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EFFECT OF CULTIVAR AND GROWING SYSTEM ON THE PHENOLOGICAL AND QUALITY ATTRIBUTES OF TOMATO

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Abstract

Tomato is a staple crop with diverse cultivars, and their adaptability to environmental changes prevalently derives from distinct genetic traits that influence their phenology, fruit quality, and antioxidant constituents. Also, environmental conditions and agronomic techniques have an effect on these. This experiment was carried out at the VRDS Bacau in subdivided plots, with three replicates in protected areas in which the influence of two factors was evaluated: the cultivar (genotype 1 to genotype 10) and the growing system (conventional and organic). Data collection involved phenological observations (flowering time, fruit set, maturation, and overall growth) and chemical analyses (acidity, carotenoid content). Regarding the influence of the cultivar on the phenological characteristic values are reached by G2 for soluble solids, G4 for TSS, G1 for water%, and G2 for lycopene and beta carotene. Tomatoes grown organically were found to have richer flavour profiles and deeper colour intensity compared to their conventionally grown counterparts, which tended to be more uniform in size and shape.

Key words: *genotypes, growing system, plant breeding, phenological properties, nutritional quality.*

INTRODUCTION

Tomatoes are among the most widely cultivated and consumed vegetable crops worldwide, playing a vital role in human nutrition and culinary traditions. As a member of the *Solanaceae* family, tomatoes showcase an impressive range of morphological, flavor, color, and growth trait diversity. This variation can be traced back to their long history of domestication and selective breeding. Understanding the classification of tomato cultivars is essential for comprehending their agricultural, genetic, and culinary characteristics. A cultivar, short for "cultivated variety", is a plant variety developed through selective breeding, distinguishing it from wild species. Tomato cultivars can be classified based on several key criteria, including growth habit (determinate vs. indeterminate), fruit type (e.g., cherry, beefsteak, plum), and resistance traits (such as resistance to specific pests or diseases). Additionally, cultivars can be further categorized as heirloom or hybrid varieties, each offering unique traits that cater to specific farming practices and consumer preferences. This classification system helps to shed light on the diverse genetic makeup and breeding potential of tomatoes, which is crucial for ensuring agricultural productivity and sustainability. The selection of tomato cultivars is influenced by various factors, such as ease of germination, cold tolerance, uniformity, absence of imperfections, reduced axillary buds, and resistance to diseases and pests (Umeohia and Olapade, 2024).

The phenological development of plants determines their growth and productivity. Days to blooming, fruiting, and crop maturity are significant phenological events that impact a crop's productivity. In 2023, Donoso and Salazar, in a study about plant agromorphology of indeterminate tomato, demonstrated that the landraces studied showed great diversity of agromorphological and phenological traits, and this diversity might be key to yield improvement in tomatoes.

The fruit's maturity, cultivar, soil, growing system, temperature conditions, and the farming technique used to develop the plants all affect the tomato fruit's chemical composition (Coyago-Cruz et al., 2018; Hasnain et al., 2020).

The primary components that contribute to the quality of tomatoes are glucose, fructose, citric acid, lycopene, β-carotenoids, quercetin, chlorogenic acid, and succinic acid (Li et al., 2024). The lycopene and antioxidant levels in tomato genotypes vary among cultivars (Taber et al., 2008). Tilahun *et al*. (2017) observed that the cultivar had a significant effect on the phenolic content of tomato fruits. Ilić et al. (2013) confirm that the most important variable in the micronutrient content of tomatoes is cultivar. According to Martínez-Valverde et al. (2002), the concentrations of lycopene and the various phenolic compounds (flavonoids (quercetin, kaempferol, and naringenin) and hydroxycinnamic acids (caffeic, chlorogenic, ferulic, and p-coumaric acids), as well as the antioxidant activity, were significantly influenced by the tomato variety. According to research by Cortés-Olmos et al. (2014) and Kavitha et al. (2014), tomato cultivars, especially traditional varieties, vary widely in terms of their carotenoid levels, which leads to a significant source of genetic variation. Also, Flores et al. (2017) found substantial variation throughout 53 traditional tomato cultivars in terms of size, shape, color, carotenoid profiles, and concentrations. A study undertaken to analyze the genotypic variability linked with certain traits in twenty-five distinct tomato genotypes revealed that the evaluated genotypes possessed significantly significant variation (Zannat et al., 2023).

Typically, conventional farming systems use synthetic pesticides, herbicides, and fertilizers to increase yields and manage diseases and pests. Because the inputs in these systems are frequently more controlled, yields may be higher, but there are also worries about the environmental impact and consumer preference for chemical-free products. On the other hand, organic farming methods place more emphasis on crop rotation, natural inputs, and biological pest control, all of which can have a different effect on fruit qualities, disease resistance, and plant growth than conventional methods. Although organic tomato production is thought to be healthier and more ecologically friendly, there is ongoing discussion regarding yield and quality issues. A key variable in the success of the organic tomato culture is variety selection. In fact, the variety's genetic components can affect a number of crucial aspects, including fruit quality, disease resistance, and production potential. Research results on the effects of organic and conventional production on fruit quality are sometimes contradictory. Several studies report better taste, higher vitamin C contents, and different levels of other quality-related compounds (Ruiz Espinoza et al., 2021; Vélez-Terreros et al., 2021), whereas several other studies have found the opposite or no differences in quality characteristics between organically and conventionally grown vegetables (Kapoulas et al., 2011). Organic cultivation provided an advantage to obtaining fruits and vegetables with higher amounts of phenolic compounds, which brings additional value to these crops in terms of antioxidant potency as well as a lower environmental impact (Basay et al., 2021). By keeping diseases and pests under control, organic agriculture maintains the natural balance, ensures soil fertility, and optimizes the use of energy and natural resources while preserving the continuity of existence in the environment (Yüzbaşioğlu, 2018). While some research has indicated that organically grown tomato fruits contain more bioactive compounds than conventionally produced ones, not all of these studies have been consistent. The amounts of phenolics and carotenoids vary substantially and are frequently influenced by cultivation, genotype, and ripeness. Hallmann (2012) demonstrated that the organic growing system affects tomatoes quality parameters, such as nutritional value and phenolic compound content, and also that the second significant factor of the nutritional value of tomatoes is the type of fruit. In general, the application of organic fertilizers significantly improved most of the qualities, such as TSS, SS, lycopene, and nitrate content, with no significant change in the sugar/acid ratio (Gao et al., 2023; Fan et al., 2023; Stoleru et al., 2024). Also, Borguini et al. (2013) confirmed that the type of production (conventional and organic) would affect the production of secondary metabolites by the plants. Mohammed et al. (2020) show that tomatoes fruits cultivated in an organic system were significantly different in mineral nutrients and dry matter content from a diverse genetic background point of view. Vélez-Terreros *et al*. (2024) did another study that demonstrated that while organic tomatoes had a slightly better nutritional composition, including AA, lycopene, and total phenolics, the nutritional and nutraceutical properties of the final product may depend on the cultivar, harvest time, genetic and agricultural factors, growing conditions, and production region.

Measuring the growth and harvesting traits of the local tomato population, such as plant height, fruit set percentage, and overall yield, is essential for determining the viability of plastic tunnels for vegetable production. The analysis of both types' productive performance and qualitative features (such as fruit size, shape, color, and taste) is critical for selecting the best assortment and assuring production efficiency.

Hence, in the present work, a specific survey on tomato, within a protected field long-term study on organic and conventional horticulture and the different genotypes of tomato, is presented. Since the variables affecting tomato quality are complex and interconnected, more research is required to fully understand the interdependencies. The main objective of the present study was to assess how the combination of tomato genotypes and different growing systems impacts the phenology, morphology, and quality of the fruits, providing insights into the best practices for growing tomatoes with superior quality, efficiency, and productivity.

MATERIALS AND METHODS

The plant material consisted of 10 cultivated tomato genotypes belonging to diverse cultivar groups, including elite cultivars and heirlooms with different origins, landraces for the fresh market with determinate and indeterminate growth from Romania originating from different regions of this country. The panel set was assembled from the germplasm collections of the Vegetable Research and Development Station from Bacau, Romania. The research was carried out in the organic and conventional systems in plastic tunnels during spring and summer 2024 at VRDS Bacau, characterised by a typical temperate climate (46°5846201″ N, 26°9511173"E, 158.96 m a.s.l.).

The experiment was set up using seedlings produced in alveolar pallets with 70 alveoli, and sowing was carried out on March 5th using a textured substrate and a medium fertilisation comprising microelements. Manual planting was performed after the seedling had become fully developed in the third decade of April, at 48 days old. During the vegetation period, frequent assessments on pest and disease resistance, as well as plant development progress in protected areas, were performed. Manual weeding was done around the plants whenever necessary and at frequent times, and Mospilan treatments were used in the conventional method to combat pests and diseases. Cropmax and Codamix were used to fertilise the plants in the organic system and Complex 20:20:20 in the conventional one.

The experiment was divided into 5 furrows with two rows in each furrow, a one-meter path between each variety, 35 cm between plants, and 70 cm between rows. Each variant had 10 plants, and the space required for each plant was 0.245 sq m.

During the vegetation period, measurements of the crown diameter and plant height were made, the date of flowering, the appearance of the first fruit, and the ripening of the fruit were noted to subsequently calculate the specific number of days for each parameter. In our experiment, 7 measurements of height (first measurement before planting, then two weeks apart) and diameter at the base of tomato plants were made, each being scored from 1 to 7 for each parameter. HP1 - height in a certain phenophase, DP - stem diameter in a certain phenophase (HP1 ... Hp7; DP1 ... DP7). To measure the diameter of plant base and fruit diameter and the fruit height, a caliper was used that shows values in both inches and mm, and to measure the fruit mass, a Kern analytical balance was used.

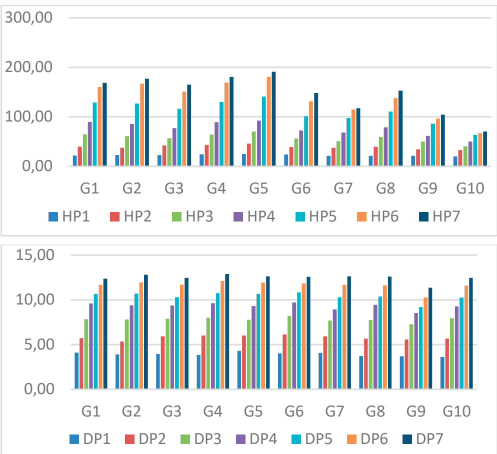
The dry matter (DM) content was determined by drying the freshly collected samples for 24 hours at 70 ± 2°C in a forced air-drying oven (Biobase) to provide a uniform mass (Stoleru et al., 2020; Caruso et al., 2019). Tomato juice was squeezed from fresh tomatoes onto a digital refractometer to identify total soluble solids (TSS), and outcomes were expressed in °Brix using AOAC method 932.12 (AOAC, 2005).

The pigments, lycopene and β-carotene, were assessed using spectrophotometry. The absorbance of the etheric extract was measured at several wavelengths, 452 nm for carotene and 472 nm for lycopene, using a BOECO S-20 spectrophotometer in comparison to a petroleum ether blank. The absorbance values for lycopene and β-carotene were multiplied with 14.105, respectively, with 19.96 to calculate the total fractions.

For statistical analysis, the IBM SPSS Statistics application, version 26.0, was utilized. Tukey's test was used to estimate the significant difference between the variant means. Differences across groups were considered significant at $p \leq 0.05$. The results were given as means and standard deviations.

RESULTS AND DISCUSSIONS

Tallness, shortness and other morphological differences are varietal characteristics, which are controlled and expressed by certain genes (Fayaz et al., 2007). Plant height increased gradually with time and continued up to 100% flowering (Biswas et al., 2014; Sanjida et al., 2020). Plant height differed among the varieties of tomato due to the variation of varieties (Olaniyi et al., 2010). Amare and Gebremedhin (2020) found in an experiment that the tallest tomato plant has a height of 112 cm and the shortest has a height of 73 cm. In another study, it was discovered that the highest plant height was 93.8 cm in V2 (BARI hybrid tomato), and the lowest (87.3 cm) was found in V1 variety at 60 DAT (Sanja et al., 2020). According to Fayaz et al. (2007), the genetic potentiality of summer tomato varieties may be the cause of the variations in plant height.

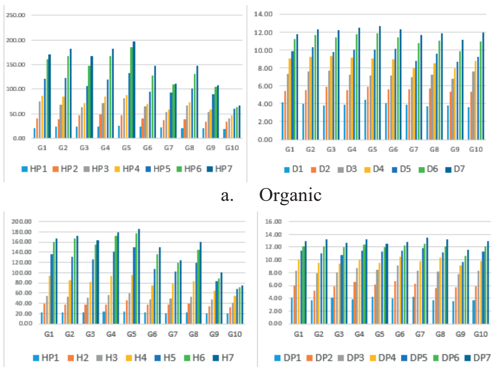


(G1 - genotype 1, …., G10 - genotype 10, HP - height in a certain phenophase; DP - stem diameter in a certain phenophase)

Figure 1 Plant height and diameter at the base of the plants depending on the cultivar

In a study conducted in Iasi in 2018-2019, Stoleru et al. (2020) demonstrated that the height of tomato plants depending on the cultivar showed values between 206.4 and 224.2 cm; however, depending on the cultivation system, the maximum was reached at 227 cm for the conventional system and 204.4 for the organic system.

As can be seen in the graph (Figure 1), the values increase progressively for each genotype from one time interval to another. From the point of view of cultivar analysis, G5 reached the maximum height value of 191.11 cm, while the lowest value was reached by G10 (70.67 cm). In the case of the diameter at the base, G4 (12.60 mm) reached the maximum point, and G9 (11.35 mm) the minimum value. From a statistical point of view, it is observed that there are no significant differences, demonstrating a natural growth process.



G1 - genotype 1, …., G10 - genotype 10, HP - height in a certain phenophase; DP - stem diameter in a certain phenophase)

Figure 2. Plant height and diameter at the base of the plants depending on the growing system

It can be seen that the growth trend is also upward in the case of the influence of the growing system, the maximum values being reached by G5, and the minimum values by G10 in both cases for the plant height. In the case of the diameter at the base of the plant, there are no significant differences that can be observed between the values of measurement no. 7. Following the analysis of these graphs, it can be concluded that the genotypes G1, G2, G3, G4, G5, G6, and G8 present an indeterminate growth of the plant, specific to protected spaces, solariums, being followed by G7, G9, and G10, which present a determinate growth.

The flowering stage of the tomato plant begins when the plants have burst into a yellow bloom that ends in small green fruits after pollination. The number of flowers initiated in an inflorescence depends on the variety and environmental conditions. Increased irradiance or decreased plant density and decreased temperatures positively influence the number of flowers formed in an inflorescence. Low air temperatures (<10°C) during inflorescence initiation promote inflorescence branching, usually resulting in more flowers per inflorescence (Wien and Stützel, 2020). Furthermore, Abdelmageed and Gruda (2009) and Singh et al. (2014) claimed that environmental and genotypic factors affect tomato plants' ability to flower early or late. According to some scientific works, the number of days until 50% flowering was between 40 and 49 days (Meseret and Kassahun, 2012), so 49.67 and 67 days conform to Tujuba and Ayana, 2020. Their inherited traits, which include early acclimatization to the growing environment to promote growth and development, may have contributed to their early or late flowering days. In our study, depending on the cultivar, the data show significant variations between the values of the genotypes studied, the data being between 63.83 (G9) and 75.83 (G2) days from emergence. Taking into account the day the genotypes were planted, the number of days until the appearance of the first flower is between 16 and 28 days.

Regarding the crop system, the values demonstrate significant differences between the cultivars, in the conventional one, the genotype that bloomed the fastest being G9 with 54.33 days from emergence, and the most delayed genotype being G2 with 71.67 days. In the organic crop system, the values varied between 71.00 (G10) and 80 days (G2).

Table 1. Phenological data depending on the cultivar

V	Days till starting flowering	Days till fruit development	Days till harvest
G1	73.17±1.17 ab	81.00±0.67 ab	111.33±0.59 bc
G2	75.83±1.06 a	84.50±0.46 a	118.83±0.09 a
G3	69.67±1.57 bc	77.50±1.33 bc	112.50±0.57 bc
G4	72.00±1.58 ab	81.83±1.04 ab	116.83±0.57 a
G5	72.33±1.46 ab	81.50±1.26 ab	113.50±1.27 b
G6	70.67±1.40 bc	78.83±0.96 bc	113.17±0.35 bc
G7	67.00±1.96 cd	74.50±1.42 cd	111.83±1.08 bc
G8	69.50±1.43 ab	79.67±1.28 ab	112.17±1.18 bc
G9	63.83±2.37 d	71.83±2.14 d	109.50±1.33 c
G10	65.833±1.46 bc	76.67±0.57bc	110.50±0.63 bc
Ss.	*	*	*

(V – variant; G1 – genotype 1, …., G10 – genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at p ≤ 0.05).

The number of days until tomatoes bear fruit depends on several factors, including variety, as different tomato varieties have different ripening times. In a work by Shopova, 2023, in Bulgaria, a delay in the fruiting phenophase of plants is demonstrated because after the 2nd decade of July, flowers are more likely to fall under higher temperature conditions. Thus, in the first year of the experiment, 2020, the first fruit appeared at 47, 48, and, respectively, 52 days, while in the second year of the experiment, 2021, the first fruit appeared slightly later at 48, 49, and 54 days after planting. The number of days until the appearance of the first fruit was significantly influenced by the cultivar produced. The shortest time was obtained by the genotype G9 with 71.83 days from emergence, while the maximum number of days was represented by G2. By interpreting the results, several genotypes are statistically similar in pairs, such as G1 (81.00) with G4 (81.83), G5 (81.50), and G8 (79.67), but also G3 (77.50) with G6 (78.83). When we refer to the crop system, in the organic one the values are statistically significant, the lowest results being obtained by G10 with 78.83 days and the highest being represented by G5 with 86.67 days from emergence. In the conventional system, the genotype that produced the earliest fruit is G9 (63.33), a genotype with determinate growth, and the longest time is given to the G2 genotype.

Table 2. Phenological data depending on the growing system*: a. organic*

V	Days till starting flowering	Days till fruit development	Days till harvest
G1	77.67±0.60 abc	83.67±0.17 bc	112.33±0.17 d
G2	80.00±0.29 a	86.00±0.29 ab	119.00±0.00 a
G3	76.0±0.29 bcde	82.67±0.60 cd	114.33±0.44 cd
G4	78.33±0.44 ab	85.67±0.60 ab	118.33±0.83 ab
G5	78.33±0.17 ab	86.67±0.17 a	118.00±0.00 ab
G6	76.33±0.17 bcd	82.33±0.60 cd	113.00±0.00 d
G7	74.67±0.44 de	79.67±0.73 e	115.33±1.36 bcd
G8	75.00±0.29 cde	84.67±0.17 abc	116.67±0.88 abc
G9	73.33±1.01 ef	80.33±1.20 de	114.33±1.17 cd
G10	71.00±1.50 f	78.33±0.67 e	112.67±0.60 d
Sf.	*	*	*

b. conventional

V	Days till starting flowering	Days till fruit development	Days till harvest
G1	68.67±0.60 b	78.33±0.33 b	110.33±1.09 cd
G2	71.67±0.60 a	83.00±0.50 a	118.67±0.17 a
G3	63.33±0.60 d	72.33±0.67 d	110.67±0.60 c
G4	65.67±0.60 cd	78.00±0.76 b	115.33±0.33 b
G5	66.33±0.17 bc	76.33±0.17 bc	109.00±1.32 cd
G6	65.00±0.58 cd	75.33±0.73 c	113.33±0.73 b
G7	59.33±1.20 e	69.33±1.17 e	108.33±0.17 cd
G8	64.00±1.04 cd	74.67±0.83 cd	107.67±0.33 d
G9	54.33±0.60 f	63.33±0.17 f	104.67±0.60 e
G10	60.67±0.44 e	75.00±0.50 c	108.33±0.44 cd
Ss.	*	*	*

(V - variant; G1 - genotype 1, …., G10 - genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at p ≤ 0.05).

Tomatoes can be grown in both temperate and tropical areas. Tomato ripening is accompanied by changes in the color of the tomato fruit, which acquires shades of red, pink, yellow, orange, or even black, typical of numerous hybrids. The color change signals the production of specific acids and sugars that build the flavor of tomato fruits. Different researchers (Chernet et al., 2013; Dufera, 2013) reported a wide range of differences in maturity (73 - 93 days and 69 - 156 days) for 21 tomato genotypes and, respectively, for 36 tomato genotypes. Fayaz Ahmad et al. (2007) stated that early or late maturity is attributed to genotypic character and to the extent that it is influenced by environmental factors of a particular growing area. The results of our study regarding the cultivar show that the maximum number of days to reach fruit maturity was 118.83 days (G2), an indeterminate genotype being considered in our case among the latest genotypes. The minimum number of days is reached by G9 with 109.50 days from emergence, being considered to be the most typical. Mitul et al. (2016) demonstrated in the study of 14 tomato genotypes that the number of days until first flowering varies between 74.64 and 82.50 days, while the number of days until first ripening is between 128.60 and 135.10 days.

The Tabel 2 a and b show us how the crop system influences the number of days to fruit ripening. Therefore, in the conventional system, the G9 genotype obtains the lowest number, namely 104.67 days, and the highest is represented by G2 (118.67). When we refer to the organic system, the values for G1 (112.33), G6 (113.00), and G10 (112.67) are considered statistically similar, these genotypes being considered the earliest and most suitable for this type of system. The latest genotype is represented by G2 (119.00).

Morphological characterization describes plant species using expressed phenotypes (Table 3). This method identifies key agronomic traits that can help with breeding, crop production, and the preservation and use of germplasm. Also, morphological traits are important diagnostic features that can be used for distinguishing genotypes (Chime et al., 2017).

In our study, depending on the cultivar, the lowest fruit length (5.64 cm) was found in genotype G7, while the highest value (8.57 cm) was measured in the landrace 4. Glogovac et al. (2022) reported a variation in fruit length from 3.8 to 6.3 cm in twenty tomato genotypes.

Table 3. Morphological data depending on the cultivar

V	Fruit diameter	Fruit length	Fruit mass
G1	88.57±2.33 b	61.57±1.30 e	281.50±18.42 b
G2	79.71±1.40 c	66.38±0.89 d	238.10±10.64 c
G3	71.30±1.42 d	56.75±0.71 f	168.55±8.86 d
G4	86.95±2.15 b	85.75±1.50 a	308.22±14.32 b
G5	98.60±2.04 a	75.00±1.09 b	348.50±16.73 a
G6	73.07±1.15 d	60.79±0.64 e	178.08±6.02 d
G7	61.06±0.85 e	56.43±0.56 f	122.36±4.19 ef
G8	68.66±1.29 d	70.62±1.17 c	168.64±7.90 d
G9	67.48±0.90 d	59.24±0.64 ef	145.69±4.84 de
G10	50.50±0.48 f	60.74±0.61 e	84.77±1.85 f
Ss.	*	*	*

(V - variant; G1 - genotype 1, …., G10 - genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at p ≤ 0.05).

Referring to the crop system, the values are statistically significant, which proves that the way tomato plants are cultivated significantly influences the final results.

Table 4. Morphological data depending on the growing system: *a. organic*

V	Fruit diameter	Fruit length	Fruit mass
G1	75.75±2.14 b	55.06±1.02 de	178.40±11.18 c
G2	78.45±1.79 b	65.18±1.23 c	229.67±14.08 b
G3	64.43±1.09 cd	54.73±0.74 de	131.32±6.36 cde
G4	79.13±2.54 b	83.13±2.05 a	250.46±17.29 b
G5	93.92±2.77 a	74.70±1.54 b	322.63±23.26 a
G6	68.56±1.58 c	59.01±0.84 de	157.49±8.36 cd
G7	58.04±1.11 d	54.50±0.74 e	106.76±5.17 ef
G8	64.87±1.73 cd	65.37±1.19 c	139.05±8.82 cde
G9	64.75±1.16 cd	57.13±0.94 de	128.38±4.89 de
G10	49.32±0.69 e	59.63±0.94 d	78.29±2.17 f
Ss.	*	*	*

b. conventional

V	Fruit diameter	Fruit length	Fruit mass
G1	101.40±2.48 ab	68.08±1.70 c	384.60±22.86 a
G2	80.96±2.15 c	67.58±1.28 c	246.53±16.05 b
G3	78.17±1.94 cd	58.76±1.12 d	205.78±13.56 bc
G4	94.77±2.84 b	88.37±2.12 a	365.98±17.46 a
G5	103.29±2.78 a	75.31±1.56 b	374.36±23.50 a
G6	77.58±1.23 cde	62.57±0.86 d	198.67±6.97 bc
G7	64.07±1.05 g	58.35±0.70 d	137.96±5.26 de
G8	72.45±1.66 ef	75.87±1.51 b	198.22±10.74 bc
G9	70.21±1.19 fg	61.36±0.69 d	163.01±7.13 cd
G10	51.67±0.62 h	61.85±0.73 d	91.24±2.51 e
Ss.	*	*	*

(V - variant; G1 - genotype 1, …., G10 - genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at p ≤ 0.05).

In the conventional system (Table 4 b), the G4 genotype obtained the highest value for both fruit length (88.37 mm) and fruit weight (365.98 g). The latter value showed a statistically significant correlation with the G5 genotype (374.36 g). The lowest fruit length was recorded by G7 (58.35 mm), with values statistically similar to those obtained by G3, G6, G9, and G10. The minimum fruit weight was found in G10, with a value of 91.24 g.

Regarding fruit diameter, G5 exhibited the maximum value (103.29 mm), while G10 had the smallest (51.67 mm) (Table 4 b). Stoleru et al. (2020) reported fruit mass values ranging from 161 to 183 g, depending on the cultivar and cultivation system. In the organic system, the average fruit mass was 175 g, while in the conventional system, it was 160 g.

As a result of analysing the key indicators of the biochemical composition of tomato fruits, significant differences were observed among the studied accessions. One of the key indicators of tomato fruit quality and its technological properties is the dry matter (DM) content. In an experiment carried out in 2021, Kurina et al., 2021 demonstrated that the dry matter content in the fruits of cultivated tomatoes was in the range of 3.72-8.88% (Cv = 14.7%), and in the fruits of wild species - 9.62- 11.33% (Cv = 6.2%). Fruits with a high concentration of dry matter not only taste better but also yield more during processing, and offer superior transportability and longer shelf life during storage. In our study, the dry matter content did not show statistically significant differences across cultivars. The genotype values ranged from 4.24 to 5.39, with the highest value recorded for G4 and the lowest for G1. Regarding the cropping systems, the conventional system yielded similar results to the organic system, with values ranging from 3.87 to 5.82 in the conventional system, and from 4.19 to 6.18 in the organic system. These results suggest that the organic cropping system positively influences dry matter accumulation, as indicated by the higher values observed.TSS content has a significant impact on fruit flavor and increases yield while lowering dehydration costs during processing, making it a crucial indicator of technological quality. From a cultivar point of view, TSS varied from 4.55 in genotype G9, which is statistically similar to G10 (4.63) (Table 5), to 6.81°Brix in the traditional variety G2. Some researchers reported similar TSS variation from 2.02 to 4.57°Brix (Aoun et al., 2013), 3.4 to 6.8°Brix (Henareh et al., 2015), and 4.6 to 6.3°Brix (Glogovac et al., 2022).

Depending on the cultivation system, the genotype with the highest total soluble solids value in the conventional system was G2 (6.74), while the lowest value was observed in G9 (4.35), which was statistically similar to G10 (4.40) (Table 6 b). In a study of 12 tomato genotypes, Mahmoud and Osman, 2023 showed that total soluble solids ranged between 3.87 °Brix and 5.57. In the organic system, significant differences were observed, with values ranging from 4.75 (G9), statistically similar to G10 (4.87), to 7.00 (G5), which was statistically comparable to G2 (6.87) (Table 6 a). Swetha et al. (2018) demonstrate that the organic tomatoes have a 4.7 °Brix, while those inorganics have 4.1°Brix. Also, similar results (4.76 and 5.08°Brix) were obtained by de Zoran et al. (2014) in an organic system.

Table 5. Physiological characteristics depending on cultivar

V	TSS (%)	DM %	Water%	Lycopene mg 100 g $^{-1}$ F.W.	β-carotene mg 100 g $^{-1}$ F.W.
G1	5.78 ± 0.03 cd	4.24 ± 0.51	95.76 ± 0.51	8.37 ± 0.45	12.47 ± 0.91
G2	6.81 ± 0.04 a	5.02 ± 0.61	94.98 ± 0.61	9.09 ± 0.34	13.98 ± 0.67
G3	5.92 ± 0.03 bcd	4.87 ± 0.21	95.13 ± 0.21	8.17 ± 0.51	12.18 ± 0.92
G4	6.03 ± 0.06 bc	5.39 ± 0.47	94.61 ± 0.47	8.54 ± 0.35	12.80 ± 0.78
G5	6.40 ± 0.28 ab	4.30 ± 0.35	95.70 ± 0.35	8.38 ± 0.38	12.62 ± 0.71
G6	5.45 ± 0.06 d	4.25 ± 0.46	95.75 ± 0.46	8.02 ± 0.33	11.92 ± 0.59
G7	5.47 ± 0.09 d	5.09 ± 0.45	94.92 ± 0.45	7.71 ± 0.76	11.55 ± 1.41
G8	5.52 ± 0.14 d	5.32 ± 0.31	94.68 ± 0.31	8.56 ± 0.54	12.89 ± 1.10
G9	4.55 ± 0.10 e	4.64 ± 0.42	95.36 ± 0.42	7.60 ± 0.74	11.35 ± 1.31
G10	4.63 ± 0.11 e	5.23 ± 0.34	94.77 ± 0.34	7.77 ± 0.58	11.60 ± 1.02
Sf.	*	ns	ns	Ns	ns

(V - variant; G1 - genotype 1, …., G10 - genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at $p \leq 0.05$).

Table 6. Physiological characteristics depending on the growing system*: a. organic*

V	TSS (%)	DM %	Water%	Lycopene mg 100 g $^{-1}$ F.W.	β-carotene mg 100 g $^{-1}$ F.W.
G1	5.73 ± 0.02 bc	4.19 ± 0.97	95.81 ± 0.97	9.39 ± 0.03 bc	14.49 ± 0.06 b
G2	6.87 ± 0.06 a	6.18 ± 0.59	93.82 ± 0.59	9.85 ± 0.02 a	15.46 ± 0.04 a
G3	5.89 ± 0.06 bc	5.04±0.12	94.96 ± 0.12	9.31 ± 0.05 bc	14.24 ± 0.04 c
G4	6.00 ± 0.09 b	4.96 ± 0.66	95.04 ± 0.66	9.33 ± 0.03 bc	14.54 ± 0.04 b
G5	7.00 ± 0.18 a	4.31 ± 0.09	95.69 ± 0.09	9.23 ± 0.02 c	14.21 ± 0.06 c
G6	5.54 ± 0.03 cd	4.71 ± 0.51	95.29 ± 0.51	8.75 ± 0.07 e	13.24 ± 0.11 e
G7	5.30 ± 0.05 d	5.68 ± 0.02	94.32 ± 0.02	9.41 ± 0.03 b	14.71 ± 0.03 b
G8	5.82±0.04 bc	5.44 ± 0.04	94.56 ± 0.04	9.76 ± 0.01 a	15.35 ± 0.01 a
G9	4.75 ± 0.08 e	4.72 ± 0.56	95.28 ± 0.56	9.24 ± 0.00 c	14.27 ± 0.03 c
G10	4.87 ± 0.08 e	5.25 ± 0.75	94.75 ± 0.75	9.07 ± 0.03 d	13.88 ± 0.03 d
Ss.	*	ns	ns	*	*

(V - variant; G1 - genotype 1, …., G10 - genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at $p \leq 0.05$).

b. conventional

V	TSS (%)	DM %	Water%	Lycopene mg 100 g $^{-1}$ F.W.	β-carotene mg 100 g $^{-1}$ F.W.
G1	5.82 ± 0.05 bc	4.29 ± 0.60	95.71 ± 0.60	7.36 ± 0.04 cd	10.4 ± 0.07 c
G2	6.74 ± 0.03 a	3.87 ± 0.41	96.13 ± 0.41	8.32 ± 0.02 a	12.49 ± 0.01 a
G3	5.95 ± 0.04 bc	4.69 ± 0.43	95.31 ± 0.43	7.03 ± 0.03 e	10.11 ± 0.03 d
G4	6.05 ± 0.09 b	5.82 ± 0.69	94.18 ± 0.69	7.76 ± 0.02 b	11.05 ± 0.10 b
G5	5.80 ± 0.12 bc	4.30 ± 0.77	95.70 ± 0.77	7.54 ± 0.02 c	11.03 ± 0.01 b
G6	5.36 ± 0.09 de	3.80 ± 0.77	96.20 ± 0.77	7.28 ± 0.01 d	10.60 ± 0.01 c
G7	5.63 ± 0.10 cd	4.49 ± 0.80	95.51 ± 0.80	6.02 ± 0.01 g	8.39 ± 0.01 f
G8	5.21 ± 0.07 e	5.20 ± 0.68	94.80 ± 0.68	7.36 ± 0.01 cd	10.43 ± 0.05 c
G9	4.35 ± 0.08 f	4.56 ± 0.74	95.44 ± 0.74	5.95 ± 0.12 g	8.43 ± 0.16 f
G10	4.40 ± 0.02 f	5.22 ± 0.07	94.78 ± 0.07	6.47 ± 0.01 f	9.31 ± 0.02 e
Ss.	*	ns	ns	*	*

(V - variant; G1 - genotype 1, …., G10 - genotype 10; Ss. - statistical significance: * significative, ns – insignificant; Values represent the average ± standard error. Within each column, different letters mean significant differences between variants, according to Tukey's test at p ≤ 0.05).

A mature tomato fruit consists of approximately 90-95% water, with the remaining 5-10% being dry matter, predominantly carbohydrates (Wang et al., 2011). Rusu et al. (2023) observed that the water content of tomatoes varies depending on the cultivar, ranging from 93.59% to 94.03%. In our study, water content varied from 64.61% in cultivar G4 to 95.76% in cultivar G1. In the conventional cultivation system, water content ranged from 94.18% (G4) to 96.20% (G6), while in the organic system, it ranged from 93.83% (G2) to 95.81% (G1). Additionally, Kondratyeva and Molchanova (2022) reported that the water content of four tomato genotypes ranged between 92.5% and 95.1%.

Tomatoes and their derivatives are abundant in carotenoids, including lycopene, ascorbic acid, and phenolic compounds, all of which contribute to their nutritional value, colour, and flavour. Genetics, ripeness, and environmental factors all affect tomato composition (Shah et al., 2015). The carotenoid content, particularly lycopene, is a critical determinant of tomato quality. Studies have shown that the concentration of lycopene varies significantly with the maturity of the fruit, with mature tomatoes exhibiting higher levels compared to immature ones (Park et al., 2018). Additionally, the cultivar plays a crucial role in determining carotenoid profiles; for instance, certain cultivars like cherry tomatoes have been reported to possess higher levels of β-carotene and total carotenoids compared to standard varieties (Figàs et al., 2015).

Environmental factors, such as salinity and fertilization, also influence carotenoid accumulation, demonstrating the complex interplay between genetics and growing conditions (Paolo et al., 2018). Carotenoid concentrations have been shown to vary significantly among different tomato cultivars, with traditional varieties in particular offering a broad source of genetic diversity (Cortés-Olmos et al., 2014; Kavitha et al., 2014). Pandurangaiah et al. (2020) demonstrate that among the tomato lines was a significant difference in the total carotenoid content. The dark red fruit contained the highest carotenoid content with 23.80 mg/ g^{-1} F.W. The lycopene content ranged between 0.85 and 15.10 mg/ g^{-1} F.W. The least amount of carotene content was 0.80, and the highest content was represented by 8.56 mg/ g^{-1} F.W. In our study, depending on the cultivar, the lycopene content values ranged between 7.60 (G9) and 9.09 mg/g^{-1} F.W. (G2), and those in beta carotene ranged between 11.35 (G9) and 13.98 mg/g^{-1} F.W. (G2).

From a statistical point of view, no significant differences were observed between the results. The conventional system showed statistically significant differences in both lycopene and beta carotene content.

The highest levels for both compounds were found in the G2 genotype, with a maximum of 8.32 for lycopene and 12.49 mg/ g^{-1} F.W for beta carotene. On the other hand, the G9 genotype exhibited the lowest lycopene content at 5.95 mg/ g^{-1} F.W, while the G7 genotype had a beta carotene content of 8.39, which was statistically similar to G9's value of 8.43 mg/ g^{-1} F.W. In the organic system, the obtained values were noticeably higher. The highest values were achieved by G2 (9.85) and G8 (9.76), which were statistically similar, while the lowest values were 15.46 and 15.35, respectively.

CONCLUSIONS

The selection of cultivar is a critical factor in shaping the quality characteristics of tomatoes. Furthermore, the genetic composition of tomato cultivars plays a significant role in the accumulation of beneficial compounds, such as carotenoids and phenolic compounds, which are vital for both nutritional value and sensory appeal. Regardless of the crop system or genotype studied, the highest values in terms of plant height and diameter at the base were obtained by the G5 genotype, an indeterminate cultivar, and the lowest values were obtained by the G10 genotype.

When focusing solely on the cultivar, the genotype with the longest time to fruit ripening is G4, taking approximately 117 days, while the earliest is the determinate growth genotype, G9, at 109.5 days. In the conventional system, the genotype with the shortest ripening period is G9, at 104.67 days, while the longest period is observed in G2, which takes 118.67 days. In the organic system, G1 is the most suitable genotype in terms of the earliest appearance of ripe fruits, taking 112.33 days, while G2 again has the longest period at 119 days.

Variation in fruit morphology is a prevalent characteristic among cultivated tomato. Regarding the organic system and the cultivars studied, the genotypes with the highest values obtained regarding the biometric measurements of the fruits were G5 for fruit diameter, G4 for fruit length and G5 for fruit weight. For the conventional system the maximum values were reached by G5 for diameter, and G4 for fruit length and fruit weight.

When examining the physiological characteristics according to cultivar, significant differences were observed in total soluble solids (TSS). The G2 cultivar achieved the highest value, indicating firmer fruits with a longer storage life, while G9 exhibited the lowest TSS value. No significant differences were found in dry matter, water percentage, beta carotene, or lycopene content across the cultivars.

Regarding the growing system, in organic cultivation, the G2 cultivar performed best in terms of the qualitative traits studied, while G9 and G10 had the lowest values for TSS, and G6 had the lowest for both lycopene and beta carotene. In conventional cultivation, no significant differences were found for dry matter and water percentage. However, the highest TSS and lycopene values were seen in G2, while G10 had the lowest for TSS and lycopene, and G9 had the lowest for beta carotene.

Preliminary analyses revealed the variability among accessions for all the evaluated traits, providing criteria to identify landraces that were less adapted to greenhouse conditions or that responded poorly to the management practices. This information will help in selecting the varieties to be included in the next experimental trial.

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