



Agronomic performance and physicochemical quality of tomato fruits under organic production system

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ABSTRACT

Tomatoes are a highlight in the organic vegetables production, but in order to cultivate them, there is a lack of information on cultivars adapted to the organic system. The objective of this study was to evaluate the productive performance and to characterize the quality attributed to tomato fruits under the organic production system. The experiment was conducted in field, on an agroecological farm, in the municipality of Verê, Paraná State - Brazil. The experiment consisted on fourteen tomato cultivars, under a randomized complete block design, with four replications. The evaluated traits were the total and commercial fruit production, total and commercial number of fruits, mass and average diameter of commercial fruits and physicochemical quality traits (firmness, pH, color (L*, C and h°), soluble solids (SS), titratable acidity (TA), and the ratio of SS/TA). Considering together production traits and fruit quality aspects, the cultivars Netuno, Aguamiel, and Cordilheira can be considered the best choices, having potential to be recommended for organic production system.

Keywords: *Solanum lycopersicum*; organic agriculture; productivity; post-harvest.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is consumed, mainly, in its natural form and appreciated for its nutritional composition, being a source of carotenoids (lycopene, α , and β carotene), phenolic compounds (phenolic acids and flavonoids), vitamins (ascorbic acid and vitamin A) and glycoalkaloids (tomatine) (Chaudhary *et al.*, 2018; Fernandes *et al.*, 2020). Hence, there is a necessity to offer high quality fruits, free of pesticide residues, and in sufficient quantities to meet consumer demand. Thus, sustainable food production systems, such as organic agriculture, have been strengthening worldwide, with an increase in the area for production and the quality of the produced food, especially focusing on fruits and vegetables, conquering the consumer market, which seeks for healthier products (Smith-Spangler *et al.*, 2012; Eisinger-Watzl *et al.*, 2015; Mie *et al.*, 2017).

Conventional tomato cultivation is often based on the excessive use of soluble chemical fertilizers and pesticides, leading to fruit contamination, offering health risks to

farmers and consumers, in addition to causing environmental imbalance, with the elimination of natural enemies and loss of biodiversity (Pignati *et al.*, 2017; Thakur, 2017; Ishaq *et al.*, 2020). In this context, there is an increasing expansion of organic cultivation, where the production costs can be reduced to the conventional system; in addition, presenting a greater profitability (Souza & Garcia, 2013; Adamtey *et al.*, 2016).

However, there are some obstacles to the organic tomato production, such as the difficulty in controlling tomato phytosanitary problems, being susceptible to pathogens and insects, vulnerable to nutrient deficiency. Furthermore, there is a lack of technical information on tomato cultivars that perform well in organic cultivation systems and in different producing regions (Melo *et al.*, 2009).

Several tomato cultivars are available to meet the demand for tomato production, but these cultivars were not developed for organic agriculture. These cultivars were developed for conventional agriculture with high input of chemical fertilizers and high use of pesticides. There is a lack of information about genotypes which are more

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adapted according to the climatic conditions of each region and the form of cultivation (Sediyama *et al.*, 2014). Information on forms of cultivation and capacity of the genotype to adapt the different locations is of paramount importance. When the requirements of different genotypes are not met, it can result in yield losses and reduced fruit quality. Thus, the production of organic tomatoes is linked to the choice of cultivars associated with adequate cultural management resulting in plants with health, productivity and able to supply high quality fruits to the consumer market (Souza & Resende, 2014).

When cultivars are released for conventional agriculture, their set of traits is already defined. Later, when evaluated and recommended for organic cultivation, the cultivar is simply adapted to this type of cultivation. Otherwise, a very different set of traits is aimed for cultivars developed specifically for organic farming. The attributes required for a good tomato cultivar for the organic production system consist of three main aspects: sensory, phytosanitary, and morphological. In the sensory aspect, breeders look for cultivars with contrasting textures, colors, sizes, acidity, °Brix; that is, which differ from what is usually offered by cultivars from the conventional agriculture. In addition, cultivars with a greater genotype \times environment interaction are interesting, in order to take advantage of the unique characteristics conferred by the *terroir* where they are grown. In the phytosanitary aspect, cultivars with genetic resistance to diseases and pests are essential, since the use of pesticides is prohibited. Considering the morphological aspect, plants with a determined growth habit, open architecture and able to tolerate intercropping are the most appropriate for organic farming.

In this context, the objective was to evaluate the productive performance and to characterize the quality attributes of tomato fruits under organic production system.

MATERIALS AND METHODS

The experiment was conducted in the field on an agroecological farm, located in the municipality of Verê, Paraná State - Brazil, during the months of August 2015 in January 2016. This property has been under an organic production system for approximately 15 years, 14 years of them certified by the Ecovida Agroecology Network, through the Participatory Guarantee System. The property receives technical advice from CAPA - Center for Support and Promotion of Agroecology, which was a partner in the development of this study. These farmers are associated with a cooperative (COOPERVEREDA) specialized in the production and processing of organic products. Verê is located at an average altitude of 485 m, and coordinated 25°52' S and 52°54' O. The climate of the region, according to Köppen's classification (Alvares *et*

al., 2013), is Cfa (humid subtropical), with summer temperature above 22 °C and in winter, below 18 °C, with a precipitation index of 1,800 mm year⁻¹.

The experimental area was under fallow for three years, the plant material was mowed and furrowed following a minimal soil preparation, adding 3.15 t ha⁻¹ of Calfort calcite limestone to adjust soil pH.

The chemical analysis of the soil, carried out before the installation of the experiment, presented the following contents: organic matter OM = 44.23 g dm⁻³; P = 10.28 mg dm⁻³; K = 136.85 mg dm⁻³; pH (CaCl₂) = 5.00; H + Al = 6.69 cmol_c dm⁻³; Ca = 3.70 cmol_c dm⁻³; Mg = 1.40 cmol_c dm⁻³; cation exchange capacity = 12.14 cmol_c dm⁻³; rate of base saturation = 44.89%. The fertilization was carried out based on the results of the soil analysis and the requirement of the tomato crop (Alvarenga, 2004). A total of 11 t ha⁻¹ of an organic fertilizer was applied, with the following chemical composition: 2.22% of N, 2.29% K and 1.39% P. During seedling transplant, a fertilization of 116 g plant⁻¹ of Master thermophosphate (allowed for organic production) was used.

Fourteen tomato cultivars developed for conventional agriculture (Afamia, Aguamiel, Alambra, Araucaria, Batalha, BRS Kiara, BRS Nagai, BRS Portinari, Cordilheira, Fusion, Minotauro, Monalisa, Netuno, and Paron) were evaluated under organic farming conditions. Important characteristics of each cultivar were described in Table 1. The choice of cultivars occurred as follows: some cultivars were already cultivated by the farmers (Paron, Alambra, and Batalha), and the others were collectively introduced in the study, contemplating the suggestions of researchers, technicians of the organization and the interests of the farmers. The experimental design consisted of a randomized complete block design with four replications. The experimental unit consisted by ten plants. The useful part for evaluation purposes were the five plants located in the central part.

The seedlings were produced in 128 cells trays, using substrate from organic compost. Transplanting was performed 30 days after sowing, when plants had from three to four definitive leaves, adopting spacing of 0.60 m between plants and 1.2 m between lines.

The plants were conducted with two stems, and the staking was performed in an upright position by using a twine. Apical pruning was performed at 70 days after transplantation (DAT), when most cultivars were at a height between 1.80 and 2.00 m. The side dressing fertilization was carried out at 40, 55, 70, and 85 DAT, using 144 g plant⁻¹ by applying the same organic fertilizer used for transplanting. Furthermore, a foliar fertilization with *supermagro biofertilizer* (3%) was applied biweekly. Due to the high rainfall index during the experiment, it was not necessary to use irrigation (Figure 1).

The crop management adopted in the experiment such as: sprouting, apical pruning, weeding and phytosanitary control were carried out following the management allowed for certificate organic farming. For the control of tomato leafminer (*Tuta absoluta*), eggs from *Trichogramma* spp were released. The small tomato borer (*Neoleucinodes elegantalis*) and the tomato fruit borer (*Helicoverpa zea*) were controlled by the application of Dipel (*Bacillus thuringiensis* var. kurstaki). The control of late blight of tomato

(*Phytophthora infestans*) was carried out using the Bordeaux mixture (0.5%).

The fruits were harvested at the ideal maturation point, recognized by the visualization of the fruits when they started to become reddish. During the crop cycle, seven harvests were performed (01, 11, 17, 26, and 30 December 2015, and 06 and 14 January 2016), evaluating the following traits: total fruit production (TFP, in g plant⁻¹), commercial fruit production (CFP, in g plant⁻¹), total fruit quantity (TFQ, in fruits plant⁻¹), commercial fruit quantity

Table 1: Characteristics of fourteen tomato cultivars released for conventional agriculture tested for adaptation to the organic production system

Cultivars	Group	Resistance ¹
Afania	Slicer tomatoes	ToMV; V; F1, F2, F3; TSWV; TYLCV; N;
Aguamiel	Roma tomatoes	F1, F2, F3; ToMV; S; TSWV; V; TYLCV;
Alambra	Slicer tomatoes	TMV; V; F1, F2; C1-5; N
Araucária	Slicer tomatoes	V; F2; N; TMV; TY
Batalha	Slicer tomatoes	TMV; V; F1, F2, F3; C 1-5; N
BRS Kiara	Santa Cruz	V1; F1, F2; TMV; C2; N;
BRS Nagai	Saladette	V1; F1, F2; TMV; TSWV; TY; N;
BRS Portinari	Slicer tomatoes	V1; F1, F2; C2; TMV; TY; N;
Cordilheira	Saladette	TMV; F2; V; N; TSWV; TYLCV
Fusion	Slicer tomatoes	F1, F2, F3; ToMV; V; C5
Minotauro	Slicer tomatoes	F1, F2, F3; TSWV; A; S; N
Monalisa	Slicer tomatoes	V1; F1, F2; ToMV
Netuno	Roma tomatoes	V; F1, F2; TMV; N
Paron	Slicer tomatoes	F1, F2; V1; TMV; C1-5; TSWV

¹ ToMV= Tomato mosaic virus; TMV= Tobacco mosaic virus; TYLCV= Tomato Yellow Leaf Curl Virus; TSWV= tomato spotted wilt virus; TY= Germivirus; V= Verticillium dahliae; V1= Verticillium dahliae, race 1; N=Nematodes; F1= Fusarium oxysporum f.sp. melonis, race 0; F2= Fusarium oxysporum f.sp. lycopersici, race 1; F3= Fusarium oxysporum f.sp. lycopersici, race 2; A= Alternaria solani; S= Stenfilium; C1-5 = Cladosporium fulvum race 1 and race 5; C2= Cladosporium fulvum race 2; C5= Cladosporium fulvum race 5.

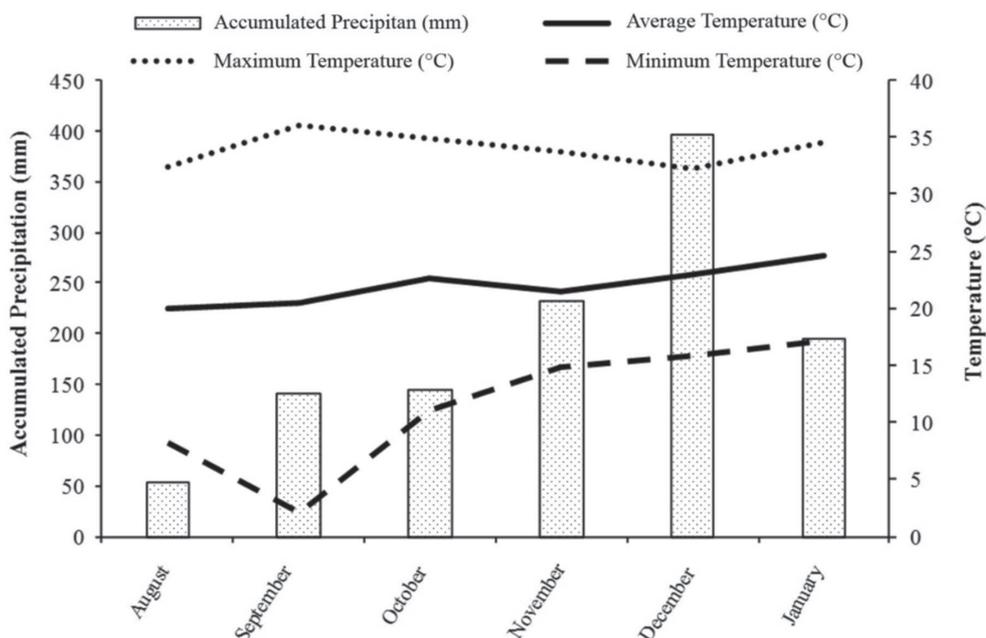


Figure 1: Accumulated precipitation (mm), maximum, minimum and average temperature (°C) during the months of August 2015 to January 2016 in the municipality of Verê, Paraná State – Brazil. Source: GEBIOMET, 2016.

(CFQ, in fruits plant⁻¹), average commercial fruit mass (CFM, in g), obtained as CFP/ CFQ. The average fruit diameter (AFD, in mm) was measured with a digital pachymeter.

The qualitative analysis of the fruits was performed removing the ripe fruits positioned in the third cluster of each plant. The analysis was performed according to the methodology proposed by the Adolfo Lutz Institute (2008), being evaluated: soluble solids (SS) content, titratable acidity (TA) and pH were determined from juice prepared in a centrifuge. The content of SS was measured using a digital refractometer and the results expressed in Brix°. The TA was determined by titrating 10 mL of tomato juice with 0.1 N NaOH to pH 8.2. The TA was expressed as a percentage, assuming citric acid as the predominant acid in tomato juice. The results determined the relationship between SS and TA (SS/TA). The color was determined with a digital colorimeter, using the configuration of luminosity (L*) and Hue angle (h°), with three readings at different points in the equatorial region of each fruit. The fruit firmness (FF) was analyzed with a bench penetrometer using a 2 mm diameter tip. The measurement was performed with the absence of epidermis, at three equatorial points of each fruit. Statistical analyses were performed using analysis of variance (ANOVA) and grouping of means by the Scott-Knott test at the 5% probability level, using the Assistat software (Silva & Azevedo, 2016).

RESULTS AND DISCUSSION

In Brazil, there are no tomato cultivars developed for organic agriculture. To change this scenario, two possibilities can be considered: the first is the evaluation of cultivars developed for conventional agriculture, which are able to adapt to the cultivation conditions of organic agriculture. The second is the development of cultivars specifically for organic agriculture; it requires the identification of germplasm sources and the entire breeding process a time span of about 10 years. This study falls under the first option. Thus, throughout the text, the differences between the first and second option are discussed considering sensory, phytosanitary, morphological and market aspects. The market aspect is not directly related with the cultivar itself, but essential for cultivar adoption by the farmers.

Regarding the evaluated production components, the cultivars Aguamiel, Alambra, Batalha, BRS Nagai, Fusion, and Netuno presented the best performance for CFP (Table 2). Otherwise, Monalisa and BRS Portinari presented the worst performance for TFP. Compared with the literature, Melo *et al.* (2009) and Matos *et al.* (2012) obtained higher values for CFP and TFP for some cultivars here evaluated. The lower production values could be a consequence of the unfavorable climatic conditions to tomato cultivation

in the target region due to the high precipitation index. In December/2015 there was an accumulation of 400 mm, influencing the smaller amount of CFP. Furthermore, the occurrence of high daily temperatures, above 32 °C, resulting in sterile pollen and floral abscission resulted in reduced production (Gusmão *et al.*, 2006; Zhou *et al.*, 2016; Santiago & Sharkey, 2019).

The cultivars Netuno, Aguamiel, and Cordilheira presented higher average values of TFQ and CFQ. In the experiment, these cultivars presented a longer production cycle, influencing the amount of fruit produced. In other studies, tomato cultivars of the Roma group showed good performance for TFQ, the cultivar Netuno showed 76.0 fruits plant⁻¹ (Shirahige *et al.*, 2010). However, it is important to note that in organic agriculture, the productivity can be less important compared to some attributes, like as the organoleptic properties, color, shape among many others, which make the product unique or special. In other words, the consumer values the consumption experience. In this way, consumers of organic products are willing to pay more for products with certain qualities, which pays off the lower productivity.

In relation to CFM, the highest value was observed in the cultivar Batalha, with 164.57 g fruit⁻¹, different from the other cultivars also presenting a greater AFD, together with the cultivars Araucária and Fusion. The cultivars belonging to the Slicer group have morphological characteristics of plurilocular fruits and, therefore, of greater caliber, resulting in higher values of CFM and AFD compared to cultivars from the Roma group (Alvarenga, 2004).

The pH ranged from 4.62 to 4.92, with the cultivars Cordilheira and Aguamiel showing highest values, differing significantly from the others (Table 3). The Netuno cultivar had a pH of 4.72, in other studies under organic management, a lower value of 4.2 was found (Araujo *et al.*, 2014). A great range for pH in tomatoes is from 3.7 to 4.5 (Silva & Giordano, 2000). For industrial purposes, the pH below 4.5 prevents the proliferation of microorganisms. However, tomatoes with a less acidic pH are preferred by the consumers (Borguini & Silva, 2005).

The adequate relationship of SS/TA contributes to the formation of the flavor of the tomato fruit, with high values indicating mild flavor due to the combination of sugar and acid, while low values are correlated with acid flavor (Beckles, 2012). Here, the cultivars Cordilheira, Afamia, Aguamiel, BRS Kiara, BRS Portinari, Minotauro, Netuno, and Paron showed the highest SS/TA ratio. According to Kader (2013), the optimal SS/TA ratio for tomato consumption is above 10; thus, all cultivars studied showed higher values for the SS/TA ratio. The cultivars of the present study showed satisfactory results for the physicochemical quality given the climatic conditions, high rainfall and high temperatures. This is due to the ecological

management of the area, where the plants would be able to develop and extract the necessary nutrients, because the soil is biologically, physically and chemically balanced, providing the plants with the necessary nutrients for growth and production, optimizing agricultural yield under adverse conditions (Kamiyama *et al.*, 2011).

The cultivar BRS Kiara (85.39 °h) and BRS Portinari (77.82 °h) presented the highest values for °h (Table 3). The °h parameter shows the average color of the fruits, the higher the color angle (°h) obtained, the closer to yellow; and the lower, the color approaches red (Borguini

& Silva, 2005). These cultivars presented a color pulling more towards the yellow, being a characteristic of these cultivars.

For the variable L*, which represents the fruit luminosity, the lowest value was found in the cultivar Cordilheira, not differing from the cultivars Aguamiel, Alambra, Batalha, Minotauro, Monalisa, and Paron (Table 3). These cultivars have a lower degree of brightness, due to the ripening of the fruits, and the luminosity is lower in ripe fruits, a consequence of the loss of brightness of the fruits due to the synthesis of carotenoids (Camelo & Gómez, 2004).

Table 2: Total fruit production (TFP), commercial fruit production (CFP), total fruit quantity (TFQ), commercial fruit quantity (CFQ), commercial fruit average mass (CFM) and average fruit diameter (ADF) for fourteen tomato cultivars under organic production

Cultivars	TFP	CFP	TFQ	CFQ	CFM	ADF
	(g plant ⁻¹)	(g plant ⁻¹)	(fruits plant ⁻¹)	(fruits plant ⁻¹)	(g fruit ⁻¹)	(mm)
Afamia	3342.6 a*	1740.8 b	27.9 d	13.8 b	128.45 b	39.71 b
Aguamiel	3997.5 a	2123.6 a	45.5 a	22.0 a	96.89 d	38.54 b
Alambra	3806.1 a	2069.5 a	29.9 d	14.6 b	139.20 b	38.13 b
Araucária	3563.1 a	1775.3 b	32.8 c	12.8 b	137.42 b	44.15 a
Batalha	3437.0 a	1936.4 a	26.6 d	11.8 b	164.57 a	46.15 a
BRS Kiara	3444.9 a	1283.5 b	33.9 c	11.3 b	113.48 c	34.85 c
BRS Nagai	3636.3 a	1840.9 a	28.6 d	13.3 b	143.35 b	39.42 b
BRS Portinari	2915.9 b	1598.8 b	28.1 d	13.1 b	120.63 c	31.66 c
Cordilheira	3300.1 a	1621.0 b	45.0 a	18.2 a	87.03 d	29.99 c
Fusion	3581.9 a	2100.1 a	31.7 c	15.6 b	132.97 b	42.78 a
Minotauro	4223.7 a	1497.3 b	36.5 b	10.8 b	140.36 b	38.52 b
Monalisa	2456.6 b	1470.4 b	24.8 d	13.6 b	107.52 c	38.19 b
Netuno	3815.1 a	2209.6 a	42.6 a	22.1 a	101.13 d	32.31 c
Paron	3368.1 a	1524.6 b	28.3 d	10.4 b	145.39 b	36.86 b
CV (%)	11.9	17.8	10.6	19.3	11.04	10.51

* Means followed by the same letter, in the column, belong to the same group by the Scott-Knott test at 5% probability level.

Table 3: Mean values of pH, soluble solids (SS), titratable acidity (TA), SS/TA ratio, luminosity (L*), Hue angle (h°), and fruit firmness (FF) of fourteen tomato cultivars under organic farming

Cultivars	pH	SS (°Brix)	TA (%)	SS/TA	L*	Hue (°h)	FF (N)
Afamia	4.76 b*	4.23 a	0.27 b	16.49 a	42.49 a	70.57 b	2.03 b
Aguamiel	4.88 a	3.74 b	0.22 b	17.20 a	40.13 b	67.25 b	1.57 b
Alambra	4.78 b	3.64 b	0.30 a	12.11 b	39.30 b	66.18 b	1.38 b
Araucária	4.70 b	3.54 b	0.34 a	10.48 b	42.20 a	71.27 b	3.03 a
Batalha	4.68 b	3.89 b	0.32 a	12.21 b	39.34 b	65.81 b	1.49 b
BRS Kiara	4.73 b	3.92 b	0.27 b	14.49 a	44.68 a	85.39 a	3.43 a
BRS Nagai	4.72 b	3.87 b	0.36 a	10.96 b	41.28 a	69.38 b	2.14 b
BRS Portinari	4.74 b	4.53 a	0.31 a	14.46 a	41.07 a	77.82 a	2.06 b
Cordilheira	4.92 a	4.03 b	0.24 b	18.58 a	37.30 b	56.21 b	1.76 b
Fusion	4.62 b	3.43 b	0.33 a	10.61 b	42.79 a	69.06 b	2.78 a
Minotauro	4.79 b	4.42 a	0.25 b	18.05 a	39.59 b	66.33 b	1.78 b
Monalisa	4.69 b	3.88 b	0.37 a	10.75 b	40.36 b	59.57 b	1.24 b
Netuno	4.72 b	4.34 a	0.31 a	14.08 a	42.29 a	76.37 a	1.48 b
Paron	4.69 b	4.44 a	0.31 a	16.71 a	40.07 b	66.52 b	1.69 b
CV (%)	1.68	7.86	17.33	25.12	5.16	12.83	38.04

*Means followed by the same letter, in the column, belong to the same group by the Scott-Knott test at 5% probability level.

All traits evaluated in Tables 3 and 4, followed the conventional agriculture pattern. When we consider these traits from the organic agriculture perspective, the requested values are quite different from those presented here. It indicated that no useful genetic variability is present in these materials, in an organic agriculture point of view. Thus, it is necessary to appeal to germplasm banks, which include wild relatives, old cultivars, and landraces, to obtain genotypes with the desired composition for organic production system (Vela-Hinojosa *et al.*, 2019; Roohanitaziani *et al.*, 2020; Londoño-Giraldo *et al.*, 2021).

The FF is one of the most important attributes of the quality of tomato fruits for fresh consumption, as well as for industrial cultivation, being related to the post-harvest conservation (Bertin & Génard, 2018), which interferes with transport and commercialization. The cultivars BRS Kiara, Araucária and Fusion presented higher values, 3.43, 3.03, and 2.78 N, respectively. Similar results were found by (Melo *et al.*, 2009), for the cultivars Avalon (3.0), Sahel (3.0) and Jane (2.5), analyzed on the organic system. However, in organic cultivation, fruits with low FF can be interesting if their textural and culinary quality is considered. The shorter shelf life can be a positive differential in local businesses practiced by the Participatory Guarantee System.

It is important to highlight, although not evaluated in this study, the importance of the phytosanitary issues for organic cultivation. Thus, it is essential to remember that the use of pesticides is not allowed. Obtaining cultivars with genetic resistance is always preferable because for many pests and diseases there are no products allowed for use in organic agriculture. In addition, when products are allowed, they are often less efficient or inefficient at all. The control of a pest or disease that is very simple in conventional agriculture can become a major problem in organic agriculture, threatening the entire production.

As for the morphological aspects, organic crops are, in general, made in diversified systems, often intercropped, being cultivars with a determined growth habit easier to intercrop. Greater spacing between plants and rows, in addition to plants with open architecture are preferable for phytosanitary reasons. In addition, as the target markets for organic products are small, and often niche markets, it is important for organic producers to have cultivars with different growing cycles, to ensure diversified production for a longer time during the year.

CONCLUSION

The cultivars Netuno, Aguamiel, and Cordilheira have potential to be cultivated under organic farming conditions.

These cultivars can increase the number of cultivars used by organic farmers or even replace the cultivars Paron, Alambra, and Batalha which were previously cultivated, since they perform better.

All previous cultivars are from the Slicer group, whereas the cultivars that stood out in the present study belong to other groups: Netuno and Aguamiel are Roma tomatoes; and Cordilheira belongs to Saladette group.

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