




Efficiency of different organza mesh for tomato production under a low tunnel

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ABSTRACT: New non-agricultural materials, such as organza, have been tested in research and emerge as an innovative approach for tomato cultivation in tropical regions. This study assessed the effectiveness of various organza mesh types in low tunnels, specifically comparing voile organza, crystal organza, and open field conditions, using two determinate tomato hybrids (Fascínio and Thaíse). The main factors analyzed included environmental parameters, production metrics, physical fruit characteristics, and biochemical attributes. Results showed that air temperatures were lowest in the voile organza environment, with similar trends in light intensity, leaf, and fruit temperatures. Both organza types achieved higher commercial and total production compared to open field cultivation, with increases in commercial production of up to 52.2%, along with greater percentages of commercial fruits, total mass, and commercial mass. Biochemical analysis indicated that total soluble solids, lycopene, and β -carotene levels were higher in open field tomatoes. Thaíse exhibited a greater percentage of commercial fruits, while Fascínio had higher levels of lycopene and β -carotene. Despite some biochemical attributes being superior in open field tomatoes, the overall advantages of protected cultivation highlight its viability for optimizing tomato production in challenging climates.

Keywords: *Solanum lycopersicum* L.; protective nets; protected cultivation; fruit quality.

Eficiência de diferentes malhas de organza para produção de tomate em túnel baixo

RESUMO: Novos materiais não agrícolas, como a organza, têm sido testados em pesquisas e despontam como uma abordagem inovadora para o cultivo do tomateiro em regiões tropicais. Este estudo avaliou a eficácia de diferentes tipos de malha de organza em túneis baixos, comparando especificamente organza voil, organza cristal e condições de campo aberto, com duas cultivares (Fascínio e Thaíse). Os principais fatores analisados incluíram parâmetros ambientais, métricas de produtividade, características físicas dos frutos e atributos bioquímicos. Os resultados mostraram que as temperaturas do ar foram mais baixas no ambiente de organza voil, com tendências semelhantes na intensidade da luz, e nas temperaturas das folhas e frutos. Ambos os tipos de organza alcançaram maior produtividade comercial e total em comparação ao cultivo em campo aberto, com incrementos na produção comercial de até 52,2%, além de maiores porcentagens de frutos comerciais, de massa total e de massa comercial. A análise bioquímica indicou que os sólidos solúveis totais, assim como os níveis de licopeno e de β -caroteno, foram mais elevados em tomates de campo aberto. Thaíse apresentou maior porcentagem de frutos comerciais, enquanto Fascínio apresentou níveis mais altos de licopeno e β -caroteno. Apesar de alguns atributos bioquímicos serem superiores em tomates de campo aberto, as vantagens gerais do cultivo protegido ressaltam sua viabilidade para otimizar a produção de tomate em climas desafiadores.

Palavras-chave: *Solanum lycopersicum* L.; redes protetoras; cultivo protegido; qualidade dos frutos.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the world's most widely cultivated fruit vegetable. In 2023, global production reached more than 192 million tons, with Brazil ranking eighth among the largest producers, accounting for 4,166,017 tons (FAOSTAT, 2025). The significance of tomato consumption is closely linked to its chemical composition, as it is an important source of micronutrients and contains high

levels of bioactive compounds such as lycopene and β -carotene (SEABRA JÚNIOR et al., 2022).

To maintain the quality of tomatoes, it is necessary to consider the environmental conditions of the cultivation. Open field cultivation, for example, is particularly challenging because extreme temperature variations and irregular precipitation can affect the growth and development of the plants. Additionally, direct exposure to pests and diseases is

more intense in open environments, which can result in significant losses in production and fruit quality (VALLAD et al., 2018; DOUST et al., 2023).

The use of protective screens or shading nets in agriculture offers numerous advantages that contribute to improved crop health and production. These screens effectively regulate light exposure, reducing excessive sunlight while optimizing the light spectrum for plant growth. By mitigating thermal stress and photoinhibition, they promote favorable physiological responses in plants, enhancing overall production and the accumulation of beneficial compounds. Additionally, protective screens serve as a barrier against insect pests, reducing the need for chemical pesticides and fostering a more sustainable farming approach. With a variety of materials available – such as organza made from silk, polyester, and polyamide – these screens can be tailored to specific environmental conditions and crop requirements, ensuring versatility and effectiveness in diverse agricultural settings (CARVALHO et al., 2014; MAHMOOD et al., 2018; SEABRA JÚNIOR et al., 2019).

Despite these advantages, there remains an urgent need for further studies exploring the application of various agricultural species and types of shading nets. This research aims to address this gap by evaluating the effectiveness of different organza meshes (specifically voile and crystal organza) in enhancing tomato production under low tunnels. We seek to determine whether these specific types of organza can impact the morphophysiological and biochemical parameters of tomato plants. By investigating these factors, we aim to provide insights into the differences between shaded net cultivation and open field conditions for tomato plants, which could assist in enhancing agricultural practices.

2. MATERIAL AND METHODS

2.1. Location

The study was conducted in the experimental area of the Nova Mutum University Campus (UNEMAT), located at the geographical coordinates of latitude 13°49'44" S, longitude 56°04'56" W, and an altitude of 460 meters, in the municipality of Nova Mutum, Mato Grosso, Brazil. The region's climate is classified as hot and semi-humid tropical, with two well-defined seasons: a dry season (May to September) and a rainy season (October to April). The average annual temperature is 24°C, with an annual precipitation of 2,200 mm.

2.2. Treatments and experimental design

Six treatments were arranged in a 3 x 2 factorial scheme, consisting of three cultivation environments and two tomato cultivars, each with four replicates. The evaluated environments included an open field (no coverage) and two types of protective meshes (voile organza and crystal organza), installed under low tunnels. Each experimental plot consisted of eight plants, spaced at 1.2 x 0.40 m.

2.3. Environmental monitoring

Light intensity in the environments was measured using a Testo 540 lux meter, positioned above the beds to capture internal light levels. Light values were recorded in lux and are presented as kilolux (klux) for clarity (1 klux = 1000 lux), representing relative differences in light availability among environments. The air temperature was monitored using a digital HM-02 thermohygrometer, installed in the plant canopy.

2.4. Installation of protected environments

Low tunnels were constructed using half-inch diameter PVC pipes, each 3 m in length, to form arches. The arches were secured to the ground using 0.5 m iron rebars, which were buried 0.3 m deep along the sides of the planting beds. Each bed was equipped with eight arches for structural support.

2.5. Seedling production, soil preparation, and fertilization

A tomato crop cycle was planned, with sowing conducted on June 14, 2019. Tomato seedlings were grown in a nursery under a protected environment covered with polyethylene plastic film. Expanded polystyrene trays with 162 cells filled with commercial substrate were used for seedling production. Fertilization with a 10 g·L⁻¹ of 10-10-10 fertilizer (N-P-K) was performed 15 days after sowing.

Soil preparation began with the collection of soil samples from the experimental area for physicochemical analysis. For tomato cultivation, fertilization was achieved through the incorporation of 10 tons per hectare of cured chicken manure into the planting bed soil. The chemical composition of the dry matter includes key elements: nitrogen (N) measured by the Kjeldahl method at 1.08%, phosphorus (P) at 2.25%, potassium (K) at 2.32%, calcium (Ca) at 17.22%, magnesium (Mg) at 0.68%, and sulfur (S) at 0.87%. Additionally, micronutrients such as zinc (Zn) at 730 ppm, iron (Fe) at 18 ppm, manganese (Mn) at 658 ppm, copper (Cu) at 106 ppm, and boron (B) at 43.6 ppm were also analyzed. The carbon to nitrogen ratio (C/N) of the manure was found to be 5.77, with a pH of 7.38 in water and a moisture content of 27.36%. Additionally, chemical fertilization was based on the results of the soil analysis, applying 10% nitrogen (N), 100% phosphorus pentoxide (P₂O₅), and 10% potassium oxide (K₂O) at planting. After transplanting, the remaining nitrogen and potassium fertilizers were applied every three days to ensure optimal nutrient availability for the tomato plants.

Doses were adjusted throughout the cycle: 3% N and 4% K₂O until 55 days after sowing, 4% N and 4.3% K₂O until 83 days, and 3% N and 3% K₂O until the end of the cycle (115 days after sowing). Fertilizers were supplied via fertigation. The sources used included 04-14-08 compound fertilizer and single superphosphate (18% P₂O₅) for initial fertilization, while potassium nitrate (13% N, 46% K₂O) and urea (45% N) were used for fertigation applications.

The beds measured 23 m in length, 1.20 m in width, and 0.20 m in height, covered with white-faced mulch film. Irrigation was conducted using a drip system to ensure uniform water distribution. Irrigation was implemented using a pressure-compensating drip irrigation system (Rain Bird®, Raindrop 8 mm dripline), which operates at a nominal flow rate of 1.23 liters per hour at a pressure of 1.0 bar. The tomatoes received an irrigation depth of approximately 2.0 mm per day, achieved during a 30-minute irrigation cycle.

2.6. Morphological analyses

All ripe fruits from the five central plants were evaluated until the end of the tomato production cycle. With each harvest, the characteristics of total and marketable fruit production were analyzed, including the total number of fruits and the number of marketable fruits. Additionally, the thickness of the fruit wall and peduncle, as well as the

performance of the tomato cultivars, were assessed in the different growing environments. Measurements were obtained using a digital caliper (Mitutoyo®, model 500-196-30), featuring an accuracy of ±0.02 mm.

2.7. Biochemical analyses

The content of total soluble solids, vitamin C, maturity and precocity index, titratable acidity, lycopene, and β-carotene was evaluated.

Total soluble solids, expressed in °Brix, were measured using a digital refractometer (Meiyya; n = 3).

Vitamin C content was determined according to AOAC (AOAC, 2020). The sample was thawed at room temperature, and a 20 mL aliquot was diluted in 50 mL of 1% oxalic acid. This mixture was titrated with 0.02% sodium 2,6-dichlorophenolindophenol until a pink color developed, with results expressed in mg per 100 g. The maturity index was calculated by dividing the TSS results by titratable acidity (TA). The fruit production precocity index was determined using the following equation, expressed as a percentage:

$$IP = \frac{(PC1 + PC2 + PC3)}{PCM} \times 100 \quad (01)$$

where: IP = precocity index; PC = commercial production from the first three harvests; PCM = total commercial production.

Titratable acidity was determined using a 20 mL sample of pulp diluted in 100 mL of CO₂-free distilled water. The solution was titrated with 0.1 M NaOH until reaching a pH of 8.2, with results expressed as a percentage.

Lycopene and β-carotene were determined following the methods of Nagata and Yamashita (1992). A 1 mL aliquot of pulp was mixed with 4 mL of acetone and 6 mL of hexane, vortexed for 20 seconds. After phase separation, the supernatant was collected, and absorbance readings were taken at 505 nm and 453 nm using a spectrophotometer. Carotenoid levels were expressed in mg per 100 g of fresh matter.

2.8. Statistical analysis

After normality analysis, the data were subjected to analysis of variance and homogeneity. When significant, the data were further analyzed using the Scott-Knott test at p < 0.05, utilizing SISVAR software (version 5.3). The data are presented in the tables and figures, considering the types of cultivation and the cultivars. For the data that did not show interaction between the types of cultivation and the cultivar, only the mean values were displayed. The mean for both cultivars was used for the types of cultivation, as well as the mean values for each cultivar. This way, it is possible to demonstrate whether there is an effect of the screens on the environmental, morphological, and biochemical data.

3. RESULTS

3.1. Environmental parameters

The highest air temperatures were recorded in the environment covered with crystal-type organza mesh (47.15°C) and in the open field (43.62°C). The voile organza cover resulted in a maximum air temperature reduction of 2.61°C compared to the open field, which corresponds to a decrease of 6% (41.01°C). Conversely, the crystal organza increased the air temperature by 3.53°C relative to the open field, representing an increase of 8.1% in maximum air

temperature. In terms of minimum temperatures, similar readings were observed, with the crystal environment at 16.48°C, the open field at 16.89°C, and the voile environment at 17.75°C (Table 1).

Table 1. Average leaf and fruit temperature (°C) of tomato plants cultivated under different net types (voile organza and crystal organza) in low tunnel and open field environments.

Tabela 1. Temperatura média das folhas e frutos (°C) de plantas de tomate cultivadas sob diferentes tipos de rede (voile organza e cristal organza) em ambientes de túnel baixo e campo aberto.

		Leaf temp.	Fruit temp.
Environment	Open field	28.61 a	30.88 a
	Voile organza	22.53 b	24.55 b
	Crystal organza	24.13 b	25.62 b
Cultivar	Fascínio	24.56 a	26.91 a
	Tháise	25.61 a	27.12 a
C.V.(%)		7.11	6.53

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation.

*Médias seguidas por letras diferentes nas colunas verticais diferem significativamente pelo teste de Scott-Knott com probabilidade de 5%. C.V. – Coeficiente de variação.

Regarding the thermal amplitude provided by the environments, the low tunnel with a crystal organza cover recorded the highest average air temperature at 30.67 °C, which is 3.94 °C higher than the open field conditions (23.26 °C). In contrast, the lowest amplitude was observed under the voile organza cover, which also averaged 23.26 °C (Table 1). When analyzing light intensity, the voile organza (82.5 klux) and crystal organza (94.3 klux) coverings resulted in reductions in the luminosity of 26% and 16%, respectively, compared to the open field, which averaged 112.0 klux. The greater light blockage provided by the voile organza may have contributed to the lower temperatures observed in both the environment and the soil within that tunnel (Table 1).

Regarding leaf and fruit temperatures, no significant differences were observed among the cultivars. However, there were significant differences between the environments, with both net types showing reduced temperatures compared to the open field. Specifically, reductions of 21% and 15% were noted for leaf temperatures under voile organza and crystal organza, respectively, and reductions of 20% and 17% were observed for fruit temperatures (Table 1).

3.2. Morphological parameters

Upon analyzing the morphological parameters, no statistical difference was observed between cultivars. However, when compared to open-field cultivation, the use of voile organza and crystal organza promoted increases in production: total yield rose by 18.5% and 32.6%, while commercial yield showed even more substantial gains of 38.0% and 52.2%, respectively (Table 2).

For the total fruit and commercial fruit variables, the different cultivation types did not show significant differences among themselves. However, the cultivation methods did exhibit notable differences. For total fruits, the environments using voile and crystal organza showed increases of 23% and 19%, respectively, compared to open field conditions. The same pattern was observed for commercial fruits, with increases of 23% and 19%, respectively, when using voile and crystal organza compared to the open field (Table 3).

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Table 2. Averages of total and commercial production (t ha⁻¹), total and commercial production (t ha⁻¹) across different organza types (voile organza and crystal organza) for low tunnel and open field cultivation environments.

Tabela 2. Médias da produção total e comercial (t ha⁻¹) em diferentes tipos de organza (organza voile e organza cristal) para ambientes de cultivo em estufa e campo aberto.

		Total production	Commercial production
Environment	Open field	74.16 b	54.10 b
	Voile organza	87.91 a	74.68 a
	Crystal organza	98.30 a	82.30 a
Cultivar	Fascínio	86.23 a	67.84 a
	Thaíse	87.35 a	72.88 a
C.V.(%)		12.70	14.59

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation.

Table 3. Averages of total and commercial fruits (n./plant) across different organza types (voile organza and crystal organza) for low tunnel and open field cultivation environments.

Tabela 3. Médias de frutos totais e comerciais (n./planta) em diferentes tipos de organza (organza voile e organza cristal) para ambientes de cultivo em estufa e campo aberto.

		Total fruits	Commercial fruits
Environment	Open field	89.81 b	83.41 b
	Voile organza	107.64 a	102.96 a
	Crystal organza	105.98 a	99.33 a
Cultivar	Fascínio	99.93 a	93.22 a
	Thaíse	102.35 a	97.25 a
C.V.(%)		8.35	11.28

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation.

In terms of average total and commercial mass, cultivation in protected environments proved superior to open fields. The average total mass was 23.44% higher in the cultivation with voile organza compared to open fields and 19.09% higher with crystal organza. The average commercial mass for the cultivation with voile organza increased by 19.85% compared to open fields, while crystal organza allowed for an 18% increase (Table 4).

Table 4. Averages of total mass and commercial mass (g/plant) across different organza types (voile organza and crystal organza) for low tunnel and open field cultivation environments.

Tabela 4. Médias da massa total e da massa comercial (g/planta) em diferentes tipos de organza (organza voile e organza cristal) para ambientes de cultivo em túnel baixo e campo aberto.

		Total mass	Commercial mass
Environment	Open field	83.41 b	89.81 b
	Voile organza	102.96 a	107.64 a
	Crystal organza	99.33 a	105.98 a
Cultivar	Fascínio	93.22 a	99.93 a
	Thaíse	97.25 a	102.35 a
C.V.(%)		11.28	8.35

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation.

For the physical characteristics of the fruit, wall thickness in tomato cultivars showed no significant differences among the cultivars. However, the Fascínio cultivar showed superior

results for the peduncle scar, with an average of 11.16 mm, while the Thaíse cultivar had an average of 9.12 mm (Table 5). When analyzing by cultivation type, it was noted that the wall thickness was greater when using organza fabric (6.58 mm), which statistically differed from the others, which had the same average of 6.00 mm. Regarding the peduncle scar, a higher measurement was recorded (11.32 mm), statistically differing from the other cultivation environments (Table 5).

Table 5. Average wall thickness and peduncular scar (millimeters), of tomato fruits cultivated among different mesh types (voile organza and crystal organza) for low tunnel and open field growing environments.

Tabela 5. Espessura média da parede e cicatriz do pedúnculo (milímetros) de frutos de tomate cultivados em diferentes tipos de tela (voile organza e cristal organza) em ambientes de cultivo em túnel baixo e campo aberto.

		Wall thickness	Peduncular scar
Environment	Open field	6.00 b	11.32 a
	Voile organza	6.58 a	9.80 b
	Crystal organza	6.00 b	9.31 b
Cultivar	Fascínio	6.27 a	11.16 a
	Thaíse	6.11 a	9.12 b
C.V.(%)		5.07	7.79

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation.

3.3. Biochemical parameters

Based on this analysis, it was observed that fruits from all cultivation types could be marketed for fresh consumption (Table 6). The total soluble solids (TSS) measurements revealed values of 3.54 °Brix for the Fascínio cultivar and 3.51 °Brix for the Thaíse cultivar, with no statistical differences between them. Among the cultivation environments, a statistical difference was recorded between voile organza (3.49 °Brix) and crystal organza (3.38 °Brix), which was lower than that recorded in open fields (3.70 °Brix).

For the levels of vitamin C, an interaction between cultivars and environments was observed; thus, the data are presented in a factorial manner. For the environments, no statistical differences were found for the cultivar Fascínio. However, for the cultivar Thaíse, the open field environment yielded the highest mean (15.78 mg/100 g), significantly differing from the voile organza and crystal organza environments. Conversely, when considering the differences between cultivars, it is noted that the fruits of the Fascínio cultivar, grown under organza covers, exhibited the highest values (12.53 mg/100 g in voile organza and 13.72 mg/100 g in crystal organza) compared to Thaíse (8.85 mg/100 g in voile organza and 9.75 mg/100 g in crystal organza). Therefore, an increment of 41% was observed for Fascínio in the cultivation under voile organza and 40% under crystal organza compared to Thaíse (Table 6).

Regarding titratable acidity (TA), it was found that for the cultivar Fascínio, the tunnel with voile organza (0.22 g/100 g) differed statistically from both crystal organza and open field, which had higher values (0.25 and 0.26 g/100 g, respectively). For the cultivar Thaíse, higher acidity levels were observed when using both organza tunnels, with no statistical difference between them (0.23 g/100 g for voile organza and 0.27 g/100 g for crystal organza), but differing from the open field (0.21 g/100 g). When considering the

differences between cultivars, only the open field result was statistically distinct, with Fascínio (0.26 g/100 g) being superior to Thaíse (0.21 g/100 g) (Table 6).

Table 6. Average levels of vitamin C (mg/100 g), and titratable acidity (TA, g/100 g) of pulp of tomato fruits cultivated under different mesh types (voile organza and crystal organza) for low tunnel and open field growing environments.

E	Vitamin C		TA	
	Fascínio	Thaíse	Fascínio	Thaíse
OF	11.67 aB	15.78 aA	0.26 aA	0.21 bB
VO	12.53 aA	8.85 bB	0.22 bA	0.23 bA
CO	13.72 aA	9.75 bB	0.25 aA	0.27 aA
C.V.(%)	18.31		6.39	

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation. E – environment; OF – open field; VO – voile organza; CO – crystal organza.

*Médias seguidas por letras diferentes nas colunas verticais diferem significativamente pelo teste de Scott-Knott com probabilidade de 5%. C.V. – Coeficiente de variação. E – ambiente; OF – campo aberto; VO – organza voile; CO – organza cristal.

Regarding the precocity index, the Fascínio cultivar showed better results when grown in open fields (2.06%), statistically differing from those cultivated under organza screens. In contrast, the Thaíse cultivar exhibited a higher value with crystal organza (2.39%). When comparing the cultivars, a statistical difference was observed in open field cultivation, with Fascínio displaying a higher precocity index, whereas crystal organza favored the Thaíse cultivar (Table 7).

In terms of maturity index (TSS/TA ratio), no statistical differences were found for the Fascínio cultivar across different cultivation types. However, for the Thaíse cultivar, the lowest maturity index was recorded when grown under crystal organza (11.72), compared to open fields (16.08) and voile organza (15.03). Among the cultivars, a statistical difference was observed only in open field conditions, where the Thaíse cultivar had a higher index (16.08) compared to Fascínio (13.43) (Table 7).

Table 7. Average precocity index (%) and maturity index (TSS/TA ratio) of tomato fruits cultivated under different mesh types (voile organza and crystal organza) for low tunnel and open field growing environments.

Tabela 7. Índice médio de precocidade (%) e índice de maturação (relação SST/AT) de frutos de tomate cultivados sob diferentes tipos de tela (voile organza e cristal organza) em ambientes de cultivo em túnel baixo e campo aberto.

E	Precocity index		TSS/TA	
	Fascínio	Thaíse	Fascínio	Thaíse
OF	2.06 aA	1.16 bB	13.43 aB	16.08 aA
VO	1.05 bA	1.76 bA	15.55 aA	15.03 aA
CO	1.15 bB	2.39 aA	13.66 aA	11.72 bA
C.V.(%)	34.95		9.98	

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation. E – environment; OF – open field; VO – voile organza; CO – crystal organza.

In the analysis of pigments, lycopene and β -carotene, a similar pattern was observed for both, with open-field cultivation showing superior results compared to tomatoes grown under organza tunnels, with values of 3.1 mg/100 g and 0.6 mg/100 g, respectively. Among the cultivars, Fascínio exhibited higher concentrations than Thaíse for

both pigments, with values of 3.3 mg/100 g and 0.6 mg/100 g, respectively (Table 8).

Table 8. Average levels of lycopene and β -carotene (mg/100 g) in tomato fruits cultivated under different mesh types (voile organza and crystal organza) for low tunnel and open field growing environments.

Tabela 8. Níveis médios de licopeno e β -caroteno (mg/100 g) em frutos de tomate cultivados sob diferentes tipos de tela (voile organza e cristal organza) em ambientes de cultivo em túnel baixo e campo aberto.

		Lycopene	β -carotene
		Environment	Open field
	Voile organza	2.3 b	0.4 b
	Crystal organza	2.2 b	0.5 b
Cultivar	Fascínio	3.3 a	0.6 a
	Thaíse	1.7 b	0.4 b
C.V.(%)		16.67	22.06

*Means followed by different letters in the vertical columns differ significantly by the Scott-Knott test at 5% probability. C.V. – Coefficient of variation.

4. DISCUSSION

Regarding environmental parameters, temperature is a critical climatic factor influencing tomato cultivation. Filgueira (2013) indicates that optimal temperatures for tomato production range from 21-28 °C during the day and 15-20 °C at night, promoting leaf expansion, light interception, flowering, and fruit development, which leads to early production. However, temperatures below 10 °C or above 36 °C can severely affect the crop (Alvarenga, 2013).

Therefore, modifying air temperature with low tunnels plays an important role in alleviating physiological stress in plants through specific biochemical pathways. This adjustment can also reduce post-harvest disorders (SEABRA JÚNIOR et al., 2019). The effectiveness of this approach is influenced by the type of covering used; for instance, while the voile type is effective in lowering air temperatures, the crystal type has been shown to raise them.

The purpose of protected environments is to create a microclimate that enhances plant development and production. These environments can alter the incident light spectrum, affecting internal luminosity (SEABRA JÚNIOR et al., 2019). Light plays a significant role in crop growth, development, and yield. Within the non-limiting range, increased irradiance enhances canopy carbon assimilation and photoassimilate production, thereby supporting vegetative growth and fruit development (HEUVELINK et al., 2025). However, under excessive light conditions, often associated with higher leaf temperature and vapor pressure deficit, plants tend to increase transpiration and reduce stomatal conductance to prevent excessive water loss, which limits CO₂ diffusion into the leaf and constrains photosynthesis, ultimately decreasing production (ZHAO et al., 2025).

Regarding morphological and production parameters, recent studies indicate that tomato plants grown under protected or moderated light environments tend to exhibit superior growth and yield compared with those cultivated under excessive radiation. Heuvelink et al. (2025) demonstrated that optimizing light conditions enhances canopy carbon assimilation and biomass partitioning, resulting in improved plant growth and fruit production. Conversely, under open-field or high-radiation conditions,

excessive irradiance combined with high evaporative demand can increase transpiration and induce stomatal limitation, thereby restricting CO₂ assimilation and reducing photosynthetic performance, which ultimately compromises growth and yield (ZHAO et al., 2025). In this context, shading screens play a key role in mitigating excessive radiation and vapor pressure deficit, creating a more favorable microclimate for plant development and production (HEUVELINK et al., 2025; ZHAO et al., 2025).

Thus, the enhancement in tomato production can be credited to controlled light intensity, as well as the leaf and fruit temperatures provided by organza coverings. Proper management of these parameters through tunnel usage maximizes returns while minimizing inputs, thereby reducing energy expenditure. This directly impacts tomato development and growth, playing a crucial role in preventing crop stress (SHAMSHIRI et al., 2018). Consequently, there is less loss in production due to poor fruit formation from physiological disturbances, as well as reduced losses from pest attacks, since these environments also act as physical barriers against harmful insects and animals.

Based on the findings, open field conditions are not ideal for cultivation, as fruits produced in such environments tend to have lower mass due to high light exposure and adverse climatic conditions. This negatively affects their physicochemical quality, resulting in blemishes and nutritional disorders. The importance of protected cultivation environments is thus underscored, as this technology addresses specific limitations related to enhancing solar radiation capture, improving light utilization through the diffusion of solar rays (FERNÁNDEZ et al., 2018).

Among the biochemical parameters, soluble solids – primarily composed of sugars (approximately 85 to 90%) – are responsible for fruit flavor, linking this characteristic to taste and palatability (Santos et al., 2018). Soluble solids influence yield, consistency, and final product quality (SIDDIQUI et al., 2015). Genotypes producing fruits with a soluble solids content above 3 °Brix can be marketed as fresh fruit (SCHWARZ et al., 2013). Therefore, the values observed are within the acceptable range for fresh consumption.

It was found that the TSS content was higher in the open field compared to protected environments. The results indicate that this factor is influenced by stress conditions associated with high temperatures, low humidity, and high solar radiation. These conditions stimulate the fruits to produce higher levels of sugars, acids, and bioactive compounds (ARAYA et al., 2021). Scott; Lawrence (1975) assert that high temperatures influence fruit quality by increasing the synthesis of secondary compounds, allowing plants to accumulate higher concentrations of soluble sugars. Shading can reduce levels of sugar, ascorbic acid, and pigments in tomatoes (ABREU et al., 2019; TAMIM et al., 2022).

In terms of vitamin C, the Thaíse cultivar generally exhibited higher content when grown in an open field, supported by Murariu et al. (2021), who reported a higher value (18.57 mg/100 g) for outdoor cultivation compared to those grown in plastic tunnels. This may relate to direct light exposure, which promotes greater accumulation of this antioxidant. Increased vitamin C levels are also noted under conditions of low nitrogen availability, such as full sunlight and drought. Regarding titratable acidity, which refers to organic acid quantities in plant cells and tissues, this factor

influences flavor, microbial stability, and storage quality (ODEDIRAN et al., 2023). Murariu et al. (2021) found significant variation in their study, ranging from 0.19% to 0.57%, depending on genotypes and cultivation environments. This variation was also observed in our study, albeit with a narrower range (0.21 to 0.27 g/100 g). Tomatoes are considered to have good flavor when their TSS/TA ratio exceeds 10 (PAULA et al., 2015). Thus, the fruits cultivated in this study are suitable for fresh consumption.

The maturity index results align with Bezerra et al. (2018), who found values of 11.81, 15.01, and 17.93 based on different experimental regions.

Lycopene plays a crucial role in plants, serving as a photosynthetic pigment that captures light and protects plant tissues from photooxidative damage (LI et al., 2021). Lycopene concentration in tomatoes varies with temperature and light quality exposure, accumulating primarily in the later ripening stages. Fruits grown in open fields benefit from greater direct sunlight, stimulating increased lycopene production, which enhances their protective abilities against environmental stress and UV radiation damage.

β-carotene, a red-orange pigment that also presents superior content with open field cultivation, plays essential roles in photoprotection and contributes to plant hormone synthesis. Its concentration increases as fruits ripen (KAPOOR et al., 2022), highlighting its importance not only for coloration but also as a precursor to vitamin A, vital for human health and pollinator attraction (BEER et al., 2024).

Overall, this study underscores the significant impact of different cultivation environments and tomato cultivars on fruit production and quality attributes. The use of organza tunnels demonstrated advantages over open-field cultivation by reducing stress factors such as light intensity and temperature, thereby enhancing plant characteristics. However, it is important to recognize that these same stressors contribute to the enhancement of biochemical characteristics, including vitamin C, lycopene, and β-carotene.

5. CONCLUSIONS

There is a significant influence of cultivation environments and tomato cultivars on production and fruit quality attributes. The use of low tunnels made of organza material reduces temperatures and light intensity, increasing production and improving post-harvest characteristics, such as the reduction of peduncular scar. In contrast, open field cultivation favors the biochemical quality of tomatoes, raising levels of vitamin C, lycopene, and β-carotene, which are related to stress conditions in plants. The Thaíse cultivar showed a higher percentage of marketable fruits compared to Fascínio, which, in turn, presented higher levels of lycopene and β-carotene. The results indicate that organza tunnels benefit tomato cultivation by impacting environmental, morphological, and biochemical parameters, with an increase in production of up to 52.2% compared to open field cultivation.

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