

HEITOR ARANTES MENDONÇA

**MORPHOAGRONOMIC CHARACTERIZATION AND IMAGE-BASED
HERBIVORY ANALYSIS FOR PEST RESISTANCE IN DWARF TOMATO USING
ARTIFICIAL NEURAL NETWORKS**

MONTE CARMELO – MG
MINAS GERAIS – BRASIL

2025

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de “Mestre”.

Orientadora: Dr. Gabriel Mascarenhas Maciel

Coorientador: Dra. Ana Carolina Silva Siquieroli

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Reuniu-se na sala virtual , a banca examinadora, designada pelo Colegiado do Programa de Pós-graduação em Agricultura e Informações Geoespaciais, assim composta: Prof. Dr. Gabriel Mascarenhas Maciel (Presidente - Universidade Federal de Uberlândia, Campus de Monte Carmelo), Prof. Dr. Jair Rocha do Prado Universidade Federal de Uberlândia - UFU) e Prof.^a Dra. Paula de Aguiar Silva (Universidade Federal do Triângulo Mineiro - UFTM). Iniciando os trabalhos o presidente da mesa, Dr. Gabriel Mascarenhas Maciel, apresentou a Comissão Examinadora e o candidato, agradeceu a presença do público, e concedeu ao discente a palavra para a exposição do seu trabalho. A duração da apresentação do discente e o tempo de arguição e resposta foram conforme as normas do Programa.

A seguir o senhor presidente concedeu a palavra, pela ordem sucessivamente, aos examinadores, que passaram a arguir o candidato. Ultimada a arguição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu o resultado final, considerando o candidato:

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I dedicate

To God and my family for all their support, affection and compassion.

BIOGRAPHY

Heitor Arantes Mendonça was born in 1996 in Uberlândia, Minas Gerais. He moved with his family to Iturama, Minas Gerais, where he studied Biological Sciences at the Federal University of Triângulo, Iturama Campus. He has been working as a teacher in the state education system since 2018. He completed his 2nd degree in Special Education at UFSCar and a specialization in Science Teaching at UFTM. In 2021, he began his Master's degree in Education at the State University of Mato Grosso do Sul, UEMS Paranaíba, and in 2022, his Master's degree in Agriculture and Geospatial Information at the Federal University of Uberlândia, UFU Monte Carmelo Campus. In 2025, he began working as a full-time teacher in the municipal education system of the city of Iturama, Minas Gerais.

SUMMARY

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ABSTRACT

MENDONÇA, HEITOR ARANTES. **MORPHOAGRONOMIC CHARACTERIZATION AND IMAGE-BASED HERBIVORY ANALYSIS FOR PEST RESISTANCE IN DWARF TOMATO USING ARTIFICIAL NEURAL NETWORKS** 2025, 24 pages. Dissertation (master's degree in Agriculture and Geospatial Information) – Universidade Federal University of Uberlândia, *Campus* Monte Carmelo, Minas Gerais, Brazil¹

Abstract: Dwarf tomato plants with optimized combining ability offer distinct advantages for hybrid development, including superior agronomic performance, fruit quality, and pest resistance. However, Santa Cruz-type dwarf tomato germplasm remains undercharacterized. This study evaluated morphological traits on seven populations of Santa Cruz-type dwarf tomatoes, the donor parent UFU MC TOM 1, the recurrent parent UFU-TOM-MOTHER-2, and the control cultivar Caniati. Additionally, the wild accession *Solanum pennellii* was included to quantify acylsugar content. Pest resistance was evaluated through acylsugar quantification and analyses of herbivory caused by *Tuta absoluta* and *Liriomyza huidobrensis*. Populations UFU-Sci#6.12-2.1.5, UFU-Sci#6.12-2.1.7, and UFU-Sc#8.3.2-2.1.2 emerged as superior, exhibiting elevated acylsugar levels, reduced pest damage, and improved fruit quality. Importantly, acylsugar content was strongly associated with increased pest resistance, particularly against *T. absoluta* and *L. huidobrensis*, mimicking the defensive profile of the wild *S. pennellii* accession. These findings support the development of pest-resilient, productive tomato cultivars aligned with sustainable agriculture goals.

Keywords: *Solanum lycopersicum*, dwarfism-associated genes, acylsugars, *Tuta absoluta*, *Liriomyza huidobrensis*.

¹Orientador: Prof. Dr. Gabriel Mascarenhas Maciel - UFU

INTRODUCTION

The tomato (*Solanum lycopersicum*, Solanaceae) is one of the most economically and nutritionally important crops worldwide (O'Connor et al. 2022). Its fruits are consumed in various forms and represent a significant source of bioactive compounds, notably lycopene, which is associated with the prevention of several diseases (Quinet et al. 2019, Jiménez Bolaño et al. 2024).

Due to its domestication process, the tomato is highly susceptible to a broad spectrum of arthropod pests, which primarily target leaves and fruits, resulting in significant yield losses (Jaiswal et al. 2020). In Brazil, tropical climatic conditions further exacerbate the prevalence of these pests during tomato cultivation (Bacci et al. 2021). Pest control in tomato production heavily relies on the use of chemical pesticides, increasing the risk of environmental contamination and health hazards (Mazzei et al. 2021, Pignati et al. 2022).

For decades, efforts have been directed toward developing pest-resistant tomato cultivars through genetic improvement. *Bacillus thuringiensis* genes encoding Cry proteins have been isolated and introduced into various crop species, including tomato (Fischhoff 1987). For instance, the transgenic line AB25 expressing the Bt-cry1Ab gene demonstrated high efficacy in reducing herbivory in tomato plants (Koul et al. 2014). However, the adoption of transgenic tomatoes remains restricted, with approvals for cultivation granted only in Canada and the United States. In Brazil, transgenic pest-resistant tomato cultivars are not yet authorized for commercial use (Kumar et al. 2020, CTNBio 2024).

In contrast, conventional breeding approaches have shown promising results, particularly utilizing the wild relative *Solanum pennellii*. The presence of acylsugars in *S. pennellii* leaves has been associated with satisfactory levels of pest resistance (Resende et al. 2020, Oliveira et al. 2022, Gomes et al. 2023, Mutschler et al. 2023). However, the use of *S. pennellii* for generating F1 hybrids may be limited by unfavorable traits such as reduced fruit size (Semel et al. 2006).

Among the innovative strategies in tomato breeding, the use of dwarf tomato plants for combining ability has gained traction (Pereira et al. 2024). The development of hybrids with standard plant architecture can be efficiently achieved through the direct combination of a dwarf male parent with a standard female parent. The inheritance of the

dwarf architecture trait in tomato (*Solanum lycopersicum*) follows a monogenic pattern, governed by recessive alleles (Maciel et al. 2015). Hybrids derived from dwarf male parents have demonstrated higher productivity, compact growth, increased inflorescence density per linear meter, and enhanced pest resistance (Pereira et al. 2024). However, there is limited information on the morpho-agronomic traits and pest resistance of dwarf tomatoes with a Santa Cruz genetic background.

This study aimed to characterize Santa Cruz-type dwarf tomato populations, focusing on plant morphology, productivity, fruit quality, and pest resistance.

MATERIALS AND METHODS

Experimental location and genotypes used

The experiment was performed at the Horticultural Experimental Station of the Federal University of Uberlândia (UFU), (lat 18° 42' 43.19" S, long 47° 29' 55.8", alt 873 m asl). The plants were grown in an arched greenhouse with a height of 4 m ceiling, anti-aphid net side curtains.

Seven populations of Santa Cruz dwarf tomato plants were evaluated (UFU-Sci#6.1,2-2.1.1, UFU-Sci#6.1,2-2.1.2, UFU-Sc#6.1,2-2.1.3, UFU-Sc#6.1,2-2.1.4, UFU-Sc#6.1,2-2.1.5, UFU-Sc#6.1,2-2.1.7 e UFU-Sc#8,3.2-2.1.2), plus donor parent (UFU MC TOM 1), recurrent parent (UFU-TOM-MOTHER-2) and the commercial control cultivar Caniati, totaling 10 genotypes. The wild accession *S. pennellii* was used to examine acylsugar content, a variable related to pest resistance (Maluf et al. 2010, Maciel et al. 2024). Santa Cruz-type dwarf tomato populations belonging to the UFU tomato germplasm bank were obtained after hybridizing a homozygous pre-commercial strain with Santa Cruz-type fruit patterns (UFU-TOM-MOTHER-2) *versus* the UFU MC TOM1 dwarf strain (Maciel et al. 2015, Maciel et al. 2024) This process involved three backcrosses followed by two self-pollinations, resulting in F₃RC₃ populations. The homozygous dwarf strain UFU MC TOM1 served as the donor parent, characterized by its recessive, monogenic dwarf phenotype and production of mini tomato-type fruits (Maciel et al. 2015).

The seeds were sown in polystyrene trays with a commercial coconut fiber substrate. At 40 days after sowing, the dwarf plants were selected and transplanted into 5-L plastic pots. The experiment was conducted in a randomized block design with four replications, totaling 60 plots. Each pot consisted of six plants distributed in double rows with 0.3 × 0.3 m spacing.

Plant morphology evaluation

Plant morphology was assessed using the following quantitative descriptors, based on the guidelines of the International Plant Genetic Resources Institute (IPGRI, 1996): PH (plant height, cm), IL (internode length, cm), FS (flower size, cm), FW (average fruit weight, g), FL (fruit length, cm), FD (fruit diameter, cm), PF (pulp thickness, cm), NL (locules per fruit), and °BRIX (soluble solids content).

Plant height was measured 50 days after transplanting, from the base of the plant to its apex. Internode length was determined as the distance between two consecutive nodes on the main stem, measured with a digital caliper. Average fruit weight was calculated as the ratio of total fruit mass to the number of fruits harvested per experimental plot. Fruit dimensions were assessed by measuring length and diameter with a digital caliper. Pulp thickness was determined as the distance from the fruit epidermis to the inner locules, measured after a horizontal fruit sectioning. The number of locules per fruit was recorded by counting the visible internal compartments following the fruit cut. Soluble solids content (°BRIX), an indicator of fruit sweetness and quality, was measured using a refractometer (Atago PAL-13810) on a homogenized sample from each plot.

Acylsugar quantification

Acylsugar levels (nmol cm⁻² of leaf area) were determined 30 days after transplanting. For the analysis, samples of eight leaf discs (equivalent to 4.2 cm²) were collected from the upper third of each plant within the plot. Extraction and quantification of acylsugars were performed according to the methods described by Resende et al. (2002), with modifications by Maciel and Silva (2014).

Reaction of plants to infestation of leafminer *Tuta absoluta* (Meyrick) and *Liriomyza huidobrensis* (Blanchard)

The same plants used for acylsugar quantification were assessed for *T. absoluta* and *L. huidobrensis* herbivory. Temperature and humidity were monitored throughout (Figure 1). Infestation began 18 days post-transplant, with insect releases in a greenhouse using Santa Clara cv. pots every 50 cm. Eight days later, six assessments at two-day intervals rated plant and leaflet injuries (Oliveira et al. 2012). Ratings were summed after seven assessments. Injury levels (scale 1–5) followed Maluf et al. (1997) and Labory et al. (1999). Herbivory area was then measured via ImageJ using ten scanned leaflets per plot (Schneider et al. 2012).

Statistical analysis

Statistical assumptions were assessed through tests for normality (Lilliefors test), homogeneity (Oneill-Matheus test), and additivity (Tukey test). Data were subjected to analysis of variance using the F test ($p < 0.05$). Means were compared using the Scott-Knott test ($p < 0.05$) and Dunnett test ($p < 0.05$), with the dwarf lineage (donor parent) UFU MC TOM 1 serving as the control for comparison purposes.

Genetic diversity was represented by a dendrogram and heat map obtained from maximum and minimum distances.

To classify treatments by neuron count, morphological and production variables were selected. An artificial neural network was trained to optimize the hidden layer neuron count, enhancing classification accuracy. Various configurations were tested until the ideal was found (Haldorai et al. 2024). Neuron-to-input distances were calculated to identify nearest neighbors. Neurons were then clustered using the UPGMA method, generating a dendrogram (Khaki et al. 2020).

The selection index and genotype-ideotype distance analysis assessed dwarf tomato performance. The ideotype was defined by ideal agronomic traits: reduced height, short internodes, high flower production, and superior fruit quality. Euclidean distance measured each genotype's proximity to the ideotype, with a weighted average determining the final distance (Olivoto and Nardino 2021). The selection index prioritized populations closest to the ideotype. Statistical analyses were conducted using the GENES software (Cruz 2013) and R (R Core Team 2021).

RESULTS

Morphological characterization of the dwarf tomato populations revealed significant differences in several key traits critical for the selection of superior genotypes.

Plant morphology and growth characteristics

The dwarf tomato populations exhibited an average height of approximately 50 cm, comparable to the donor parent UFU MC TOM 1 (Figure 2). In contrast, the controls, including the commercial cultivar Caniati and the recurrent parent UFU-TOM-MOTHER-2, displayed significantly greater heights, with averages of 150 cm and 160 cm, respectively.

Internode length varied considerably among the populations (Figure 2). The donor parent UFU MC TOM 1 exhibited the shortest internodes, with an average length of 2.5 cm. In contrast, the commercial cultivar Caniati had the longest internodes, averaging 7.5 cm. The recurrent parent UFU-TOM-MOTHER-2 displayed an intermediate internode length, with an average of 5.3 cm.

The leaves of the selected populations exhibited significant variations in size and shape (Figure 3). The population UFU-Sci#6.1,2-2.1.1 stood out for having larger leaves with less serrated leaflets compared to the donor parent UFU MC TOM 1. Flower size also varied, with the UFU-Sci#6.1,2-2.1.1 lineage exhibiting larger flowers with more intense coloration (Figure 3).

Fruit characteristics

The analyzed populations showed significant variation in fruit weight, size, pulp thickness, locule number, and °BRIX, key traits for tomato breeding. The donor parent UFU MC TOM1 averaged 6.6 g, while UFU-Sci#6.1,2-2.1.5 reached 49 g, a 642% increase. The commercial control (cv. Caniati) weighed 330 g (Figure 4A).

Fruit diameter ranged from 1.7 cm in UFU MC TOM1 to 6.2 cm in UFU-TOM-MOTHER-2. The UFU-Sci#6.1,2-2.1.1 population reached a diameter of 4.3 cm, nearly tripling the value observed in the donor parent UFU MC TOM1 (Figure 4A). Fruit length also varied significantly, from 3.7 cm in UFU MC TOM1 to 7.6 cm in UFU-TOM-MOTHER-2. The UFU-Sci#6.1,2-2.1.3 population exhibited a length of 5.1 cm, representing an increase of approximately 50% (Figure 4A).

Pulp thickness ranged from 0.21 cm (UFU MC TOM1) to 0.55 cm (UFU-Sci#8.3,2-2.1.2), reflecting a more than 100% increase in certain genotypes (Figure 4A).

UFU-TOM-MOTHER-2 had the highest locule average (4.71), while UFU MC TOM1 had the lowest (2.05). Backcross populations ranged from 2.55 (UFU-Sci#6.1,2-2.1.2) to 3.41 (UFU-Sci#6.1,2-2.1.5), and Caniati averaged 2.33. The Scott-Knott test grouped the recurrent parent separately, while others formed a single class; Tukey's test placed UFU-Sci#6.1,2-2.1.5 in an intermediate group. UFU MC TOM1 had the highest °BRIX (7.93), with UFU-Sci#6.1,2-2.1.4 leading backcrosses (6.25) (Figure 4A). The selection index highlighted UFU-Sci#6.1,2-2.1.1, UFU-Sci#6.1,2-2.1.7, and UFU-Sci#6.1,2-2.1.5 as the most promising for breeding (Figure 4B).

Acylsugar content and plant response to infestation by *Liriomyza huidobrensis* and *Tuta absoluta*

Acylsugar content and herbivory in UFU MC TOM-1 were similar to wild *S. pennellii*. Even after three backcrosses for the Santa Cruz fruit type, UFU-Sci#6.1,2-2.1.2, UFU-Sc#6.1,2-2.1.5, UFU-Sc#6.1,2-2.1.7, and UFU-Sc#8.3,2-2.1.2 maintained high acylsugar levels and lower herbivory than UFU-TOM-MOTHER-2 and Caniati (Figure 5).

Genetic dissimilarity and selection of superior populations

UPGMA and self-organizing map (SOM) analysis identified six genetic groups (Figure 6). The donor parent UFU MC TOM1 was in Group III, while UFU-Sci#6.1,2-2.1.5, UFU-Sci#8.3,2-2.1.2, UFU-Sci#6.1,2-2.1.7, and UFU-Sci#6.1,2-2.1.2 clustered in Group IV.

DISCUSSION

In this study, we conducted a comprehensive evaluation of seven dwarf tomato populations derived from backcrosses, focusing on the identification of valuable morphological and agronomic traits for genetic improvement programs.

The populations UFU-Sci#6.12-2.1.1, UFU-Sci#6.12-2.1.5, and UFU-Sci#6.12-2.1.7 were identified as the most promising based on superior traits such as fruit size and weight (Figure 4) and acylsugar content (Figure 5). These findings align with previous studies emphasizing the importance of detailed phenotypic characterization for selecting genotypes that meet specific market criteria and exhibit pest resistance (Cappetta et al. 2020, Zhang et al. 2024).

Plant morphology

The variation in leaf size and morphology among the evaluated populations, as shown in Figure 3, suggests that larger leaves with less serrated leaflets can directly influence photosynthetic efficiency and plant yield. These morphological traits likely enhance light interception and photosynthetic efficiency, particularly in controlled environments where maximizing photosynthetic activity can increase productivity. Previous studies have indicated that larger and less serrated leaves improve light interception, optimizing light use efficiency for photosynthesis, which ultimately leads to higher yields per plant (Zhang et al. 2024). Moreover, less serrated leaflets may reduce water loss through transpiration, making these genotypes better adapted to conditions of

high light intensity or water limitation (Li et al. 2021). The integration of these traits into breeding programs is essential for developing more efficient and resilient cultivars.

Fruit traits and selection of superior genotypes

The selected populations exhibited significant increases in fruit diameter, weight, and pulp thickness compared to the donor parent UFU MC TOM 1 (Figure 4A). These traits are critical for both the fresh market and the processing industry, where larger fruits with thicker pulp are preferred due to their higher yield and processing efficiency (Bhandari et al. 2023). The positive association between these morphological traits and market value underscores the importance of selecting genotypes that meet consumer and market demands (Ni et al. 2024). Furthermore, the increase in soluble solids content (°BRIX) in the selected populations is crucial for organoleptic quality and nutritional value, being a key determinant of fruit flavor and sweetness. Zhu et al. (2018) have demonstrated that the modulation of metabolic profiles in tomato cultivars can significantly enhance flavor characteristics and nutritional quality, which aligns with the findings observed in this study.

Pest resistance and the importance of acylsugars

The observed increase in acylsugar levels in the selected populations, which correlates with greater resistance to pests such as *T. absoluta* and *L. huidobrensis*, underscores the importance of these metabolites in integrated pest management strategies. Acylsugars, synthesized primarily in the glandular trichomes of Solanaceae species, function as defense compounds due to their chemical diversity and bioactivity (Fiesel et al. 2024). The correlation between high acylsugar levels and reduced insect-induced damage, as shown in Figure 6, highlights the role of these compounds in pest resistance. Populations such as UFU-Sci#6.12-2.1.5 and UFU-Sci#6.12-2.1.7, which exhibited the highest acylsugar concentrations, consistently showed lower pest injury scores. This suggests that breeding strategies aimed at enhancing acylsugar synthesis could be pivotal for developing cultivars with intrinsic pest resistance.

The results of this study confirm the efficacy of acylsugars in reducing insect damage, aligning with previous studies that suggest selecting genotypes with high levels of these compounds can significantly contribute to resistance against multiple pests, thereby improving cultivar durability in the field (Kortbeek et al. 2021, Resende et al. 2022).

Genetic dissimilarity analysis

Genetic dissimilarity analysis is an essential tool for identifying genotypes with desirable phenotypic and genetic traits for breeding programs. In this study, we utilized the UPGMA method and a self-organizing map (SOM) to assess genetic dissimilarity among dwarf tomato genotypes, resulting in the formation of six distinct groups (Figure 6). This analysis revealed that the populations UFU-Sci#6.12-2.1.5, UFU-Sci#8.32-2.1.2, UFU-Sci#6.12-2.1.7, and UFU-Sci#6.12-2.1.2 clustered together, sharing genetic proximity and superior phenotypic traits such as larger fruit size. Genetic dissimilarity analysis not only aids in identifying genotypes with desirable attributes but also enhances the understanding of the genetic diversity within the population, which is fundamental for developing new cultivars with multiple desirable traits (Khodadadi and Farokhzadeh 2024). Genetic diversity is crucial for resilience to both biotic and abiotic stresses and facilitates the incorporation of favorable alleles into breeding programs. Thus, genetic dissimilarity analysis is an essential step in selecting superior genotypes that can be utilized to develop cultivars better adapted to diverse environmental conditions and market demands. Similarly, Jacinto et al. (2024) employed self-organizing maps (SOM) for the analysis of morphological descriptors and successfully identified distinct groups.

Contributions to tomato breeding

This study demonstrates the effective application of advanced methodologies, such as the Selection Index - Genotype-Ideotype Distance, in identifying genotypes with superior traits for use in breeding programs. The genetic dissimilarity among the selected genotypes, as represented in the dendrogram (Figure 6), indicates a diverse genetic base that can be leveraged in future breeding efforts. This diversity is essential for the development of new cultivars that combine multiple desirable traits, high productivity, and superior fruit quality. Harnessing these genetic variations can enhance breeding strategies by incorporating diverse alleles that contribute to complex traits, thereby optimizing genetic gains in breeding programs (Yeon et al. 2024).

The genetic dissimilarity analysis, visualized in the dendrogram (Figure 6), revealed the formation of distinct groups based on the phenotypic and genetic characteristics of the studied genotypes, highlighting the populations UFU-Sci#6.12-2.1.1, UFU-Sci#6.12-2.1.5, and UFU-Sci#6.12-2.1.7 as the most promising. This approach is essential for the development of tomato cultivars that not only meet market demands but are also resilient to agronomic challenges such as biotic and abiotic stresses.

These results have significant implications for sustainable agriculture. By selecting genotypes with high pest resistance and superior fruit quality, the reliance on chemical inputs can be minimized, thereby reducing environmental impact. The integration of these genotypes into breeding programs aligns with the goals of sustainable production, promoting economic viability while conserving natural resources (Cappetta et al. 2020). The integration of phenotypic and genotypic data enables more precise and efficient selection of genotypes with potential adaptation to diverse cultivation environments, thereby enhancing productive efficiency and sustainability (Cappetta et al. 2020, Yeon et al. 2024). Thus, the use of these advanced methodologies facilitates the development of tomato cultivars that are more productive, resilient, and well-suited for sustainable agricultural production systems.

CONCLUSION

This study characterized Santa Cruz-type dwarf tomato populations, identifying genotypes with high agronomic potential and pest resistance. The populations UFU-Sci#6.12-2.1.5, UFU-Sci#6.12-2.1.7, and UFU-Sci#8.3,2-2.1.2 stood out for their higher acylsugar content, reduced pest damage, and superior fruit quality.

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Figures

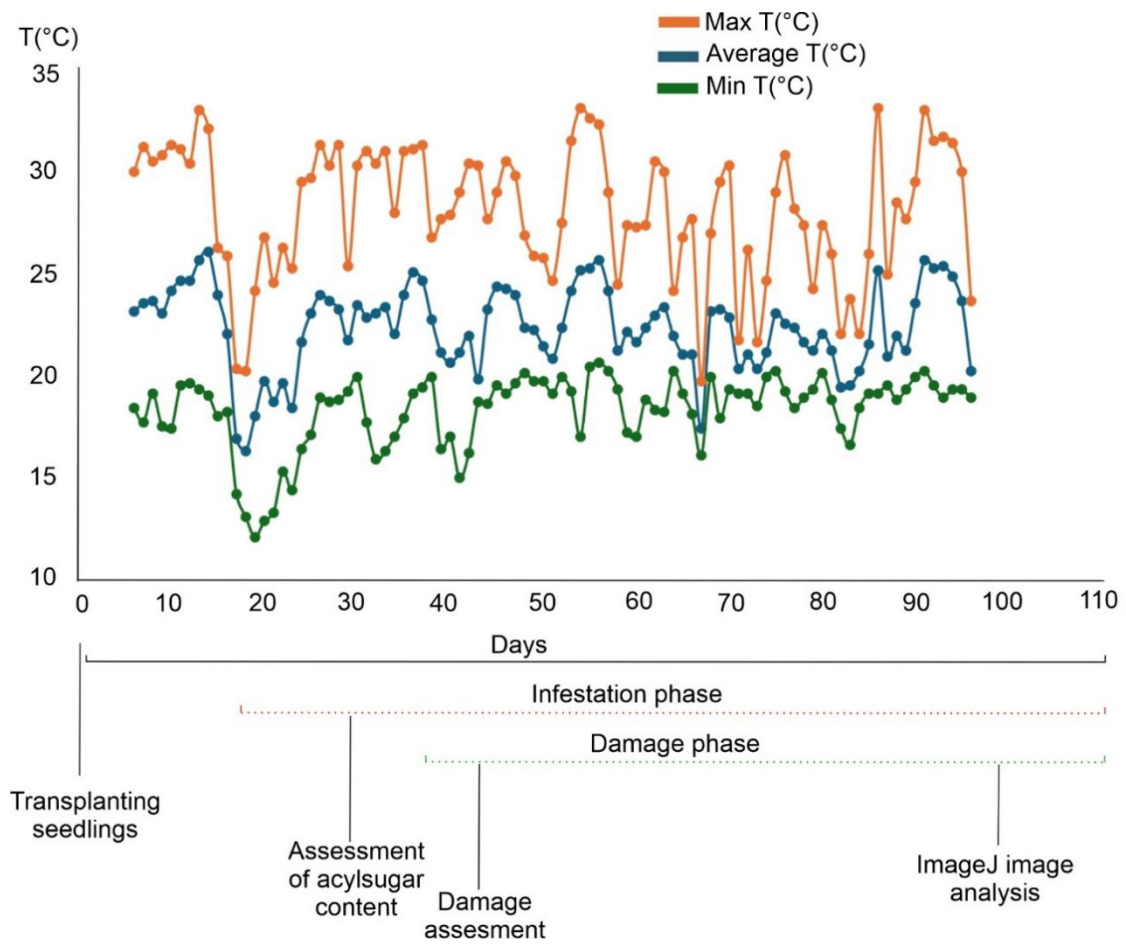


Figure 1. Climate conditions during the execution of the experiment. Maximum temperature (Max T), Average temperature (Average T) (Minimum temperature (Min T).

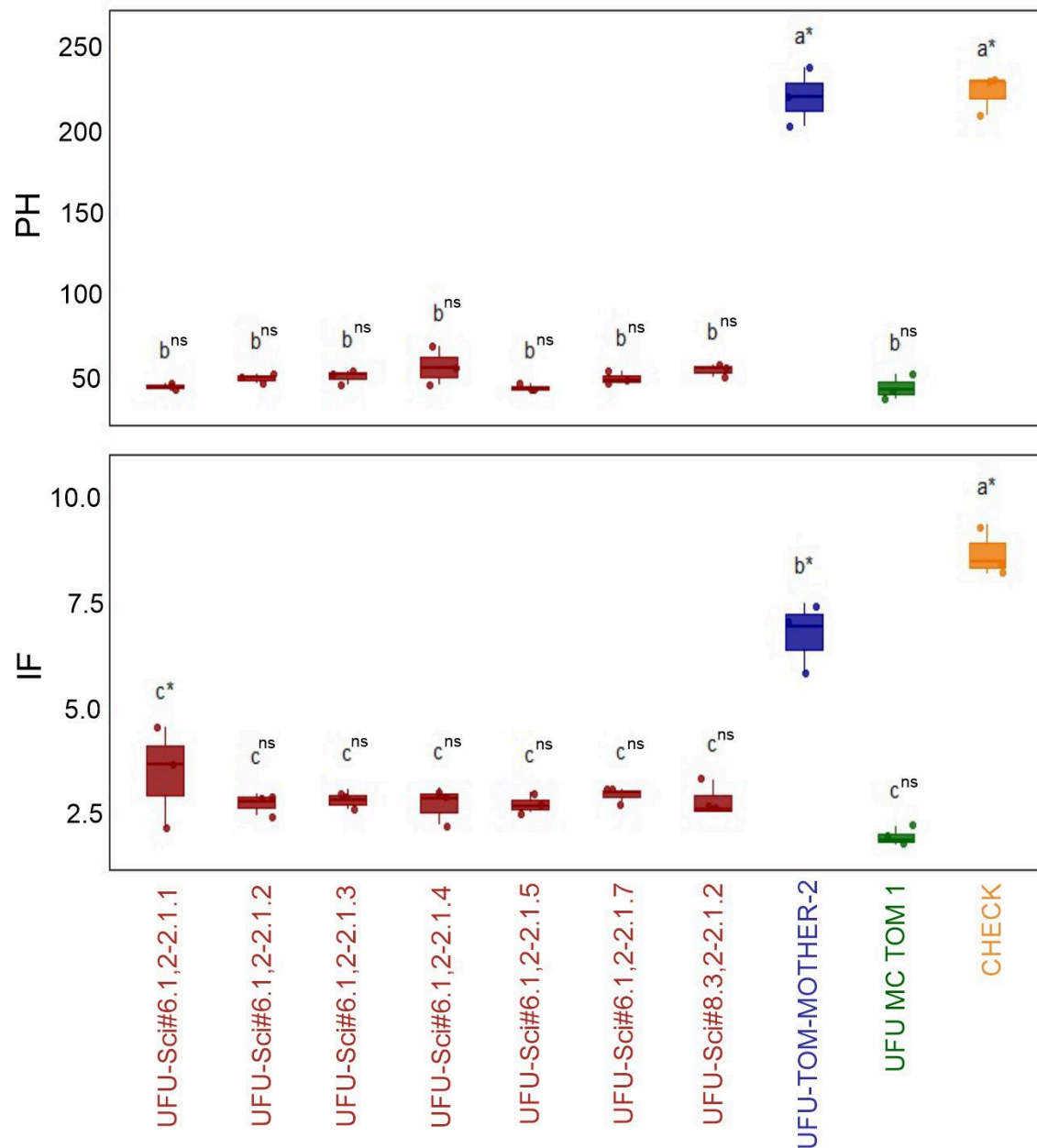


Figure 2. F₃RC₃ populations of dwarf tomato, recurrent parent (UFU-TOM-Mother 2), donor parent (UFU MC TOM 1), and control (cv. Caniati). Means followed by distinct letters differ significantly according to the Scott-Knott test at 0.05. Asterisk Means differ from the dwarf donor parent UFU MC TOM 1 according to the Dunnett test at a 0.05 probability level. IF: internode length (cm); PH: plant height (cm).

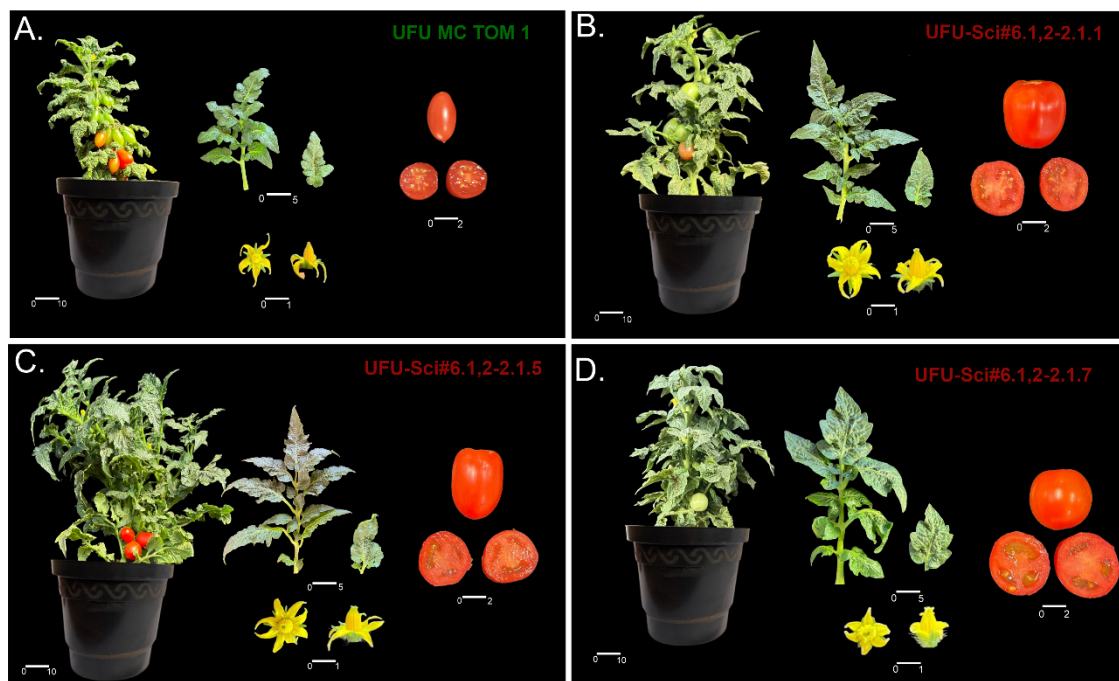


Figure 3. Leaf, flower, and fruit morphology of the three standout populations compared to the donor parent UFU MC TOM 1.

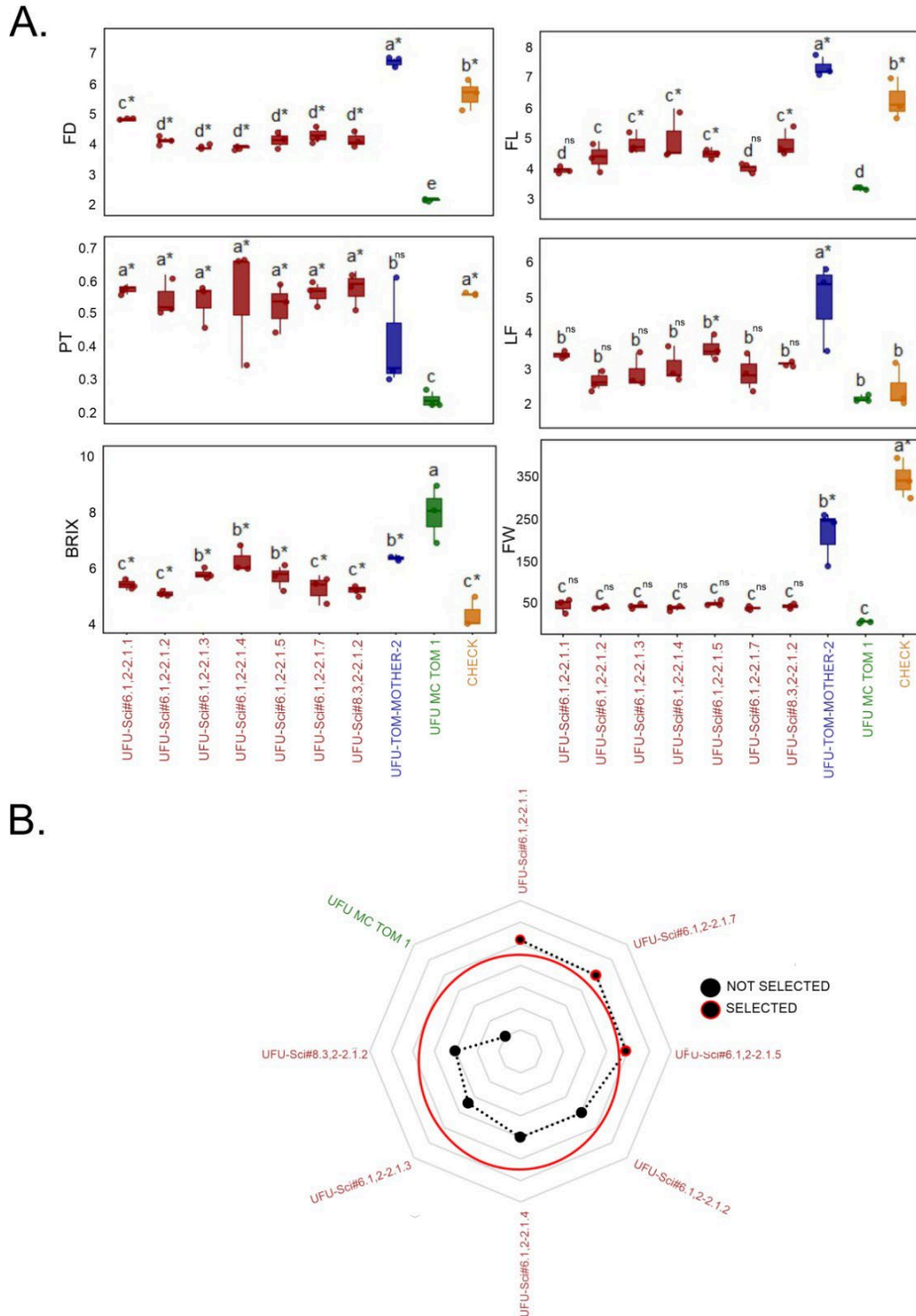
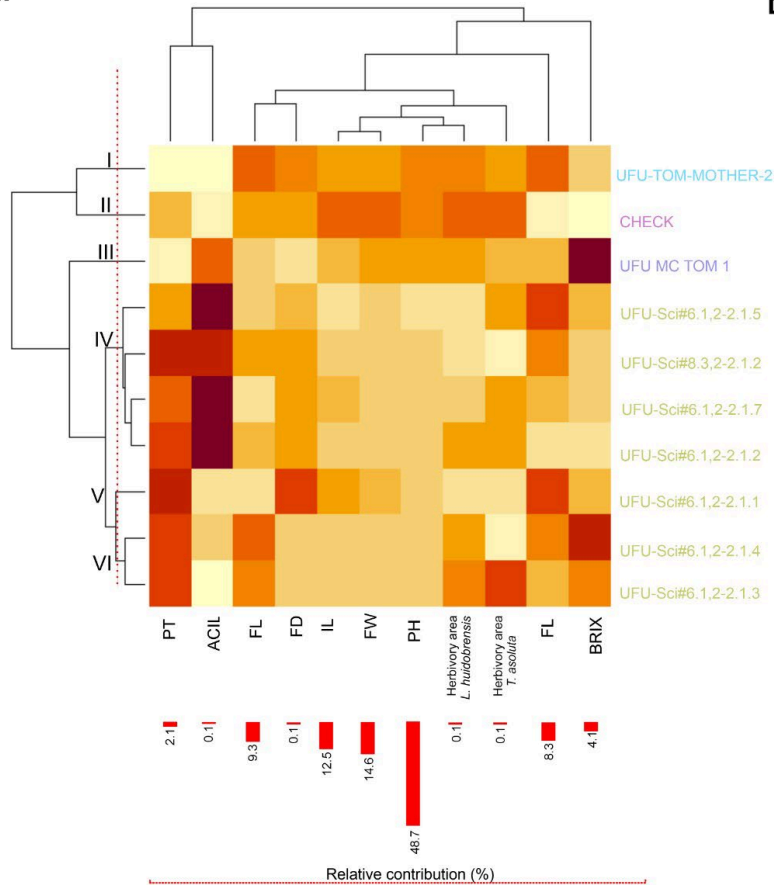


Figure 4. Morphological and Agronomic Traits of F_3RC_3 Dwarf Tomato Populations and Parental Lines with Selection Index Based on Genotype-Ideotype Distance. **A.** F_3RC_3 populations of dwarf tomato, recurrent parent (UFU-TOM-MOTHER-2), donor parent (UFU MC TOM 1), and control (cv. Caniati). Means followed by distinct letters differ significantly according to the Scott-Knott test at 0.05. * Means differ from the dwarf donor parent UFU MC TOM 1 according to the Dunnett test at a 0.05 probability level.; FD: fruit diameter (cm); FL: fruit length (cm); PT: pulp thickness (cm); LF: locules per fruit; °BRIX: soluble solids content; PM: average fruit weight (g). **B.** Selection Index - Genotype-Ideotype Distance Based on Morphological and Agronomic Traits.

A.



B.

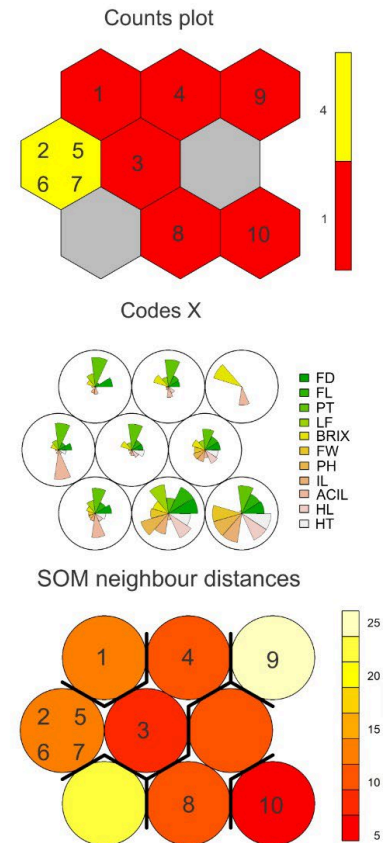


Figure 6. Dendrogram, Heat Map, and Treatment Classification of Dwarf Tomato Populations Based on Morphological and Agronomic Traits Using the UPGMA Method **A.** Dendrogram and heat map. **B.** Treatment classification based on the number of neurons, neuron representation, the magnitude of variable influence, distances to nearest neighbors, and neuron clustering using the UPGMA method based on distances. PT: pulp thickness (cm); ACIL: acylsugar content; FL: fruit length (cm); FD: fruit diameter (cm); IL: internode length (cm); FW: average fruit weight (g); PH: plant height (cm); herbivory area calculation for *Liriomyza huidobrensis* and *Tuta absoluta*; LF: locules per fruit; °BRIX: soluble solids content.