried out. The volume applied in each application allowed to cover the leaves without draining. At 10 days after planting (DAP) the following products were applied: 10 L of water, 34 g zinc sulfate heptahydrate (21% Zn, 11% S), 24 g manganous sulfate monohydrate (31% Mn, 18% S), 10 g copper sulfate pentahydrate (25% Cu, 12% S), 10 g of borax decahydrate (11% B) and 5 g sodium molybdate (39% Mo). At 18 DAP: 0.3% solution of the commercial product containing 8% water-soluble copper, chelate (herein called Product A), and 0.3% solution of the commercial product containing 8.1% water-soluble calcium oxide (herein called Product B), in 15 L of water. At 27 DAP: 20 L water, 68 g zinc sulfate, 20 g borax, 10 g sodium molybdate, 60 mL product A and 60 mL product B. At 32 DAP: 60 mL product A, in 20 L water. At 44 DAP: 20 L water, 80 g iron chelate 13%, 50 g zinc sulfate, 20 g borax, 200 g magnesium sulfate, 60 g manganous sulfate, 40 mL product B and 20 g copper sulfate. At 59, 66 and 73 DAP: 40 g iron chelate 13%, 50 g zinc sulfate, 10 g borax, 100 g magnesium sulfate, 60 mL product A and 60 mL product B, in 20 L water. At 85 and at 95 DAP: 20 L water, 50 g zinc sulfate, 60 g borax, 100 g magnesium sulfate, 40 mL product B, 60 mL product A, 20 g manganous sulfate and 20 g potassium sulfate. At 99 DAP: 40 g borax, 40 mL product B and 5 g iron chelate in 20 L water. At 106 DAP: 15 g zinc sulfate, 25 g borax, 50 g magnesium sulfate, 40 mL product B, 40 mL product A, 5 g manganous sulfate, 25 g potassium sulfate and 2 g sodium molybdate in 20 L water. At 111 DAP: 40 g of iron chelate, 50 g zinc sulfate, 20 g borax, 100 g magnesium sulfate, 40 mL product B and 60 mL product A, in 20 L water. At 116 DAP 40 mL product B and 10 g borax in 20 L water.

Trickle irrigation system was used and black plastic film (mulching) was used in the lines in order to prevent weed growth. The irrigation frequencies ranged from one to three times a day, depending on the plant phenological stage and on the weather conditions. The flow was, approximately, 3.2 L/h plant with duration of 15 minutes each irrigation.

The experiment was carried out using individual staking system of the plants with ribbon, in one stem, neither with apical pruning nor with fruit thinning, with average of eight clusters, the plants being distributed in simple rows (0.35x1.2 m). Sprout thinning was carried out at least once a week, during all the crop cycle.

Phytosanitary control was carried out with registered products for the crop, whenever it was necessary, all of them allowed by Brazilian legislation for organic agriculture. Moreover, biological control was used, through inundative release of the parasitoid *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae), every fifteen days, associated with applications of the entomopathogen *Bacillus thuringiensis* in order to control tomato leafminer (*Tuta absoluta*). Despite organic production systems are characterized by low external input use, natural biological control, besides handling some physical factors of the environment may limit the tomato leafminer growth (Medeiros *et al*., 2011). The mites used for biological control were *Phytoseiulus macropilis*, to control spider mite (*Tetranychus urticae*) and *Neoseiulus barkeri*, to control the broad mite (*Polyphagotarsonemus latus*), both released biweekly. The predatory bug *Orius insidiosus* was used to control the thrips *(Frankliniella occidentalis, Caliothrips phaseoli),* released every fifteen days. The tomato fruit borer (*Neoleucinodes elegantalis*) and the earworm moth (*Helicoverpa zea*) were controlled through weekly application of *Bacillus thuringiensis*.

Fruits were harvested at greenish stage considered optimum harvest time, when apical portion of the fruits starts to become reddish (stage known as "unripe").

Agronomic traits evaluated

In order to obtain the production components, the fruits were harvested and weighed at greenish stage ("unripe"), in 11 harvests. The following traits were evaluated: a) total fruit yield (total fruit mass of each plot, with results expressed in t/ha); b) marketable fruit yield {total mass of fruits with transverse diameter higher than 33 mm and no defects (disease and pest symptoms or physiological disorders and, or physical damage), with results expressed in t/ha}; c) non-marketable fruit yield [total mass of fruits with transverse diameter lower than 33 mm and some defects (disease and pest symptoms or physiological disorders and, or physical damage), with results expressed in t/ha]; d) number of marketable fruits per plant (counting the fruits of each plot dividing by the number of plants multiplied by the total of harvests with results expressed per plant).

Univariate data analysis

The agronomic data were subjected to analysis of variance and F-test (5%), considering cultivar effect as fixed and block effect as random. Then, the average values were ranked, according to Scott-Knott 5%. Data were transformed into $\sqrt{x+1}$ aiming to meet the assumptions of the analysis of variance.

Multivariate data analysis

Multivariate analysis was carried out, through grouping and canonical variable techniques, aiming to organize the plants in groups according to their composition standards. For the grouping analyze, Mahalanobis distance was used as dissimilarity measure. The hierarchical groupings were obtained through UPGMA method [Unweighted Pair Group Method with Arithmetic Mean (Sneath & Sokal, 1973)]. The validation of the grouping was determined by the cophenetic correlation coefficient according to Sokal & Rohlf (1962). The significance of the cophenetic correlation coefficient was calculated using Mantel test with 1,000 permutations (Mantel, 1967). To obtain the matrices of genetic dissimilarity, the authors used the computer software Genes (Cruz, 2008). Dendrogram was obtained using the software Statistica 7.1 (Statsoft, 2005). The authors used pseudo t12 method (Mingotti, 2005) to define the number of groups, using the package "NbClust", R statistical computer software (Charrad *et al*., 2011). The authors also calculated the relative contribution of variables according to the criterion of Singh (1981) based on Mahalanobis generalized distance.

RESULTS AND DISCUSSION

A significant effect among the cultivars for total yield ($p<0.05$), total number of marketable fruits per plant ($p\leq0.01$) and marketable yield ($p\leq0.01$) was noticed. The cultivars HTV 0601, Granadero, Netuno, Santa Clara and Bari showed yield higher than the others, with 68.7, 63.6, 57.8, 56.7 and 55.9 t/ha, respectively (Table 1). Of these five cultivars with the highest yield, HTV 0601 and Santa Clara belong to the Santa Cruz group, the others, to Italian group.

The authors verified that cultivar HTV 0601 obtained average yield higher than the Brazilian average, which in 2013 was 66.1 t/ha (IBGE, 2014), even under organic management. These values are within the range of values found by Melo *et al.* (2009), which obtained total yield (TY) ranging from 43.6 t/ha (Colibri F1) to 115.3 t/ha (Sahel) under protected environment in an organic production system. However, whereas the total yield of cultivar Avalon was 62.5 t/ha in the research mentioned, in this present work, the total yield was only 38.8 t/ha. On the other hand, cultivar Santa Clara showed higher total yield, 56.7 t/ha, when compared to Caliman *et al*. (2005), which value found was 30.04 t/ha. Probably this variation of yield, among the cultivars and other studies, was due to the fact that this experiment was carried out in open environment, allowing a greater influence of climate on cultivars, since the amount of nutrients, which are absorbed by the plant, range during the cycle and edaphoclimatic conditions (Papadopoulos, 1991). Moreover, other factors, such as the use of nutrients with lower solubility, also influence in nutrient absorption, in each cultivar.

With respect to the values of marketable yield (MY), two groups were formed by Scott-Knott test, one represented by the cultivars HTV 0601, Granadero, Netuno, Bari and IAC 4 which obtained the highest values: 59.3; 50.2; 49.3; 48.8 and 45.8 t/ha, respectively (Table 1), and the other for the remaining genotypes (ranging from 30.7 to 43.3 t/ha).

In the first group, formed by the most productive cultivars, 'IAC4' is the only open-pollinated cultivar and 'HTV 0601' is the only to represent Santa Cruz group.

The values obtained in this work are close to the ones found by Melo *et al.* (2009), under protected environment and under organic production system, with marketable yield ranging from 23.1 t/ha (Colibri F1) to 77.1 t/ha (Sahel), approximately. The average value in this work exceeded the value obtained by Caliman *et al*. (2005), which was 24.78 t/ha in open environment, for cultivar Santa Clara. However, when the authors compare to results in conventional production systems, the values found in the present study were lower than the ones found by Matos *et al*. (2012), who obtained average marketable yield of 94.5 t/ha.

A reduction of marketable yield is noticed when it is compared to the total yield. The marketable yield of cultivar Santa Clara was 29% lower than the total yield, under protected environment and 18% lower, in open environment (Caliman *et al*., 2005). In this work, the yield of cultivar Santa Clara showed values close to the one found by Caliman *et al*. (2005), the marketable yield being 23% lower when compared to the total yield. The average reduction of total yield to marketable yield obtained corroborates with Machado *et al*. (2007), with 17.3% and 21.3%, for cultivars Heinz 9780 and Kátia, respectively. That fact shows that, even under organic system, the proportion in reduction of total yield to marketable yield remained within the values found in other studies.

In relation to total number of marketable fruits per plant (MF), cultivars HTV 0601, Netuno, Bari, Granadero and IAC 5 showed the highest values: 48.9, 48.7, 44.7, 44.0 and 42.1, respectively. The other cultivars

Table 1. Mean values of total yield (TY), marketable yield (MY), non marketable yield (NM) and number of marketable fruits per plant (MF) of tomato cultivars (valores médios de produtividade total (TY), produtividade comercial (MY), produtividade não-comercializável (NM) e número de frutos comerciais por planta (MF) das cultivares de tomate). Piracicaba, ESALQ, 2010.

Varietal group	Cultivar	TY (t/ha)	MY (t/ha)	NM (t/ha)	MF
Santa Cruz	IAC 1	48.9 b	38.1 b	10.8 a	38.5 b
Santa Cruz	IAC 2	43.5 b	35.0 b	8.5 a	34.5 b
Italiano	IAC 3	46.6 b	33.8 b	12.8 a	34.5 b
Italiano	IAC 4	53.0 b	45.8 a	7.2 a	40.5 b
Santa Cruz	IAC 5	48.0 b	38.2 b	9.8 a	42.1 a
Italiano	IAC 6	40.5 b	30.7 b	9.8 a	35.4 b
Santa Cruz	Avalon	38.8 b	33.6 b	5.2 a	34.8 b
Santa Cruz	HTV 0601	68.7 a	59.3 a	9.4 a	48.9 a
Italiano	Netuno	57.8 a	49.3 a	8.5 a	48.7 a
Italiano	Granadero	63.6 a	50.2 a	13.5 a	44.0 a
Santa Cruz	Debora Victory	49.1 b	38.0 b	11.1 a	37.9 b
Italiano	Pizzadoro	42.4 b	32.4 b	10.0 a	32.3 b
Italiano	Bari	55.9 a	48.8 a	7.2 a	44.7 a
Santa Cruz	Santa Clara	56.7 a	43.3 b	13.4 a	39.5 b
General average		51.0	41.2	9.8	39.7
CV (%)		50.99	55.41	52.53	27.77

Means followed by the same letter in the column belong to the same group by Scott-Knott test ($p>0.05$) [(médias seguidas pelas mesmas letras nas colunas pertencem ao mesmo grupo pelo teste de Scott-Knott ($p>0.05$)].

Table 2. Dissimilarity based on Mahalanobis distance among 14 tomato cultivars (dissimilaridade baseada na distância de Mahalanobis entre 14 cultivares de tomate). Piracicaba, ESALQ, 2010.

Cultivar	IAC 2	IAC 3	IAC 4	IAC 5	IAC 6	Avalon	HTV 0601	Netuno	Granadero	Debora Victory	Pizzadoro	Bari	Santa Clara
IAC 1	1.30	3.21	1.06	2.11	1.90	2.29	3.49	3.33	4.38	0.55	2.14	3.70	0.38
IAC 2		1.94	1.50	4.79	2.03	0.79	6.43	6.26	5.42	0.92	0.52	4.63	1.43
IAC 3			5.36	5.38	1.56	5.16	10.63	8.64	3.23	1.45	0.82	5.47	2.26
IAC 4				3.53	3.77	1.43	1.97	2.84	5.57	1.64	3.50	3.33	1.51
IAC 5					1.75	6.70	4.26	1.15	2.55	1.84	6.07	1.32	2.71
IAC 6						4.26	7.95	4.53	2.67	0.71	2.09	2.40	2.19
Avalon							6.64	7.36	9.31	2.75	2.24	6.49	3.24
HTV 0601								1.71	6.51	4.74	9.38	4.41	3.62
Netuno									3.56	3.43	8.82	1.20	3.83
Granadero										2.35	5.63	1.74	3.12
Debora Victory											1.34	2.35	0.47
Pizzadoro												6.41	1.84
Bari													3.81

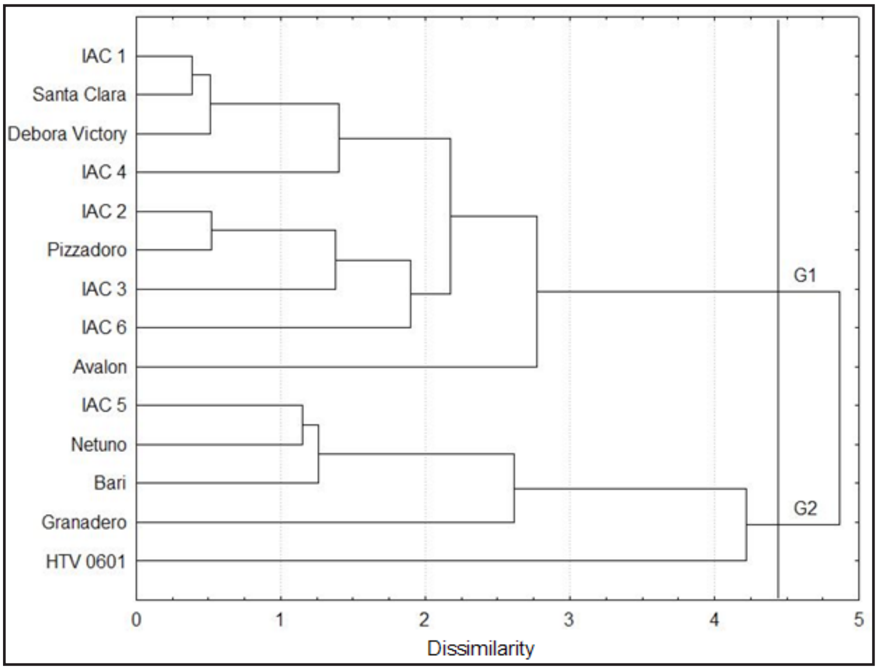

Figure 1. Dissimilarity among 14 tomato cultivars, grouped by UPGMA, based on Mahalanobis distance calculated from four production variables (dissimilaridade entre 14 cultivares de tomate, agrupadas por UPGMA, com base na distância de Mahalanobis calculada a partir de quatro variáveis de produção). Piracicaba, ESALQ, 2010.

ranged from 32.3 to 40.5 marketable fruits per plant (Table 1).

Melo *et al.* (2009) obtained values for MF ranging from 13 (Colibri F1) to 30.7 (San Vito); the cultivar Avalon reached 17.2, when evaluating tomato cultivars under protected environment and in an organic production system of marketable fruits per plant. In this work, the cultivar Avalon reached 34,8 MF.

Using individual staking system with ribbon, in one stem, Matos *et al.* (2012) obtained average number of 29.9, 26.9, 29.6, 31.1 and 33.9 of marketable fruits per plant, for cultivars Alambra, Paron, Forty, Débora Pto and Ellus, respectively.

No significant difference was noticed ($p>0.05$) among the cultivars for non-marketable yield (NY). Santa Cruz varietal group showed NY ranging from 5.2 (Avalon) to 13.4 t/ha (Santa Clara). The cultivars of Italian group ranged from 7.2 (IAC 4 and Bari) to 13.5 t/ha (Granadero). Shirahige *et al.* (2010) found average values for yield of non-marketable fruits ranging from 11.2 to 37.3 t/ha in plants which have not suffered thinning of the fruits, however, in a protected environment.

In this work, data of marketable and total yield were lower than the ones obtained in studies carried out under conventional system, mostly under protected environment. The authors highlight that cultivation was carried out in open environment, it means, under weather conditions which could make the plant more susceptible to pests and diseases, and, probably, with higher rates of fruit loss (non-marketable fruits). However, the study verifies that the yield of non-marketable fruits was 50% of the yield obtained by Shirahige *et al.* (2010), in plants which did not have fruit thinning, as in this work. Thus, the proportion of half yield was kept, both marketable and non-marketable fruits.

When the univariate analysis, for variables related to yield, is considered,

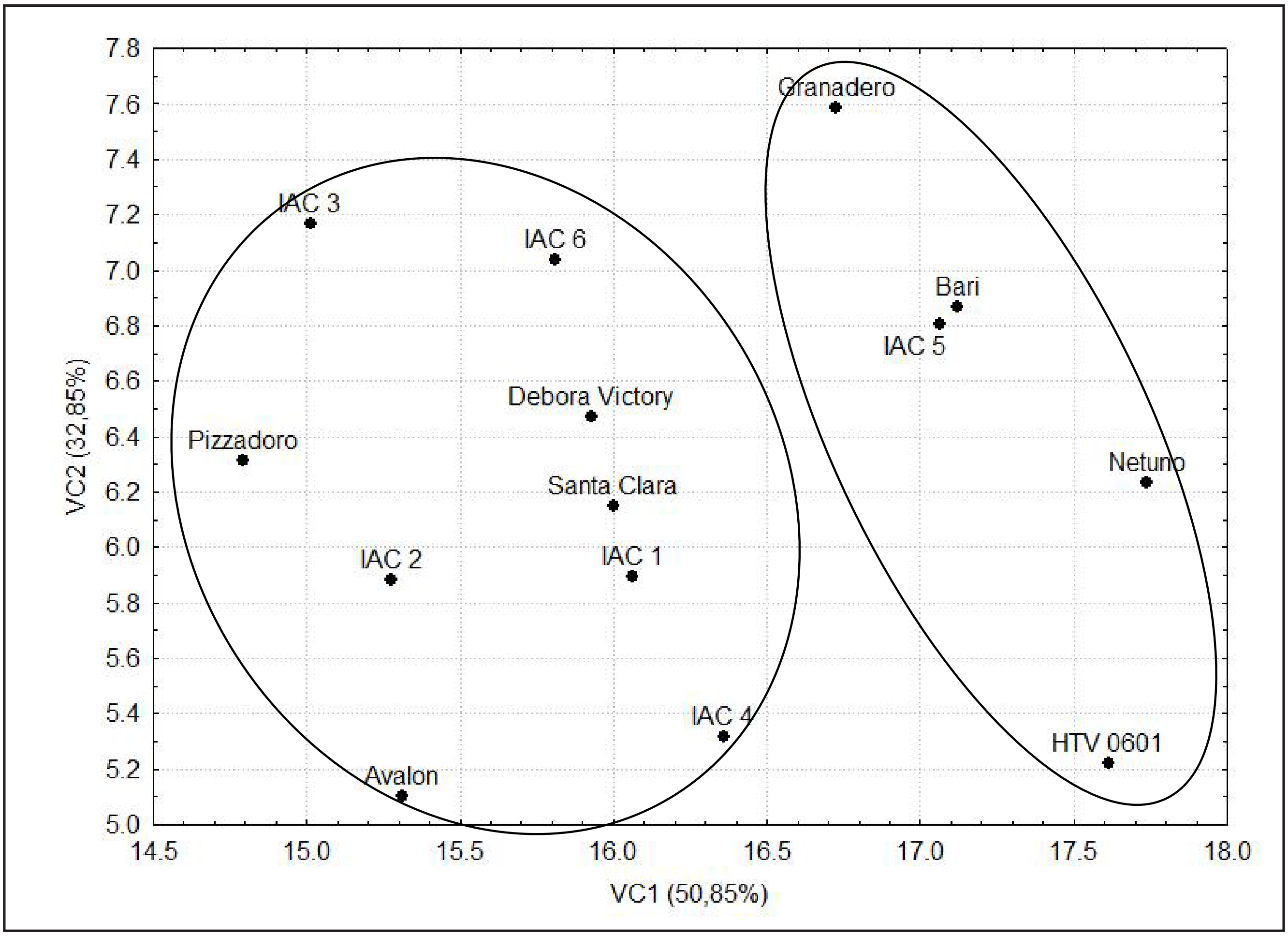

Figure 2. Cultivar score according to the first and the second canonical variables obtained through the evaluation of four variables in 14 tomato cultivars (escores das cultivares em relação às duas primeiras variáveis canônicas obtidas a partir da avaliação de quatro variáveis em 14 cultivares de tomate). Piracicaba, ESALQ, 2010.

the authors observed that the 14 cultivars showed statistical differences for evaluated variables. Nevertheless, the visualization of cultivar groups is still hard.

So, the use of multivariate procedures for yield variables allows a more explicit visualization of genetic dissimilarity of cultivars and helps the crosses in breeding programs.

Genetic divergence analysis can be carried out through predictive methods. Predictive methods are based on phenotypic differences showed by the individuals, which can be quantified in terms of dissimilarity measures, as Mahalanobis distance (Souza & Queiroz, 2004).

To identify the grouping of cultivars, based on the four yield traits evaluated, the authors obtained the dissimilarity matrix on Mahalanobis distance (Table 2) and a dissimilarity dendrogram was generated (Figure 1) through the UPGMA method. Mahalanobis distance matrix is considered the most robust distance measure available for quantitative data analysis, this being mentioned in several works as genetic distance, when applied to experimental data (Dias, 2006).

According to the results obtained through calculation of Mahalanobis distance (Table 2), the authors observed that cultivars IAC 1 and Santa Clara showed the smallest distance (0.38). They were the most similar when compared to all the others. On the other hand, cultivars HTV 0601 and IAC 3 showed the greatest distance (10.63). They were, therefore, the most dissimilar pair, when compared to the other ones.

The cophenetic correlation coefficient between Mahalanobis distance matrices and the grouping matrix was 0.65** indicating reliability to use this information based on the dendrogram (Figures 1, 2 and Table 2).

In the resulting dendrogram of quantitative data, the authors observed the formation of two groups by cutting the average dissimilarity among the accessions studied. The first group was formed by nine cultivars (IAC 1, Santa Clara, Debora Victory, IAC 4, IAC 2, Pizzadoro, IAC 3, IAC 6 and Avalon), and the second was formed by cultivars IAC 5, Netuno, Bari, Granadero and HTV 0601. The lowest dissimilarity was observed for cultivars IAC 1 and Santa Clara (0.38) which were in the same group, whereas cultivars HTV 0601 and IAC 3 showed the highest dissimilarity (10.63), which justifies their allocation into different groups

(Figure 1 and 2; Table 2). In the second group, except cultivar IAC 5, all the others showed higher values for total yield, number of marketable fruits and marketable yield (Table 1). This fact strengthens the importance of this group for a breeding program, aiming to obtain derived cultivars.

The use of canonical variable methodology aims to identify similar genotypes through graph tools, helping interpret results (Negreiros *et al*., 2008). The authors expect that most of the variance is accumulated in the first two canonical variables (Cruz *et al*., 2004).

The result of the analysis based on the canonical variables (VC) shows that two VC explain 83.7% of the total variance, VC1 being responsible for 50.85% and VC2 for 32.85% (Figure 2). Agreement between UPGMA grouping analysis and canonical variables is noticed when the distribution of genotypes in each group is observed. The five cultivars of Group 2 of the UPGMA grouping are placed at the right side of the graph. Number of marketable fruits per plant was the trait with the most relative importance for genetic divergence, with 67.30% according to Singh (1981), followed by marketable yield, non-marketable yield and total yield traits, with 14.47; 12.93 and 5.30%, respectively.

The cultivars Netuno, Granadero and Bari, of Italian group and cultivar HTV 0601, of Santa Cruz group present the highest values of total yield, number of marketable fruits and marketable yield, under organic production system, in open environment.

According to the results observed, the authors concluded that the use of univariate and multivariate techniques were in agreement. They allowed the visualization of genetic variability among the 14 tomato cultivars.

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