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Article

Agronomic Performance and Nutraceutical Quality of a Tomato Germplasm Line Selected under Organic Production System

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Abstract: Organic tomato production is increasing worldwide, thus making necessary the development of varieties adapted to this farming system. It is now well known that the implementation of local tomato plant breeding programs for organic farming is required to increase the performance of varieties in this typology of cultivation regime. In this research, the agronomic performance, nutraceutical contents, and radical scavenging activity of a tomato germplasm line (OSTGL), selected under organically grown conditions, were evaluated for two consecutive years (2018 and 2019) in comparison with the variety 'Rio Grande', frequently grown organically in Tunisia. Carotenoids, phenolics, vitamin C, and radical scavenging capacity were assayed spectrophotometrically, while tocopherols were analyzed by HPLC. All data were not affected by year-to-year variability. The OSTGL line showed significantly higher marketable yield, total phenol, flavonoid, vitamin C, α-tocopherol and γ-tocopherol contents, along with radical scavenging activity. The OSTGL red-ripe berries also showed comparable values for average weight, soluble solids, pH, titratable acidity, firmness and coloration, as well as lycopene and β-carotene contents. This open pollinated tomato germplasm line demonstrated to be an effective sustainable variety for improving fruit yield, agronomic, and nutraceutical characteristics under an organic management system.

Keywords: antioxidants; organic agriculture; radical scavenging activity; *Solanum lycopersicum*; germplasm; vitamin E

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1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the major vegetable crops grown and consumed in the world, with total production exceeding 189 million tons on a cultivated area of more than 5 million ha in 2021 [1]. Tunisia is a major producer, having about 24,540 hectares planted with tomatoes, and a production of 1,416,000 tons per year [1]. Organic agriculture occupies a leading position in the world, and Tunisia is no exception, because of policies supporting the sector accordingly to international and national strategies. Although organic fruit tree crops attained important acreage (251,569 ha for olive and 14,118 ha for all others), the area under organic vegetable cultivation in Tunisia remains low and irregular with 211 ha in 2019 [2], mainly engaged in the production of tomato, pepper, peas, garlic, parsley, artichoke, and potato crops.

Organic tomatoes are popular and largely consumed worldwide. In Tunisia, they are in rising demand. Indeed, consumers are increasingly concerned about the quality of foods and their entire production chain [3]. Additionally, the dietary consumption of tomatoes has been associated with several health benefits and reduction of several diseases, due to the presence of numerous antioxidant and bio-functional compounds [4,5]. However, available scientific data on these compounds in organic cultivation remains generally insufficient in many countries.

Variety of choice is an important criterion to be successful in organic tomato farming. In fact, the genetic factors associated to each variety may affect key parameters, including yield, resistance to diseases [6], fruit size and quality [7]. In fact, generally, yields in organic farming are lower compared to conventional ones [8–10]. In addition to higher biotic and abiotic pressure and nutrient limitation, the reductions in yields may be due to the use of varieties not selected in organic conditions. Then, it is increasingly accepted that it is best to select cultivars under organic growing conditions. To increase the performance of cultivars in organic farming, the establishment of local plant breeding programs specific to this type of agricultural management is essential [11]. The implementation of these strategies has yielded interesting results on wheat [12], as well as on tomato, particularly in the Netherlands, Italy, Germany, and Spain, where organic breeding programs have been running for years [13–16]. However, in African countries, such plant breeding programs are still at early stages of research.

Although the great interest in organic agriculture, the 'Rio Grande' is the only open pollinated variety currently used organically in Tunisia. This limits the varietal choice for farmers interested in this key crop. In addition, despite its good adaptation for a long time to the conditions of Tunisian culture, the 'Rio Grande' variety is not selected under organic growing conditions. The aim of this study was to determine whether the use of a new tomato germplasm line (OSTGL), selected under an organic regime, offers advantages over the common 'Rio Grande' variety. Agronomical, physicochemical, nutraceutical contents and radical scavenging activity were determined for two consecutive years.

2. Materials and Methods

2.1. Site Description

Tomato experiments were carried out in open field from April to July of two consecutive years (2018 and 2019) in a certified organic research station farm located in Northern Tunisia (36°48′28′′ N 10°6′4′′ E), defined by the typical Mediterranean climate. Weather data, including minimum and maximum average monthly air temperature, relative humidity, and precipitation, recorded during tomato growing for both years are presented in Table 1. During the two years, almost the same seasonal pattern was observed for all climatic data. The total means monthly rainfall recorded for the same season were 137 and 126 mm for the years 2018 and 2019, respectively.

Table 1. Weather data recorded for the two tomato growing years in 2018 and 2019.

Month	Tmin (°C)		Tmax (°C)		Humidity (%)		Rainfall (mm)	
	2018	2019	2018	2019	2018	2019	2018	2019
April	15	14	22	20	78	79	50	45
May	18	17	24	23	73	70	78	51
June	23	24	29	31	68	62	07	26
July	28	27	34	34	61	60	02	04

The texture of soil was a clay loam with 29%, 18%, and 32% for clay, loam, and sand, respectively. The soil electrical conductivity was 0.13 mS/cm and with the appropriate pH (7) for tomato. The soil contains 0.16% total nitrogen, 1.85% organic matter, 728 mg/kg magnesium, 869 mg/kg potassium, 45 mg/kg phosphorus, and 68 mg/kg calcium.

2.2. Plant Material

The promising field tomato germplasm line with fixed genetic factor (open pollinated), called OSTGL, was used in this experiment. The OSTGL germplasm line was selected by single seed descendant from several accessions preserved at the horticultural laboratory of the National Agricultural Research Institute of Tunisia to control phenotypic variation and to enhance organic seed availability. It was part of the research program, with the aim of obtaining high performance varieties adapted to organic farming. The screening and selection were realized mainly based on organic farming adaptation and performance. It was selected by the seventh generation, where the lines are assumed to be homozygous, stable, and suitable for field evaluation. The experiments have been implemented since the beginning of research work on the evaluation of the performance of open field organically grown tomato varieties in 2007 [17], and we report in this manuscript only the data from two years of investigations. The open pollinated 'Rio Grande', previously introduced by Petoseed (Saticoy, CA, USA) and actually, the only one distributed as organic seeds by the interprofessional grouping for vegetables (GIL) was employed as a control. The used seeds come from organic farming.

2.3. Experimental Design

The plot used for the experiment, which has been managed organically since 2004, was supervised by the certified organization ECOCERT. The cultivation technical procedures utilized are in accordance with the national and European organic standards. An organic fertilization consisting of 20 tons/ha of certified cattle manure from non-intensive farming was used. When necessary, certified bio pesticides and manual weed removal were applied as directed by the Technical Center of Organic Agriculture, Tunisia, and as described by Riahi et al. [18]. Irrigation was provided by drip for 1 to 2.5 h with a flow rate of 4 L per hour. It was carried out at one to two day intervals based on evapotranspiration potential and crop coefficient, using meteorological data from the research station.

Sowing was realized around mid-March 2018 and 2019, and seedlings were transplanted into the experimental field in late April in twin rows, with a spacing of 40 cm within rows and 150 cm between double rows, corresponding to a density of approximately 3 plants per m^2. A randomized complete block experimental design with four replications was conducted, involving 30 plants of each variety,.

2.4. Sample of Fruit

Tomato fruits were randomly hand-picked at the end of July for both 2018 and 2019. Approximately 2 kg of red–ripe tomatoes were sampled for each variety and block and immediately transported to the laboratory in appropriate conditions to avoid fruit damage. Part of each sample was quikly processed for physicochemical analysis, while the other part was temporarily stored at −20 °C and used, in less than a week, to measure the contents of carotenoids, phenolics, vitamins, and radical scavenging activity.

2.5. Agronomical and Physicochemical Measurements

Marketable yield and average fruit weight were extrapolated from the data collected each plant. A drop of the filtered fruit juice was placed on a digital refractometer (Atago PR-100, NSG Precision Cells, Inc., Farmingdale, NY, USA) to determine the total soluble solids (TSS), expressed in (°Brix). The pH value was measured by the mean of an electronic pH meter (WTW PH 539, Weilheim, Germany). Titratable acidity was assayed by titration with 0.1 M sodium hydroxide up to pH 8.1, and indicated as citric acid (%). For firmness, expressed in kg/cm^2, we used an electronic penetrometer (Penefel, Penefelélectronique, Setop-Giraud Technologies, Cavaillon, France). The color components CIELAB system a* (redness) and b* (yellowness) measurements were determined on the tomato skin fruit using a Minolta Chroma meter (CR-400, Konica Minolta, Inc:, Chiyoda, Tokyo, Japan). After that, the ratio a*/b* was considered.

2.6. Lycopene and β-Carotene Determinations

Antioxidants as lycopene and β-carotene from organic tomato fruits were extracted and analyzed spectrophotometrically, following to the method previously and fully described by Ilahy et al. [19]. The method uses a mixture of hexane/ethanol/acetone (2/1/1 by vol.) containing 0.05% butylated hydroxytoluene (BHT). For lycopene and β-carotene quantification, the absorbance of the hexane extract was read at 503 and 450 nm, respectively, using a Cecil BioQuest CE 2501 spectrophotometer (Cecil Instruments Ltd., Cambridge, UK). Lycopene content was determined using lycopene molar extinction e = 17.2×10^4 M^{-1} cm^{-1}. Values were indicated as milligram per kg of tomato fresh weight (mg/kg fw).

2.7. Total Phenols and Flavonoid Determinations

The determination of the total phenols content was realized according to the Folin–Ciocalteu colorimetric method as modified by Singleton et al. [20] and Eberhardt et al. [21]. In brief, 2 g of a duplicate tomato juice sample was extracted with 10 mL of methanol for 24 h. This extract (125 µL) was diluted 1/5 (*v*/*v*) with distilled water, then a Folin–Ciocalteu reagent (125 µL) was added and the mixture was allowed to stand for 3 min. Then, 1.25 mL of 70 g/L sodium carbonate solution was added for a final volume of 3 mL with distilled water. After standing for 90 min at room temperature, each sample was measured at 760 nm against a blank in a Cecil BioQuest CE 2501 spectrophotometer (Cecil Instruments Ltd., Cambridge, UK). The assay used standard curve from 0 to 300 µg gallic acid/mL, and the content was quantified as a milligram of gallic acid, equivalent to per kg of tomato fresh weight (mg GAE/kg fw).

The flavonoid content was determined as described by Zhishen et al. [22] on aliquots of the juice sample of 0.3 g. A methanolic extract of 50 microliter aliquots was used for flavonoids determination. After diluting the samples with distilled water to a final volume of 0.5 mL, 30 µL of 5% $NaNO_2$ was added. After 5 min, 60 µL of 10% $AlCl_3$ was added, then 200 µL of 1 M NaOH was added after 6 min. The absorbance was read at 510 nm in a Cecil BioQuest CE 2501 spectrophotometer (Cecil Instruments Ltd., Cambridge, UK) and results were quantified as milligrams of rutin, equivalent to per kg of fresh weight (mg RE/kg fw).

2.8. Vitamin C Determinations

Vitamin C was assessed as ascorbic acid according to the method detailed by Kampfenkel et al. [23]. In brief, 0.1 g of a duplicate tomato juice sample was extracted using 6% metaphosphoric acid and analyzed at 525 nm using a Cecil BioQuest CE 2501 spectrophotometer (Cecil Instruments Ltd., Cambridge, UK). The assay used a standard curve from 0 to 700 mmol AsA, and the content was quantified as milligram per kg of fresh weight (mg/kg fw).

2.9. Vitamin E Determinations

The extraction of vitamin E or tocopherols in tomato fruits was done on double samples with n-hexane following the method of Daood et al. [24]. The tocopherol isomers α, β, and γ contents were analyzed by the mean of a HPLC with fluorescence detection (Hitachi Chromaster, Tokyo, Japan). This system is composed of a model 5110 gradient pump, a model 5210 autosampler, and a 5440 fluorescence detector. The Nucleosil 5 mm (250 × 4.6 mm i.d.) column was used for separation with a mobile phase (99.5:0.5 n-hexane: ethanol). The excitation and emission wavelengths were detected at 295 nm and 320 nm, respectively, as mentioned by Duah et al. [25]. The isomers of α-, β-, γ-tocopherols were determined by means of external standards (Sigma-Aldrich, Budapest, Hungary) co-chromatographed with the samples. Results were indicated in milligrams of vitamin E per kg of fresh weight (mg/kg fw).

2.10. Radical Scavenging Activity Measurements

The hydrophilic (HRSA) and the lipophilic radical scavenging activities (LRSA) were analyzed according to the ABTS discoloration method detailed by Miller and Rice-Evans [26]. A sample of 0.3 g of the fruit homogenate was extracted with 50% methanol for the hydrophilic radical scavenging activity fraction, and 50% acetone for the lipophilic radical scavenging activity fraction. The extraction was accomplished for 12 h with a constant stirring of 300 rpm. A sample was centrifuged at 10,000× *g* for 7 min and the supernatant was retrieved in advance of its use for antioxidant capacity measurement. Absorbance was determined with a Cecil BioQuest CE 2501 spectrophotometer (Cecil Instruments Ltd., Cambridge, UK) set at 734 nm. Double different calibration curves were obtained using freshly prepared Trolox solutions for the hydrophilic and lipophilic fractions. A linear calibration curve was dressed with a Trolox solution (0–16 µM Trolox) and values were expressed in µM of Trolox/100 g fw. The sum of HRSA and LRSA constitutes the total radical scavenging activity (TRSA).

2.11. Statistical Analysis

The variations in all agronomical and nutraceutical values were compared by ANOVA using the package's SAS Version 9.2 software (SAS Institute, Cary, NC, USA). The least significant difference (LSD) test at the 0.05 significance level was used for mean separation. The agronomical, nutraceutical, and radical scavenging capacity data did not significantly differ between either growing seasons or its interactions with the variety, and hence, the mean value of the 2018 and 2019 years were considered.

3. Results

3.1. Agronomical and Physicochemical Characteristics

The most important agronomical and physicochemical characteristics of the new tomato germplasm line OSTGL and the control variety 'Rio Grande' cultivated under organic conditions of the assay are summarized in Table 2. The agronomical and physicochemical properties were not significantly different either between growing seasons or its interactions with the variety, and hence, the mean values of the 2018 and 2019 years were considered.

Table 2. Yield and physicochemical parameters of the different tomato varieties grown organically.

Characteristics	Varieties	
	OSTGL	**Rio Grande**
Marketable yield (t/ha)	73.2 ± 3.9^{a}	66.1 ± 4.1^{b}
Average fruit weight (g)	77.1 ± 4.1^{a}	72.3 ± 3.9^{a}
Soluble solids (°Brix)	5.3 ± 0.3^{a}	5.2 ± 0.3^{a}
pH	4.41 ± 0.03^{a}	4.39 ± 0.03^{a}
Titratable acidity (% citric acid)	0.34 ± 0.01^{a}	0.36 ± 0.01^{a}
Firmness (kg/cm^2)	4.30 ± 0.31^{a}	4.10 ± 0.21^{a}
Color		
(a*)	25.7 ± 1.0^{a}	26.2 ± 0.9^{a}
(b*)	27.3 ± 1.1^{a}	28.1 ± 0.8^{a}
(a*/b*)	0.94 ± 0.03^{a}	0.93 ± 0.03^{a}
Year (Y)	ns	ns
Variety (V)	**	**
Y × V	ns	ns

Data are means ± SE based on four replicates. Different letters indicate a significant difference at $p < 0.05$ using the LSD test. According to ANOVA, ns indicates non-significance ($p \geq 0.05$), and ** indicates significance at $p < 0.01$, for different sources of variation. a*: the index of redness; b*: the index of yellowness.

Marketable yields registered for the OSTGL and 'Rio Grande' varieties were 73.2 and 66.1 t/ha, respectively, with significant statistical differences. Compared to 'Rio Grande', the OSTGL had around 11% higher marketable yields. In regards to the mean fruit weight, soluble solids, pH, titratable acidity, firmness, and color differences were revealed to be not significant between the studied varieties. Results of average fruit fresh weight showed values ranging from 72.3 to 77.1 g, soluble solids from 5.2 to 5.3 °Brix, pH from 4.39 to 4.41, titratable acidity from 0.34 to 0.36%, and firmness from 4.10 to 4.30 kg/cm^2. Both varieties showed similar fruits coloration. The index of redness a* and yellowness b* registered for the two varieties OSTGL and 'Rio Grande' were 25.7, 26.2 and 27.3, 28.1, respectively.

For the ratio a*/b*, values were 0.94 and 0.93 for the OSTGL and 'Rio Grande' varieties, respectively. Acceptable and comparable fruit physicochemical properties were found in the diverse tomato varieties studied.

3.2. Nutraceutical Properties

Data in Table 3 showed the lycopene, β-carotene, total phenol, flavonoid, vitamin C, and vitamin E contents in the new tomato germplasm line OSTGL and the control variety 'Rio Grande' grown organically. The nutraceutical properties were not significantly different either between growing seasons or its interactions with the variety, and hence, the mean values of the 2018 and 2019 years were considered.

Table 3. Lycopene, carotenoids, total phenols, flavonoids, vitamin C, and vitamin E contents in the different tomato varieties grown organically.

Characteristics	Varieties	
	OSTGL	Rio Grande
Lycopene (mg/kg fw)	82.5 ± 4.2 [a]	79.3 ± 5.1 [a]
β-Carotene (mg/kg fw)	5.2 ± 0.4 [a]	4.9 ± 0.3 [a]
Total phenols (mg GAE/kg fw)	168.5 ± 6.3 [a]	149.8 ± 7.1 [b]
Flavonoids (mg RE/kg fw)	118.7 ± 6.2 [a]	105.8 ± 5.5 [b]
Vitamin C (mg/kg fw)	168.9 ± 7.2 [a]	153.8 ± 6.8 [b]
Vitamin E (mg/kg fw)		
α-tocopherol	21.03 ± 0.63 [a]	18.03 ± 0.54 [b]
β-tocopherol	0	0
γ-tocopherol	0.28 ± 0.01	0
Year (Y)	ns	ns
Variety (V)	**	**
Y × V	ns	ns

Data are means ± SE based on four replicates. Different letters indicate a significant difference at $p < 0.05$ using the LSD test. According to ANOVA, ns indicates non-significance ($p \geq 0.05$), and ** indicates significance at $p < 0.01$, for different sources of variation.

Lycopene and β-carotene content did not vary significantly between the analyzed varieties. In the new OSTGL tomato germplasm line and the "Rio Grande" variety, lycopene values were 82.5 and 79.3 mg/kg fw, while β-carotene values were 5.2 and 4.9 mg/kg fw, respectively. The amounts of total phenols and flavonoids were both about 12% higher in the OSTGL line (168.5 mg GAE/kg fw; 118.7 mg RE/kg fw) than in "Rio Grande" (149.8 mg GAE/kg fw; 105.8 mg RE/kg fw).

Vitamin C and vitamin E contents showed a significant variation between the two investigated tomato varieties. The new tomato germplasm line OSTGL showed higher vitamin C and vitamin E contents compared to the 'Rio Grande' variety. Vitamin C content was 168.9 and 153.8 mg/kg fw, and α-tocopherol was 21.03 and 18.03 mg/kg fw in OSTGL and 'Rio Grande' varieties, respectively. The OSTGL had about 10% and 17% higher vitamin C and α-tocopherol contents, respectively. The β-tocopherol content was below the limit of quantification in tomato fruit of the two studied varieties. The γ-tocopherol was registered only in the new tomato germplasm line OSTGL with the value of 0.28 mg/kg fw.

3.3. Radical Scavenging Activity

The LRSA, HRSA and TRSA of the new tomato germplasm line OSTGL and control variety 'Rio Grande', are summarized in Figure 1. The radical scavenging activity was not significantly different either between growing seasons or its interactions with the variety, and hence, the mean value of the 2018 and 2019 years were considered. LRSA, HRSA and TRSA showed a significant difference between the two studied tomato varieties. LRSA was 131.8 and 119.4 μM Trolox/100 g fw, and HRSA was 108.8 and 90.8 μM Trolox/100 g fw in the new tomato germplasm line OSTGL and 'Rio Grande', respectively. TRSA was higher in the new tomato germplasm line OSTGL than in 'Rio Grande' variety (240.6 and 210.2 µM Trolox/100 g fw, respectively). Compared to Rio Grande, the OSTGL had around 14% higher TRSA.

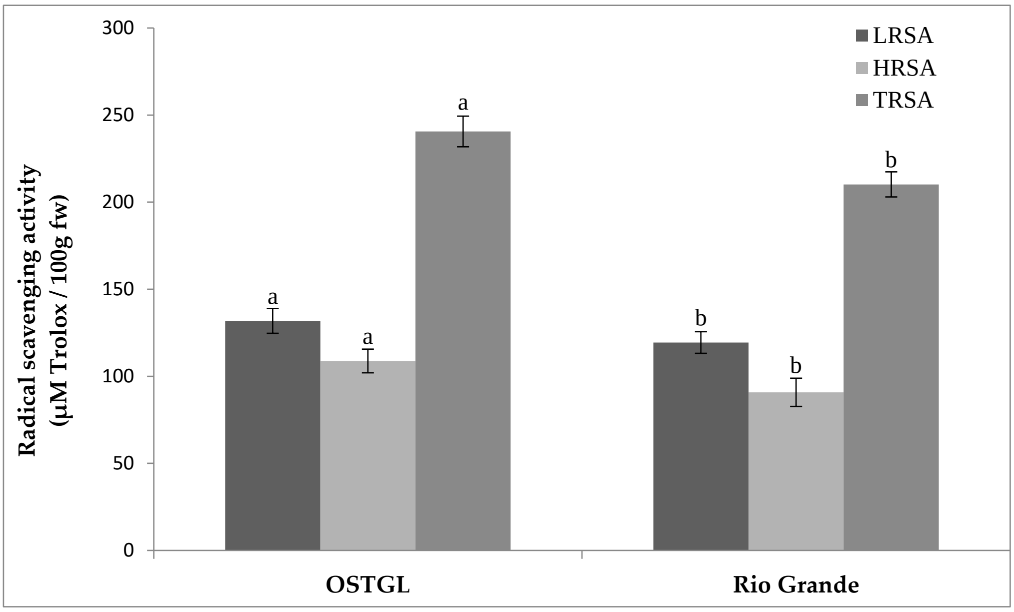

Figure 1. Lipophilic (LRSA), hydrophilic (HRSA), and total (TRSA) radical scavenging activities of the different tomato varieties grown organically. Data are mean ± S.E. of four replicates. Different letters indicate a significant difference with the LSD test ($p < 0.05$).

4. Discussion

The yields recorded in the two years of organic cultivation proved to be significantly lower than those of high-performing varieties under conventional farming regime. However, they were higher than the average of 57.70 t/ha recorded in 2021 for tomatoes grown in Tunisia [1]. Giordano et al. [27] reported comparable yields, ranging from 51.63 t/ha in 'Nemadoro' to 70.59 t/ha in 'BRS Tospodoro', for tomatoes grown under organic farming. Nevertheless, our data were considerably higher than those obtained by Sidhu and Nandwani [28], who have reported yields ranging from 25.65 to 27.25 t/ha in 'Roma' and 'Arbason F1', respectively. Lahoz et al. [29] reported that the production of organically grown tomatoes was 36% lower on average compared to conventional integrated pest management. The results were also in accord with those of Ficiciyan et al. [30], who have recently demonstrated that a group of tomato varieties coming from conservation and breeding programs under organic farming methods has a performance equivalent to or even superior to the group of conventional varieties specifically, in mixed cropping systems.

Mean fruit fresh weight was acceptable and comparable to those found in a previous study on organic field-grown tomatoes [18]. As an important quality factor, soluble solids are a good index of sweetness, as glucose and fructose were the major components of tomato fruit pulp [31]. The results for the soluble solids content in the current study are comparable with the results obtained for eight genotypes grown organically in Romania, varying from 4.10 to 5.60 °Brix [32]. In another study, De Sio et al. [33] found higher values with 5.8 to 6.1 °Brix in tomatoes grown under organic management. Our pH values are comparable with those acquired by researchers from the southwest of Spain, who found that pH values ranged from 4.33 to 4.51 in 5 traditional tomato varieties grown organically in open air [34]. Nevertheless, these values were lower than those obtained by Mazon et al. [7], who related pH values of between 4.62 and 4.92 for organically grown tomatoes. Titratable acidity is principally related to citric and malic acids, which attained approximately 15% of the dry matter in fresh mature tomato fruit [35]. The titratable acidity values of 14 tomato cultivars grown in Brazil under an organic production system [7] were in the range of 0.22 to 0.37 % results that were in accordance with the average data found in our current study. However, Dobrin et al. [36] found slightly higher values compared to the current research, ranging from 0.41 to 0.45% in 2 fresh organic tomato varieties. Firmness values were acceptable and comparable to those obtained in a previous study on tomatoes grown under an organic field system [18]. Tomato fruit firmness permitted resistance to over-maturity in the field and prevented physical damage in fruit shipping. In regard to the color fruit skin readings, the two varieties exhibited an equivalent fruit coloration, as they exhibited comparable color indexes. Ayuso-Yuste et al. [34] studied traditional varieties grown in an organic field system and found a*/b* values ranging from 0.97 to 1.72 in tomato fruit skin, which agreed with our current study.

The data also showed that lycopene and β-carotene values were equivalent in the two tomato varieties under study. Murariu et al. [32] mentioned similar average lycopene content (8.16 mg/100 g fw) in different tomato genotypes grown under organic field conditions. Lycopene concentration was also close to that formerly published for field-grown organic tomatoes of 78.4 mg/kg fw [37]. Similarly, Perkins-Veazie et al. [38] determined lycopene content in tomatoes grown organically. They found that tomatoes contained considerable lycopene contents when matured to firm red or light red stages, and that lycopene content varied between cultivars and ranged from 50 to 106 mg/kg fw. Nevertheless, values were higher than that obtained by Fracchiolla et al. [39] for organic tomatoes with 47.2 µg/g fw. Current β-carotene values were higher than those reported by Lahoz et al. [29] (1.42 mg/kg fw) and by Fracchiolla et al. [39] (0.6 µg/g fw) in tomato cultivars grown under an organic field production system.

Total phenols, as well flavonoids, of the tomato new germplasm line fruits variety were higher than the common 'Rio Grande' fruits. The values for total phenols obtained were within the range of formerly mentioned data ranging from 0.154 to 0.162 mg GAE/g fw [37]. However, higher total phenols values, between 21.5 and 21.6 mg GAE /100 mg fw, were obtained by Rodríguez Ortiz et al. [40]. Our results also agreed with those found by Martí et al. [41], who showed that variety affected total phenols in organic tomatoes and revealed that the employment of adequate cultivars can offer increased levels of polyphenols. Concerning flavonoids, the values obtained were close to those previously reported, from 0.109 to 0.113 mg RE/g fw [37].

Vitamin C, present in tomato fruit, has been related to several health benefits [42]. The vitamin C values in the new tomato germplasm line OSTGL fruits were higher than that in the common 'Rio Grande' variety. The vitamin C values obtained in this study were within the range of values recorded for organic tomatoes by Martí et al. [41], who evaluated L-ascorbic acid values in tomato fruit as being affected by organic farming and genotypes, and demonstrated that it was only affected by genotype. They found values varying from 107.54 to 136.37 mg/kg fw. However, the studied tomato varieties showed lower vitamin C content than those reported by Abou Chehade et al. [43], who found concentrations between 20.9 and 32.8 mg/100 g fw in organic processing tomatoes cultivated in open field.

Generally, when grown organically, although tomato fruit growth is reduced, tomatoes are reported to be a good source of diverse antioxidant molecules, such as phenolics, flavonoid, and vitamin C [44–46]. This is the result of the stressing conditions related to organic farming systems.

Tomato is an important source of vitamin E. It is a naturally occurring micronutrient, necessary for the regular metabolism of organisms. Structural analysis showed that vitamin E can occur in four tocopherols (α-, β-, γ- and δ) and four tocotrienols (α-, β-, γ- and δ). This essential micronutrient can be supplied through the diet and not by the human body. The vitamin E requirements recommended by the European Food Safety Authority were 13 and 11 mg/day for men and women, respectively. Data on vitamin E in organic tomatoes are limited. Comparable values for α-tocopherol, between 14.3 and 26.8 µg/g fw, in tomatoes grown under organic management were found by Fracchiolla et al. [39]. The results were in the range of those found recently by Romdhane et al. [47], who noted α-tocopherol values that varied from 17.0 to 27.7 mg/kg fw in organically grown Nemador and high lycopene tomato varieties, respectively. The γ-tocopherol content was only detected in the new tomato germplasm line OSTGL, with 0.28 mg/kg fw. Fracchiolla et al. [39] found higher values for γ-tocopherol, ranging from 3.1 to 4.1 µg/g fw. The tomato germplasm line had a significantly higher α-tocopherol and γ-tocopherol than 'Rio Grande', indicating that it could support stress better under an organic management system. High levels of tocopherols were identified as a sign of stress tolerance [48].

The radical scavenging activity was assessed by the TEAC assay, one of the most recommended methods for measuring both HRSA and LRSA of fruits and vegetables [49]. The results obtained for the two fractions, lipophilic and hydrophilic, and consequently for their sum (TRSA) were higher in ripe fruits of the new tomato germplasm line OSTGL than those of the 'Rio Grande' variety. The data were similar to those formerly found in organic tomatoes grown in Tunisia, with 123.8, 81.5, and 205.3 µM Trolox/100 g fw for LRSA, HRSA and TRSA, respectively [37]. The results of the current research were higher than those recently reported for the activities of LRSA, HRSA, and TRSA in the organically grown Nemador variety, with 107.7, 74.8, and 182.5 µM Trolox/100 g fw, respectively [47]. This is probably due to genotypic differences. An increased level of antioxidant activities was certainly due to the higher contents of hydrophilic (polyphenols and vitamins) antioxidants. A slightly higher antioxidant activity, between 273 and 296 µM Trolox/100 g fw, was determined by Rodríguez Ortiz et al. [40] according to the ABTS method.

Although the year-to-year of weather data were minor and with no or little effect on the agronomical and physicochemical properties of the varieties under study, further studies on the OSTGL line x environment interactions over several years with different climatic conditions are needed to consider its stability.

5. Conclusions

The results show that a proper selection of varieties under organic conditions induces relatively higher values of several traits: yield (11%), total phenols (12%), flavonoids (12%), vitamin C (10%), α-tocopherol contents (17%), as well as radical scavenging capacity (14%). However, longer-term, large-scale field trials are needed to consolidate them and allow commercial application of the newly selected line. In addition, the OSTGL line is a local open pollinated genetic resource that is well adapted to the country's organic growing conditions, and can be recommended, after several years of testing under many different environmental (years, locations) conditions, to diversify the choices of Tunisian farmers who want to produce organic tomatoes as an alternative to "Rio Grande", which until now was the only variety available in Tunisia as an organic seed. The OSTGL line could also be economically attractive for private, professional, small-breeding companies, or self seeded for small organic farmers.

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