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Original Research Paper

Productivity and quality of different tomato cultivars under intercropping system with maize and dry farming conditions in Southern Italy

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Abstract: This research, carried out in a typical Mediterranean environment of Southern Italy, reports some quantitative and qualitative traits of three local tomato cultivars ('Arsicolo', 'Crovarese', and 'San Marzano') plus a commercial one ('Datterino') cultivated without irrigation and intercropped with maize. For each cultivar, in addition to the determination of fruit production, tomato paste and "conserva" paste were prepared using a traditional technique of the Tanagro Valley (province of Salerno, Southern Italy). Results highlighted that 'Arsicolo' showed the best fruit yield (32.2 metric tons ha^{-1}) and tomato paste production (92.9% paste return by tomato fruits weight) due to its ancient peculiar adaptability to cultivation in dry conditions, while 'Datterino', 'Crovarese', and 'San Marzano' had 19, 16.7, 10.5 tons ha^{-1} of fruit yield and 85.7, 83.9, 76.2% of tomato paste return, respectively. Conversely, for the qualitative traits, such as total solids, soluble solids, titratable acidity, and ascorbic acid, 'Crovarese' showed the best results (9.1%, 6.6 °Brix, 0.93%, and 39.7 mg per 100 g of fresh weight, respectively). The two components extracted by the principal components analysis (PCA) explained 84.9% of the total variance in the morphological, quantitative and qualitative traits and the dendrogram obtained by hierarchical cluster analysis allowed to divide the cultivars into three groups. Our findings highlighted that local tomato cultivars, intercropped with maize, can be cultivated adopting only few sustainable field operations and with no irrigation.

Keywords: *Solanum lycopersicum* L; tomato paste; vitamin C; optical residuals; no irrigation; biodiversity.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is mainly cultivated in China, India, United States of America, Turkey, Egypt, Iran, Italy and Spain, and its global production is estimated at 189 million tons $year^{-1}$ on 5.16 million ha (FAO, 2021). In particular, in Italy the area currently devoted to tomato is of 102060 ha with a production of 6644790 tons (FAO, 2021). The Campania region, located in Southern Italy, is an important and traditional area for tomato production, characterized by different landraces such as 'Pomodorino del Piennolo del Vesuvio' and 'Pomodoro San Marzano dell'Agro Sarnese-Nocerino', widely studied and used mainly fresh and for the processing industry (Carillo et al., 2019; Caruso et al., 2019; Sacco et al., 2020; Fratianni et al., 2020; Tripodi et al., 2022). Tomato is a key-component in Mediterranean diet and one of the symbols of Italian gastronomy (Frusciante et al., 2007). An increasing interest in tomato fruit due to the its antitumoral and antioxidant effects has been observed. The compounds responsible of these beneficial properties are the carotenoids, particularly lycopene and β-carotene, vitamins C and E, phenol compounds, mainly flavonoids, fiber, potassium and phosphorus (Khapte et al., 2019).

Although tomato is largely cultivated, a decrease of yield and fruit quality has been observed due to soil acidification and salinization caused by continuous monoculture of tomato and the excessive application of fertilizers and pesticides (Liu et al., 2014). For these reasons, many researchers evaluated the possibility to cultivate tomato together with other species highlighting the positive effects of intercropping with potato, onion (Wu et al., 2016), bean (Abd El Gaid et al., 2014), garlic (Nassef and Abd El-Gaid, 2012), maize, and cowpea on the growth and yield of tomato (Olowolaju and Okunlola, 2017). Moreover, the tomato fruit quality traits, such as titratable acidity, vitamin C and dry matter contents, were reported to be positively affected by the intercropping system (Liu et al., 2014).

The intercropping contributes to (a) reduce air temperature, light and wind intensity, (b) promote the biological diversity, (c) decrease the spread of plant diseases and pests *(Tuta absoluta* Meyrick, *Alternaria solani* Sorauer), (d) improve the water and nutrients use, (d) help soil conservation, and (e) improve the quantity and the quality of products (Gomez-Rodriguez et al., 2003; Caviglia et al., 2011; Ijoyah, 2012; Liu et al., 2014; Zarei et al., 2019).

In addition, in order to optimize the use of natural water resources, dry farming, also called dryland farming, is adopted as an alternative sustainable agriculture strategy. It is a set of agricultural techniques aimed to the production without irrigation in areas with less than 500 mm of annual precipitation that exploits the moisture stored in the soil from the rainy season (Peterson, 2018).

The mechanisms associated with water-stress tolerance of plants as stomatal activity, such as reactive oxygen species (ROS) scavenging and metabolic changes and photosynthesis, have been widely studied (Osakabe et al., 2014). To maximize crop yield and improve water use, it is important the selection of tolerant genotypes (Gupta et al., 2008). The response of tomato to water stress conditions has been studied by several authors (Candido et al., 2000a, 2000b; Favati et al., 2009; Cantore et al., 2016; Lovelli et al., 2017). Even though deficit irrigation decreases fruit weight and marketable yield, this strategy may results in positive effects on fruit quality traits, such as soluble solids, dry matter, lycopene and β-carotene concentration, and fruit color (Favati et al., 2009; Lovelli et al., 2017). Drought stress and competition with other crops affect plant physiological, morphological and biochemical traits in plants, and tolerance mechanisms to cope with these stresses vary depending on the plant species (Salehi-Lisar, 2016; Khapthe et al., 2019).

Although Campania region is a source of many tomato local landraces, characterized by specific adaption capacities to the local microclimatic conditions and closely associated with the uses, knowledge, habits, dialects and traditions of farmers, still little information is available in the literature on productive and qualitative performances. In a recent study, we highlighted that local genotypes, such as 'Crovarese' and 'Arsicolo', had the best antioxidant and radical scavenging activity, thanks to the abundance of bioactive compounds with well-known antioxidant potential (Faraone et al., 2021). The rediscovery of ancient local landraces represents a fundamental strategy for preserving biodiversity and promoting new germplasm for meeting the needs of sustainable agriculture. The aim of this study was to evaluate the behavior of 'San Marzano, 'Arsicolo', 'Datterino', and 'Crovarese' when cultivated intercropped with maize (*Zea mays* L.) under dry farming conditions typical of the Mediterranean environment of Southern Italy. The intercropping system and dry farming techniques are very useful for high crop water demand, such as tomato which is cultivated mainly in dry areas like those of the Mediterranean basin (Patanè et al., 2011).

2. Materials and Methods

2.1. Agronomic trial

The open-field trial was carried out in Buccino (Salerno province, 40° 38' N; 15° 23' E, 663 m a.s.l.) on four cultivars of tomato (*Solanum lycopersicum* L.): three local cultivars, namely 'San Marzano', 'Arsicolo', and 'Crovarese'; and the commercial cv. 'Datterino Quorum F_1' (hereafter 'Datterino') (Table 1). Seeds of tomato cv. 'Crovarese' and 'San Marzano' were purchased from a private seed company (La Semiorto Sementi, Sarno, Salerno, Italy); seeds of the local cv. 'Arsicolo' were harvested and stored by a local farmer in the same year of the trial; whereas seeds of the commercial cv. 'Datterino' were obtained from another private seed company (ISI Sementi, Fidenza, Parma, Italy). Tomatoes were cultivated on a clay soil (sand: 29.44%; silt: 30.24%; clay: 40.32%) with pH 7.46, EC of 186 µS cm^{-1}, organic carbon (Walkley – Black method) of 7.32 g kg^{-1}; organic matter content of 12.63 g kg^{-1}, total lime of 13.38 g kg^{-1}, active lime of 13.75 g kg^{-1}, and bulk density of 1.26 g kg^{-3}.

The experimental design adopted was a randomized complete block design with four cultivars and three replicates (each replicate included ten plants spread on a surface of 10 m^2). Irrespective of the cultivar, tomatoes were always intercropped with maize (*Zea mays* L.) to obtain plant shading and to follow the ancient cultivation tradition of the Tanagro Valley (Salerno province).

Table 1. Characteristics of the tomato cultivars used in the experiment.

Name	Type	Habitus	Shape of fruit
Datterino	Processing cultivar	Determinate	Plum-shaped
Crovarese	Local cultivar	Indeterminate	Pear-shaped, ovoid - elongated
Arsicolo	Local cultivar	Indeterminate	Rounded shaped
San Marzano	Local cultivar	Indeterminate	Elongated, cylindrical-rectangular

Seeds of all the studied tomato cultivars were sown into 91-cell plastic trays filled with 80% of peat and 20% of vermiculite (v/v) at the end of April. The trays were transferred to a climatic chamber (25 °C for 36 h) and then to a greenhouse until the transplant (Faraone et al., 2021).

On 25 May 2016, maize (*Zea mays* L., cv. Sy Giants F_1, Syngenta Italia, Milan, Italy) was sown with spacing of 40 cm along the rows which were 90 cm apart, with a plant density of 2.77 plants m^{-2}. On 2 June 2016, tomato seedlings were transplanted at the stage of 3^{rd}-4^{th} true leaf, at a distance of 45 cm apart in the middle of the maize inter rows in order to have a density of 2.5 plants m^{-2}.

Plants were cultivated according to the local practices and no irrigation was applied to both maize and tomato plants, since the water needs were met by rainfall from June to August. Only the tomato crop was watered at the transplant. Before the beginning of cultivation, a field bean green manure was ploughed into the soil in August 2015 at 25 cm depth. Subsequently, the soil was milled, levelled and a basic fertilization was made with the addition of 72 kg ha^{-1} of N and 184 kg ha^{-1} of P_2O_5 before transplanting of tomatoes. Moreover, at transplanting a granular insecticide active against soil insects (Geotox 7.5c, Kollant S.r.l., Vigonovo, Venezia, Italy) was applied with a dose of 12 kg ha^{-1}. During the cultivation, weeds were controlled through mechanical weeding for corn, and by manual weeding for tomatoes. In addition on 10 and 25 June and on the 10 July 2016, three preventive treatments, using copper and sulfur-based formulations, were carried out against downy mildew and powdery mildew. No pruning and lateral shoot removal were done. 'Crovarese', 'Arsicolo', and 'San Marzano', which have indeterminate habitus, had the maize stems as tutor, whilst 'Datterino' was not tutored.

Harvest, at the physiological ripening of the fruits ('ripe red' stage), was carried out on 5, 14, and 24 August 2016, for 'San Marzano' and 'Arsicolo'; on 26 August and 12 and 28 September 2016 for 'Crovarese'; on 27 August and 16 and 18 September 2016 for 'Datterino'. On each harvest, the number and the weight of total and marketable fruits were measured in each elemental plot.

2.2. Tomato paste preparation

For each cv., a tomato paste was separately prepared using the traditional technique still adopted by local families in the Tanagro Valley. In details, the first step to obtain the tomato paste is making the tomato sauce. To do this, a sample of 10 kg of ripe fruits was washed thoroughly with cold water, and water was drained. Then, tomatoes were placed in a large steel pot and cooked in their juice for 15 minutes until the peel of the fruits detached from the pulp. After cooking, the fruit pulp was placed in a vegetable mill (having disks with hole sizes of 2 and 1 mm, respectively), to obtain a tomato sauce completely free of peels and seeds. Then, the sauce was filtered with an aluminium sieve to remove any other fibrous residues. After addition of 20 g of cooking salt (NaCl) per liter, the sauce was boiled in a stainless steel pot (stirring was made every ten minutes by a wooden spoon). The slow-fire cooking continued until the sauce turned into a paste with a creamy consistency, having a water content of about 70%. The tomato paste preparation took about one hour of cooking per liter of tomato sauce.

2.3. Tomato "conserva" paste preparation

To make the "conserva", the tomato paste was cooled and placed in a plastic pot (50×50×5 cm) and then left to dry under the sun. During the night, and in case of rain, pots were kept in a dry room to prevent the development of molds. The mixture was mixed several times to allow uniform drying and until it reached a dark red color with an optimal consistency and density corresponding to a water content of about 40%. The obtained tomato "conserva" paste was then placed in sterilized and dry glass jars hermetically sealed and kept away from light.

2.4. Parameters measured

2.4.1. Dry matter content (total solids) of fresh tomatoes and tomato paste

For each cv. and repetition, 10 randomly chosen fresh tomato fruits, properly washed and dried, were weighed by using an analytical balance (Sartorius AG, model CP4202S, Goettingen, Germany). Each sample was dried in a ventilated oven at 60 °C until constant weight. The dry matter content of the tomato paste was determined by the same technique used for the fresh tomatoes.

2.4.2. Soluble solids of fresh tomatoes and tomato paste

The measurement of the soluble solids content of the tomato juice was carried out separately on five fruits collected in each plot with a digital refractometer (3405 PR-32 – Palette Antago Co., USA). Before each determination, the instrument was calibrated. The tomato paste soluble solids determination was carried out using 2 g of paste per each cv., diluted with 20 g of distilled water and mixed up until complete dispersion.

2.4.3. Colorimetric characterization of fresh tomatoes and tomato paste

The color of fresh tomatoes was recorded using a tristimulus electronic colorimeter (Minolta CR – 400 Chroma Meter, Minolta Corp., Osaka, Japan). Before each measurement, the colorimeter was calibrated using the standard white plate. The colorimetric coordinates in the CIELAB color system (Konica Minolta, 2003): L^* describing lightness ($L^* = 0$ for black, $L^* = 100$ for white), a^* describing intensity in green-red ($a < 0$ for green, $a > 0$ for red), b^* describing intensity in blue-yellow ($b < 0$ for blue, $b > 0$ for yellow), were measured for five tomatoes for each cv. and repetition. On each fruit, three readings were performed on each fruit (in the basal, equatorial, and apical sides). Moreover, the a^*/b^* index was calculated (Castronuovo et al. 2015).

The tomato paste colorimetric characterization was performed through the same tristimulus electronic colorimeter used for the fresh tomato fruits. The CIELAB colorimetric coordinates were collected after the tomato paste was spread on a sheet of white paper, using a probe equipped with a transparent plexiglass to have a smooth reading without irregularities.

2.4.4. Total acidity and vitamin C content of fruits and tomato paste

The determination of total acidity was obtained by titration. For each cv., five randomly chosen fruits were washed, dried, cut in half and made into juice by an immersion blender. Then, the obtained juice was filtered and samples of 2 mL were taken and placed in a beaker containing 150 mL of distilled water. The solution was kept in agitation on a stirrer while the titration was carried out with adding NaOH 0.1 mol L^{-1} using phenolphthalein as indicator.

Vitamin C was measured according to the method reported by Tadese et al. (2014). This determination was carried out by titration based on the capacity of iodine to oxidize vitamin C. Briefly, a 10 mL of the previously blended and filtered juice was placed in a beaker and placed on a stirrer and 1 mL of an indicator represented by a starch solution was then added to the beaker with a pipette until color change.

For the tomato paste, 2 g of paste, diluted with 20 g of distilled water and mixed up to complete dispersion were used for the measurements.

2.5. Statistical analysis

Data were subjected to one-way ANOVA and mean values were separated by Student Newman-Keuls's (SNK) test at $P \leq 0.05$. In addition, mean data were standardized and subjected to principal component analysis (PCA). A cluster analysis was performed using the Euclidean distance matrix via Ward's method (Ward, 1963). Statistical analyses were performed using the software RStudio: Integrated Development for R, version 2022.07.1 Build 554 (RStudio, Inc., Boston, MA, USA).

3. Results

3.1. Yield parameters of fresh tomatoes, tomato paste, and "conserva"

Yield parameters of fresh tomatoes and tomato paste are shown in Table 2. 'Arsicolo' was the most productive cv., with 1.29 kg fruit $plant^{-1}$ followed by 'Datterino' and 'Crovarese' which, on average, produced 0.72 kg of fruit $plant^{-1}$. 'San Marzano ' turned out to be the least productive cv., with 0.42 kg fruit $plant^{-1}$ (Table 2). The highest number of fruits per plant was achieved by 'Crovarese' (68.4), while the lowest was recorded for 'San Marzano' (9.0); 'Datterino' and 'Arsicolo' produced 47.5 and 32.7 fruit $plant^{-1}$ respectively. 'San Marzano' had the highest fruit mean weight (46.5 g $fruit^{-1}$), while the lowest value was observed for 'Crovarese' (9.8 g $fruit^{-1}$) (Table 2). 'Arsicolo' showed the highest yield of the tomato (92.9%,) followed by 'Crovarese' and 'Datterino' (an average paste return of 84.8%). The lowest paste return (76.2%) was observed for 'San Marzano' fruit (Table 2). The yield in "conserva", measured after drying the paste, was highest in 'San Marzano' (11.7%), whereas 'Datterino' had the lowest (9.6%). 'Crovarese' and 'Arsicolo' had an average value of 11.2% (Table 2).

Table 2. Yield and morphological characteristics of the tomato cultivars.

Cultivars	Marketable yield (tons ha^{-1})	Fruit per plant (No $plants^{-1}$)	Mean fruit weight (g $fruit^{-1}$)	Tomato paste yield (% weight)	Tomato "conserva" yield (% weight)
'Datterino'	19.0 b	47.5 b	16.0 c	85.7 b	9.6 b
'Crovarese'	16.7 b	68.4 a	9.8 d	83.9 b	10.9 ab
'Arsicolo'	32.2 a	32.7 c	39.4 b	92.9 a	11.4 ab
'San Marzano'	10.5 c	9.0 d	46.5 a	76.2 c	11.7 a

Within each column, means followed by different letters are significantly different ($P \leq 0.05$) according to the Student–Neuman–Keul's test.

3.2. Fruit qualitative parameters

The qualitative traits of the tomato fruits were influenced by the genotype (Table 3). Total solids were higher in 'Crovarese' (9.1%,) compared to 'Datterino' (7.3%) and 'Arsicolo' (6.0%), whereas 'San

Marzano' fruits had total solids values similar to those of 'Crovarese' and 'Datterino' (Table 3).

The soluble solid content showed the highest values in 'Crovarese' and 'San Marzano' an average of 6.7 °Brix), while the lowest value was found in 'Arsicolo' fruit (4.7 °Brix). 'Datterino' had intermediate values of this parameter (5.4 °Brix; Table 3).

The highest pH values were observed in 'Crovarese' and 'San Marzano', and the lowest ones in 'Arsicolo' and 'Datterino' (Table 3). In addition, 'San Marzano' fruits presented the lowest titratable acidity (0.47%) (Table 3). 'Crovarese' and 'San Marzano' showed the highest vitamin C content (an average of 40.1 mg per 100 g of fresh weight; Table 3). The chromatic coordinates of 'Arsicolo' fruits were significantly higher than the other cultivars. Conversely, 'San Marzano' showed the lowest values for these color parameters, whereas 'Datterino' and 'Crovarese' showed similar values (Table 3).

Table 3. Qualitative fruit characteristics of the tomato cultivars.

Cultivars	Total solids (%)	Soluble solids (°Brix)	pH	Titratable acidity (%)	Ascorbic acid (mg 100 g f.w.$^{-1}$)	C olor			
						L*	a*	b*	a*/b*
'Datterino'	7.3 b	5.4 b	4.26	0.98 a	34.9 b	39.2 ab	22.3 b	22.7 b	0.98 b
'Crovarese'	9.1 a	6.6 a	4.32	0.93 a	39.7 a	39.5 ab	22.5 b	22.4 b	1.00 b
'Arsicolo'	6.0 c	4.7 c	4.26	0.93 a	32.2 b	40.4 a	26.9 a	23.9 a	1.13 a
'San Marzano'	8.2 ab	6.7 a	4.34	0.47 b	40.4 a	38.7 b	23.3 b	21.6 c	1.08 ab

Within each column, means followed by different letters are significantly different (P ≤ 0.05) according to the Student–Neuman–Keul's test.

3.3. Qualitative parameters of the"conserva" paste

Significant differences between the tomato cultivars were also observed for most of the qualitative parameters measured in the "conserva" paste (Table 4) with the only exceptions of the total titratable acidity and the brightness of the color. The dry matter content of the "conserva" paste was higher in 'San Marzano' (57.8%) compared to 'Crovarese' (52.4%). In 'Datterino' and 'Arsicolo', the dry matter content was on average 54.4% (Table 4). The optical residue (soluble solid content) of the "conserva" paste of 'Datterino' and 'San Marzano' fruits was 0.4 °Brix higher in 'Crovarese' and 'Arsicolo' (Table 4). As regards the acidity of the "conserva", 'Arsicolo' fruits had the highest pH followed by 'Crovarese', 'San Marzano', and 'Datterino'. 'Datterino' had the highest titratable acidity (0.17%;), whereas 'San Marzano' and 'Crovarese' showed the lowest values for this parameter (0.12%) (Table 4). All cultivars showed a similar content in vitamin C. As for the color, "conserva" paste of all the tomato cultivars had an a*/b* ratio higher than that of fresh fruits. The highest a*/b* ratio was found in 'San Marzano' (Table 4).

Table 4. Qualitative parameters of the "conserva" paste obtained by the fruits of the four cultivars.

Cultivars	Total solids (%)	Soluble solids (°Brix)	pH	Titratable acidity (%)	Ascorbic acid (mg 100 g f.w.$^{-1}$)	Color			
						L*	a*	b*	a*/b*
'Datterino'	54.7 ab	6.0 a	3.62 b	0.17 a	10.7	27.8	12.1 c	8.7 c	1.39 b
'Crovarese'	52.4 b	5.6 b	3.80 ab	0.12 b	10.4	29.3	16.5 b	11.4 b	1.44
'Arsicolo'	54.1 ab	5.6 b	4.00 a	0.14 ab	10.5	27.3	17.5 b	11.4 b	1.54
'San Marzano'	57.8 a	6.0 a	3.79 ab	0.11 b	10.4	29.4	21.5 a	13.0 a	1.65 a

Within each column, means followed by different letters are significantly different (P ≤ 0.05) according to the Student–Neuman–Keul's test.

3.4 Principal component and cluster analyses

The twenty-one original variables were analyzed by PCA and were reduced to two principal components (PC1 and PC2), which had, respectively, eigenvalues of 10.32 and 7.51 and explained 49.15% and 35.77% of the total variability (together PC1 and PC2 explained 84.92% of the total variability). PC1 was highly and positively correlated with total solids, total soluble solids, pH, ascorbic acid content of fruit, total solid of "conserva", colorimetric coordinate a and b of "conserva", whereas it was negatively correlated with paste yield, titratable acidity of fruit, colorimetric coordinate of fruit (Figure 1). PC2 was positively correlated with fruit mean weight, "conserva" yield, pH of "conserva", colorimetric coordinate of "conserva" (Figure 1).

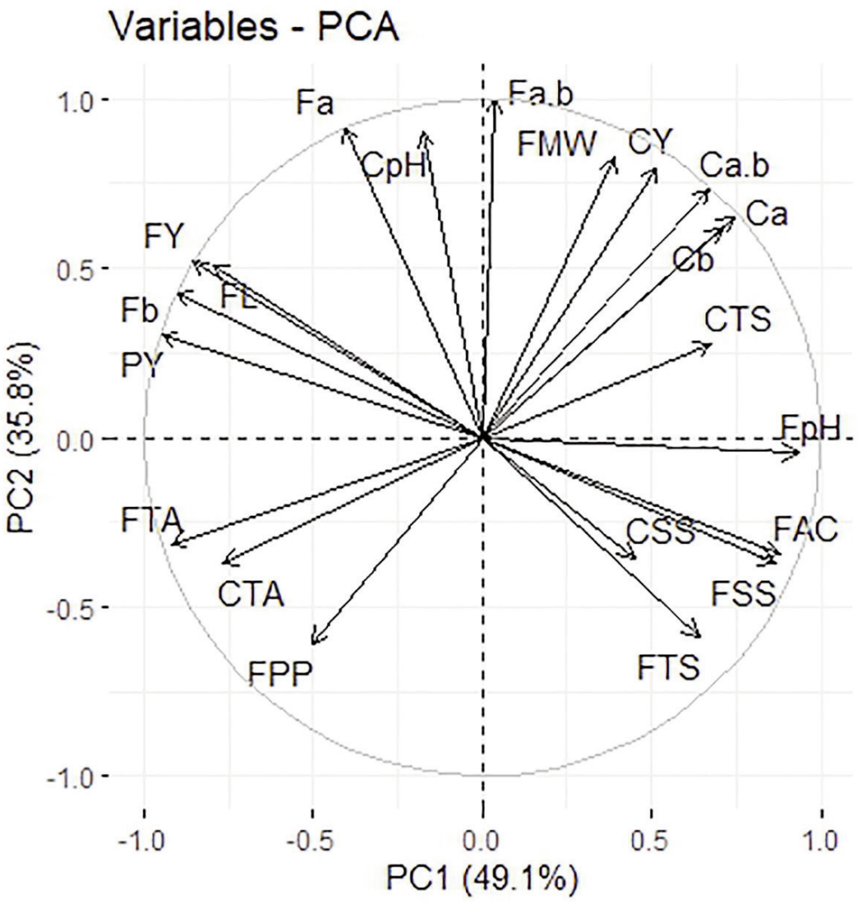

Figure 1. Correlation biplot of the two first principal components variables in the two-dimensional space. FY: Fruit yield; FPP: Fruit per plant; FMW: Fruit mean weight; PY: Paste yield; "Conserva" yield: CY; FTS: Fruit total solids; FSS: Fruit soluble solids; FpH: pH of fruit; FTA: Titratable acidity of fruit; FAC: Ascorbic acid of fruit; FL: L* of fruit; Fa: a* of fruit; Fb: b* of fruit; Fa.b: a*/b* of fruit; CTS: Total solids of "conserva"; CSS: Soluble solids of "conserva"; CpH: pH of "conserva"; CTA: Titratable acidity of "conserva"; Ca: a* of "conserva"; Cb: b* of "conserva"; Ca.b: a*/b* of "conserva".

The results from PCA showed that 'San Marzano' was located in the positive quadrant of PC1, characterized by the highest values of the "conserva" yield, fruit mean weight and colorimetric parameters of "conserva" (Figures 1 and 2). In addition, the fruit mean weight was negatively correlated with the number of fruit per plant and with titratable acidity (Figure 2). 'Arsicolo' was located in the upper left quadrant characterized by the highest values for the quantitative traits (Figure 2).

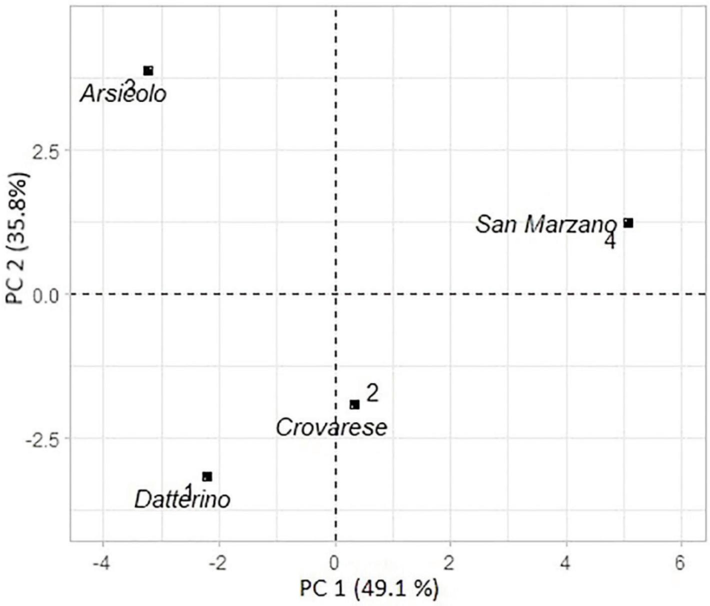

Figure 2. Biplot showing the projection from the analysis of morphological, quantitative and qualitative traits.

Cluster analysis showed that these cultivars could be grouped into three clusters (Figure 3). The cluster dendrogram indicated that 'Arsicolo', 'Datterino' and 'Crovarese' were relatively more similar among them, while 'San Marzano' did not group with the other cultivars. The similarity between 'Datterno' and 'Crovarese' was relatively more evident (Figure 3).

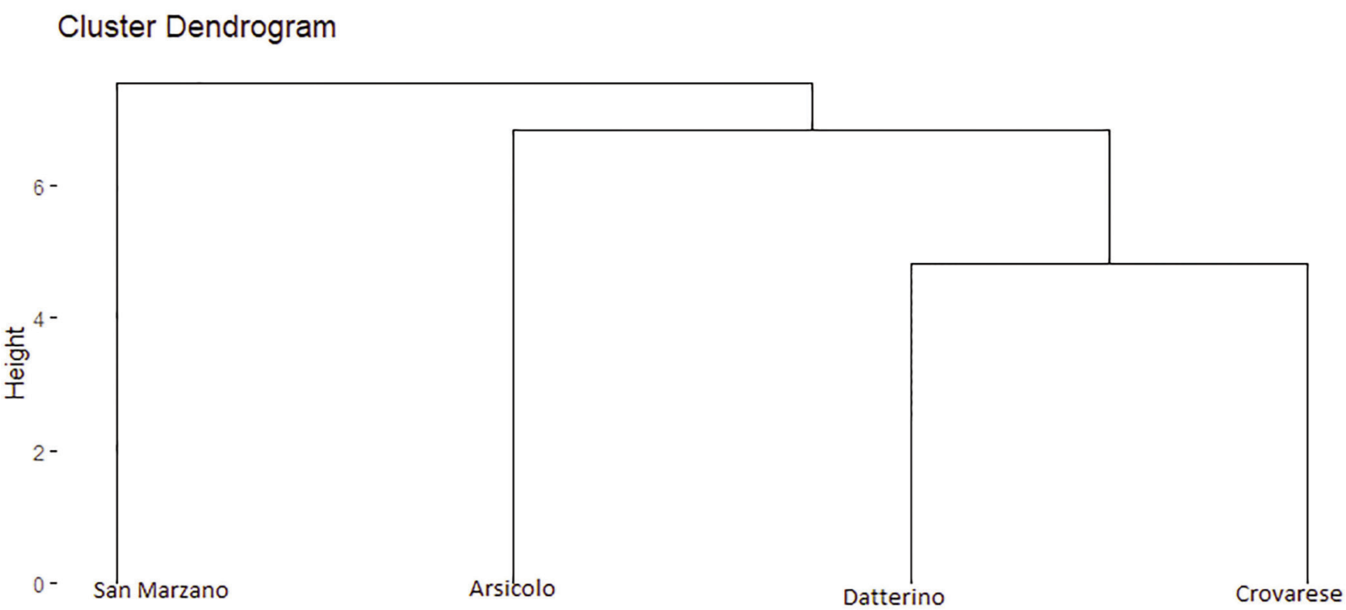

Figure 3. Cluster analysis of the tomato cultivars.

4. Discussion

Ancient and local landraces of tomato risk the extinction due to the diffusion of hybrid cultivars more resistant to different diseases (fungi, viruses and bacteria) and suitable for mechanization, but the latter are characterized by inferior qualitative and organoleptic traits (Fratianni et al., 2020). In this study, we compared the quantitative and qualitative characteristics of 'San Marzano', 'Arsicolo' and

'Crovarese' with those of the commercial cultivar 'Datterino' grown according to the ancient cultivation model (intercropping with maize and no use of irrigation) and following the traditional fruit processing (paste and "conserva" paste).

Marketable yield ranged between 1050 and 3225 g m^{-2} (10.5 and 32.2 tons ha^{-1}) and fruit mean weight of 27.9 g (Table 2). Similar results were obtained in previous studies. For instance, Cantore et al. (2016) focused the attention on the effect of deficit irrigation on yield and quality of cherry tomato in Southern Italy (Valenzano, Bari), highlighting fruit yields of 12.95 and 31.36 tons ha^{-1}, respectively, in rainfed plants and in plants exposed to deficit irrigation (50% of full irrigation). In a two-year study in Sicily (Southern Italy), Patanè et al. (2011) observed that non-irrigated plants had fruit yields ranging between 8.32 and 16.88 tons ha^{-1}. Higher values were measured by Favati et al. (2009), who reported fruit yields of 22.22 tons ha^{-1} for non-irrigated tomatoes grown in the Basilicata region (Italy).

Conversely, the fruit fresh weight of 'San Marzano' measured in our study (46.5 g $fruit^{-1}$) was lower than those reported in other studies. Indeed, Tripodi et al. (2021) recorded a fruit mean weight of 54.69 g in plants grown in Pontecagnano (Salerno, Italy). This difference could be due to the low tolerance of 'San Marzano' to these cultivation conditions. Its low adaptability to extreme conditions has been evaluated also by Moles et al. (2016), who found that 'Ciettaicale' maintained high efficiency to salt stress as compared to 'San Marzano'. The PCA and cluster analyses confirmed this result (Figure 4), indicating 'San Marzano' as a sensitive cultivar and less productive in terms of fruit yield.

In this study high yield, fruit mean weight and tomato paste yield were observed for 'Arsicolo' (Table 2) and this indicates that probably this cultivar has large adaptability to the dry farming. Plants have different adaptive mechanisms to overcome the water stress (Sanchez-Rodriguez et al., 2011), such as decreasing stomatal opening (Osakabe et al., 2014), but this may also results in reduced CO_2 exchange rates (Tahiri et al., 2022). The PCA and cluster analyses highlighted a differential response of the four cultivars to the the specific growing conditions adopted in our study (Figures 1-3). 'Arsicolo' appeared to be a tolerant cultivar which performed best under intercropping with maize (Li et al., 2020). The deeper-rooted system of tomato may absorb resources from deeper soil than the maize which is characterized by a fibrous root system (Gebru et al., 2015). In addition, the presence of maize could have decreased the excess light and then the photooxidation, a process that leads to the formation of reactive oxygen species in plant tissue damaging the chloroplasts (Li et al., 2009).

'Crovarese' and 'Datterino' demonstrated an opposite behavior producing more fruits per plant but they were of small size. This result could be related to specific adaptation strategy used by these cultivars to growing conditions of this study (water stress) (Khapte et al., 2019; Osakabe et al., 2014). Generally, a reduction of fruit weight occurs during longer and more intense periods of stress (Cantore et al., 2016). Conversely, 'San Marzano' showed the lowest production due to the reduced number of fruits per plant. This latter aspect could be caused by flower abortion or the early fruitlet drop (Marouelli and Silva, 2007). 'Arsicolo' had also good yields of "conserva" paste.

Tomato quality depends on the different factors such as the variety and is affected by the interaction between soluble sugars and acids as they influence the flavor, sweetness and sourness (Tigist et al., 2013; Tripodi et al., 2022). Total solids is particularly important to the processing industry and varies between 4.5 and 7% (fresh weight) in industrial tomatoes and from 6.5% to 9.5% in cherry tomatoes (Aoun et al., 2013). The total solids values obtained in our study were in line with the required standards (Siviero, 1998). In the tomato fruit pulp, the total soluble solids is represented by 65% of sugars (sucrose and hexoses), 13% of acids (citrate and malate;) and other minor components (phenols, amino acids, soluble pectins, ascorbic acid and minerals) (Beckles, 2012). Soluble solid content ranges between 3 to 5% (fresh weight) in large beefsteak tomatoes, between 5 and 7% in medium-sized fruit, and between 9 and 15% in cherry tomato fruit (Beckles, 2012). The values can vary between 4.5 and 12 °Brix, but, for the purposes of product acceptability by the processing industry, the threshold values indicated is equal to 4.5 °Brix. Therefore, also in the case of the optical residue, the values obtained in our study are in compliance with the required standards (Siviero, 1998).

'Crovarese' showed in general a relatively low yield but a good fruit quality, in particular in terms of solid soluble content. This result could be due to the condition of water deficit which reduced the size of fruit and enhanced the accumulation of assimilates (Khapte et al., 2019). Patanè et al. (2011) suggested the adoption of deficit irrigation strategies to maintain high fruit quality levels in terms of solid soluble content, an important parameter for industrial processing from tomato fruit to paste or concentrated juice. In the fruit, the higher the total soluble solids and in sugar content, the lower the water content and therefore the energy requirement to remove it during processing (Dorais et al., 2008).

The flavor, described as the perception of food by taste and olfaction (Pereira et al., 2021), is considered a good parameter to improve the sensory quality of tomato, and is strongly affected by pH and titratable acidity (Erika et al., 2022). In general, in our study the pH values measured in all analyzed cultivars are consistent with those reported by others authors (Favati et al., 2009; Manzo et al., 2018; Fratianni et al., 2020) and in compliance with the required standards ranging from a minimum pH of 3.9 to a maximum pH of 4.4 (Siviero, 1998). Conversely, the values of titratable acidity we measured in this study were higher than those reported in the literature. Generally, the content of citric acid in the tomato fruits varies from 0.25 to 0.5% (Siviero, 1998). Higher acidity leads to shorter heat treatment times and less qualitative damage (Dorais et al., 2008; Tigist et al., 2013). Degwale et al. (2022) studied the influence of the temperature and the time of dehydration on the physicochemical properties of tomato and indicated that the titratable acidity increased with increasing temperature and time. Thus, the dehydration process could be exploited to improve tomato fruits characterized by low acidity.

Acid ascorbic is considered to be one of the most abundant antioxidants in plants, it is important for preserving the nutritional characteristics of tomato (Raiola et al., 2018). In this study, 'Crovarese' and 'San Marzano' showed the highest content of vitamin C. Different authors confirmed that water deficit improved the tomato fruit quality increasing soluble solids, acidity and vitamin C (Colla et al., 1998; Patanè and Cosentino, 2010; Lovelli et al., 2017). There was a negative correlation between fruit yield and ascorbic acid content and fruit soluble solids as shown in PCA analysis (Figure 1).

Among the qualitative parameters, the color of tomato is the one that mostly influences the decision of consumer (Carillo et al., 2019). A higher ratio a^*/b^* corresponds to more intense the color of fruit (Dorais et al., 2008). The red color of fruit is correlated with the biosynthesis of lycopene pigment (Sipos et al., 2017) which is under genetic control and environmental conditions, mainly temperature and light (Dorais et al., 2008). In general, the color of a fresh tomato is considered acceptable when the value of the red-yellow index ratio (a^*/b^*) varies from 1.64 to 2.71 (Siviero, 1998). The highest value of red/yellow ratio obtained by 'Arsicolo' (1.13) confirmed our previous study (Faraone et al., 2021) which showed that this local cv. pointed out the high antioxidant potential due to the presence of bioactive compounds sucha s β-carotene and lycopene. Regarding the qualitative parameters of "conserva", 'San Marzano' reached the highest values of soluble solids, index of red (a^*), and ratio a^*/b^*.

5. Conclusions

The tomato is one of the most consumed vegetables in the world, both fresh and through the various processed products. In both cases it represents a rich source of bioactive compounds, including carotenoids (lycopene and β-carotene), acids, vitamins and phenolic compounds. In recent years, the choice of consumer has been oriented towards various local cultivars for sustainable production, which rediscovers ancient flavours of traditional gastronomy. 'Arsicolo' and 'Crovarese' are local cultivars of tomato still little studied and they could play an important role in preserving biodiversity and valorizing the link with territory.

The results of this study could encourage some local companies to plant cultivars such as 'Arsicolo' to obtain high yield and produce deeply colored fruit, or 'Crovarese' with a unique quality trait, such as the flavor determined by a high sugar content and ascorbic acid presence, or 'San Marzano' for its particular "conserva" product.

These local cultivars are sustainable for their lower environmental impacts due to adaption to the warm and dry climatic conditions (such as those of the Campania region) and to lower requirement of field operations such as irrigation and chemical treatments to overcome possible diseases. This latter aspect is possible thanks to the technique of intercropping system with maize which reduced the attacks of insects and pests and minimized the presence of weeds.

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