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NOTA TÉCNICA

MORPHOLOGICAL DESCRIPTION AND YIELD OF FIVE NEW TOMATO VARIETIES UNDER TWO PEST CONTROL TREATMENTS IN LOJA, ECUADOR

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ABSTRACT

Tomato is one of the most consumed vegetables, with abundant pests and diseases problems limiting its production. This research had two objectives: in the first one, the morphological characteristics of five different tomato populations were described; in the second, the yield response of candidate-to-be varieties genotypes was evaluated when submitted to chemical or biological control of pest and diseases that commonly attack the crop. The populations showed distinctive morphological characteristics, fruit firmness, size, and shape. The experimental test results indicated significant differences among varieties and in the interaction of variety x method of control. The control variety showed the lowest yield (28,630 kg·ha^{-1}) when compared to the candidate varieties, especially Variety 2 (66,090 kg·ha^{-1}). Variety 2 (cherry-size-fruit) and Variety 3 (large-size-fruit) should be taken into consideration for large-scale cultivation due to their high yield. Varieties 2 and 3 reacted adequately to both kinds of control methods, with increments in yield under chemical control. Nonetheless, the use of chemical products was minimal (3-4 applications were enough), when compared to the high number of applications that are currently used under the traditional tomato cultivation in Ecuador.

Additional keywords: Genotype, pest and disease management, *Solanum lycopersicum*, yield

RESUMEN

Descripción morfológica y rendimiento de cinco nuevas variedades de tomate frente a dos tratamientos de control de plagas y enfermedades en la provincia de Loja, Ecuador

El tomate es una de las hortalizas más consumidas, aunque presenta abundantes problemas de plagas y enfermedades que limitan su producción. La presente investigación tuvo dos objetivos: en el primero, se describieron las características morfológicas de cinco poblaciones diferentes de tomate; y en el segundo, se evaluó la respuesta en rendimiento de los genotipos, candidatos a ser variedades, al ser sometidos a tratamientos de control químico o biológico contra las plagas y enfermedades que atacan comúnmente al cultivo. Las poblaciones estudiadas mostraron características morfológicas distintivas de firmeza, tamaño y forma del fruto. Los resultados del ensayo experimental indicaron diferencias significativas entre variedades y en la interacción variedad x tipo de control. La variedad testigo mostró el rendimiento más bajo (28.630 kg·ha^{-1}) en comparación con las variedades candidatas, especialmente la Variedad 2 (66.090 kg·ha^{-1}). La variedad 2 (fruto de tamaño cereza) y la variedad 3 (fruto grande) deben tenerse en cuenta para el cultivo a gran escala debido a su alto rendimiento. Las variedades 2 y 3 reaccionaron adecuadamente al uso de ambos tipos de pesticidas, con una ventaja del rendimiento ante el uso de productos químicos. No obstante, el uso de estos productos fue mínimo (3-4 aplicaciones fueron suficientes) en comparación con su elevado uso actual en las plantaciones tradicionales de tomate en Ecuador.

Palabras clave adicionales: Genotipo, manejo de plagas y enfermedades, rendimiento, *Solanum lycopersicum*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most worldwide consumed vegetables; in Ecuador, about 2579 ha were cultivated during 2020 with a total production of 38.438 Mg (FAOSTAT, 2022). Its cultivation takes place in both Coastal and Uplands regions of the country. Tomato originated from the Andean region now encompassed by part of Chile, Bolivia, Ecuador,

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Colombia, and Peru; the last has been considered the center of origin (Ramírez et al., 2021). *Solanum* section Lycopersicon includes the cultivated tomato (*S. lycopersicum*) and 12 additional wild relatives. *S. lycopersicum* is the only domesticated species (Peralta et al., 2006). It can be further divided into two botanical types: large-fruited tomatoes *S. lycopersicum* var. *lycopersicum* (SLL) and cherry-sized early domesticated *S. lycopersicum* var. *cerasiforme* (SLC), the last is supposed to be an ancestor of the domesticated form.

Modern cultivated tomatoes exhibit a wide range of phenotypic variation mainly because of natural and human breeding-mediated introgressions from wild relatives (Labate and Robertson, 2012), in addition to spontaneous mutations that have also contributed to this seeming paradox (Tanksley, 2004). Most wild tomatoes are endemic in narrow geographical regions and also have very small populations, making them vulnerable to extinction. Therefore, to discover and maintain species diversity in biodiverse regions is extremely important (Bai and Lindhout, 2007).

In Ecuador, commercial seeds generally come from foreign varieties generated in European countries, which are neither adapted to Ecuadorian climate nor resistant to native diseases and pests (Morales et. al, 2014). Therefore, it is necessary to use the germplasm resources offered by wild species, which can adapt to pathogens and represent a large gene pool due to their survival skills, to obtain suitable varieties through tomato breeding (Nowicki et al., 2012).

On the other hand, tomato is one of the vegetables with abundant phytosanitary problems. More than 200 pests and diseases have been identified worldwide in tomato, causing losses in its production directly or indirectly (Tigchelaar, 2001). As shown by Carrilho et al. (2020) in Brazil, the main obstacle for tomato cropping is the occurrence of pests during its cycle. To remedy the drop in yield, Ecuadorian farmers use large amounts of pesticides, as well as fertilizers, causing a great impact on the environment. Chirinos et al. (2020) analyzed the pesticide management of several crops in Ecuador, including tomato, where farmers declared to apply 2.8 weekly aspersions which would represent approximately 40 applications per crop cycle, thus surpassing the previous report of 20-30 of Valarezo et al. (2003). All of this accompanied by poor management of both water and soil, which has made this crop one of the most difficult to grow in the country (Morales et. al, 2014).

This research had two main objectives: a) Morphological characterization of five tomato F_6 populations, that were developed from crosses between *Solanum* wild species and a commercial variety, and b) Evaluation of yield of representative genotypes from the populations, clear candidates to become varieties, when submitted to chemical or biological control methods against pest and diseases that commonly attack the crop.

MATERIALS AND METHODS

The study was carried out in Malacatos, Loja Province, at 4°11’35” S; 79°12’54” W; 1470 meters above sea level, annual average temperature of 20.6 ºC, with 700 to 800 mm per year rainfall; under a subtropical-dry climate.

Plant material. Tomato populations were developed since 2010, from crosses combining a commercial variety, frequently used by the tomato producers in the Loja Province, as a female progenitor, and selected wild accessions such as *S. pimpinellifolium*, *S. lycopersicum* var. *cerasiforme*; *S. neorickii;* and *S. habrochaites* as pollen donors, at the facilities of the Universidad Nacional de Loja. From the hybrids obtained, five populations in the F_6 generation, denominated ‘14’ (Variety 1), ‘55’ (Variety 2), ‘69’ (Variety 3), ‘129’ (Variety 4) and ‘179’ (Variety 5) were selected for this research; plus, the variety Conquistador, as the control.

Tomato varieties morphological characterization. Five randomly selected plants of each population F_6 were characterized (Table 1) using descriptors for SOLAN_LYC, mainly from IPGRI (1996). Descriptors included the whole plant, leaves, flower and fruits, as well as phenology.

Field management and experimental design. The six selected (F_7) genotypes were distributed in the main plots of a split-plot design and the two pest control methods in the sub-plots. The design included three replications in a total area of 1620 m^2. Evaluations were taken in 40 plants per genotype, including the commercial variety as a control. Plants were furrow irrigated twice a week, and properly fertilized with NPK plus micronutrients.

Pest/diseases control treatments. During their growth, plants were attacked by the usual pest and diseases occurring in the region, and according to the estimation of the economic damage threshold, two different control treatments were applied:

a) Biological treatment. It was based on the use of four biological products: Lecanitic (*Lecanicillium lecanii*), whiteflies controller at 0.01 $g{\cdot}m^{-2}$, sprayed during plant vegetative development (VG) and flowering (FW); Metazeb (*Metarhizium anisopliae*), fungus controller at 0.03 $g{\cdot}m^{-2}$, applied on stages VG and FW; Paecylotic (*Paecilomyces lilacinus*), nematode controller, applied on stages VG, FW and fructification, at 0.02 $g{\cdot}m^{-2}$; and Trichotic (*Trichoderma* spp.), fungus controller at 0.01 $g{\cdot}m^{-2}$.

b) Chemical treatment. Based on three commercial products: the insecticide Imidacloprid, applied once during VG and twice on FW, at 0.45 $L{\cdot}ha^{-1}$), the fungicide Azoxystrobina Difenoconazol, applied once during VG and twice on FW, at 0.7 $L{\cdot}ha^{-1}$, and the insecticide Tracer 480 (Spinosad), applied twice during VG at 0.75 $L{\cdot}ha^{-1}$.

The fruits were harvested at physiological ripening stage (when they reached 50 % red-color) and the weight (yield) was recorded.

Statistical analysis. Descriptive statistical parameters, ANOVA and Tukey´s test was performed using the statistical program MSTAT-C (version 1.4, Michigan State University, 1988)

RESULTS AND DISCUSSION

The characterized F_6 populations showed some distinctive variations: all of them presented indeterminate growth habit, but Variety 5. Varieties 2 and 3 were very tall compared to the others. Other dissimilar characteristics were found in Variety 5, for instance the semi erect leaves with medium size leaflets, of dark green color, tending to be horizontal in relation to the principal axis; flowers with short pedicels; and Variety 3, did not present green stripes in the fruit before ripening (Table 1; Figure 1).

Green shoulder size (before ripening) was small for Varieties 1, 2, and 4; and medium for 3 and 5; whereas green stripes (before maturity) were absent in Variety 3. All varieties presented flattened shape fruits except for variety 1, with circular or round shape and pink color pulp at maturity, whereas the others had flattened shape and red pulp. Also, the epidermal color was yellow in Variety 1, and uncolored for the rest. It is worth mentioning that Varieties 3, 4 and 5, along with control variety had large size fruits (Figure 1), whereas in 1 and 2 were medium size. These results are comparable to similar studies by Moya et al. (2005) and Álvarez et al. (2003). All varieties presented 3 to 4 locules and medium size pericarp thickness.

Yield. Highly significant differences were found among varieties. Table 2 shows a yield ranging from 66,085 to 41,630 $kg{\cdot}ha^{-1}$ within the studied varieties. The control yielded only 28630 $kg{\cdot}ha^{-1}$.

When considering the differences between varieties from the average yields it was obtained that Variety 2 statistically exceeded Variety 1, and no differences were found between Varieties 2 and 3. Lower yields were shown by Varieties 4 and 5, which did not presented differences between them; this gives general information on the trend in the behavior of these candidate varieties. The control variety showed the lowest yield, well below the rest.

Table 2. Average yi**e**ld of five candidate varieties and a control in the province of Loja, Ecuador

Variety	Yield ($kg{\cdot}ha^{-1}$)
1	46,395 bc
2	66,085 a
3	55,590 ab
4	43,290 c
5	41,630 c
Control	28,630 d

Different letters indicate statistical differences in the mean yield according to Tukey test ($P \leq 0.05$)

Through the plant development, we observed disease symptoms caused by the presence of *Alternaria* spp., *Fusarium* spp, *Phytophthora* spp, *Sclerotium* sp; *Verticillium* sp. and *Ralstonia* sp., and pest attacks by whiteflies and mites. In this regard, the plant yield was affected by the significant interaction that occurred between varieties and the pest control method, so it is pertinent to make individualized comparisons.

Table 1. Morphological characteristics of the F_6 tomato populations studied according to Bioversity descriptors (IPGRI, 1996)

<table>
<tr><th colspan="2">Variety (Var.)</th><th>Var. 1</th><th>Var. 2</th><th>Var. 3</th><th>Var. 4</th><th>Var. 5</th></tr>
<tr><th colspan="2">(Code)</th><th>(‘14’)</th><th>(‘55’)</th><th>(‘69’)</th><th>(‘129’)</th><th>(‘179’)</th></tr>
<tr><td colspan="2">Genetic background</td><td colspan="4">SL X SLc</td><td>SL X SH</td></tr>
<tr><th colspan="2">Trait</th><th colspan="5">Expression level score</th></tr>
<tr><td rowspan="3">Plant</td><td>Growth habit</td><td colspan="4">Indeterminate</td><td>Determinate</td></tr>
<tr><td>Stalk internode length</td><td colspan="4">Large</td><td>-</td></tr>
<tr><td>Plant heigth</td><td colspan="2">Very large</td><td colspan="2">Large</td><td>-</td></tr>
<tr><td rowspan="5">Leaf</td><td>Habit</td><td colspan="4">Semi hanging</td><td>Semi erect</td></tr>
<tr><td>Leaf blade division</td><td colspan="5">Pinnate</td></tr>
<tr><td>Leaflet size</td><td colspan="4">Large</td><td>Medium</td></tr>
<tr><td>Green color intensity</td><td colspan="4">Medium</td><td>Dark</td></tr>
<tr><td>Leaflet petiole habit</td><td colspan="4">Semi erect</td><td>Horizontal</td></tr>
<tr><td rowspan="3">Flower</td><td>Inflorescence type</td><td colspan="4">Mainly uniparous</td><td>Intermediate</td></tr>
<tr><td>Color</td><td colspan="5">Yellow</td></tr>
<tr><td>Pedicel length (with abscission)</td><td colspan="4">Medium</td><td>Short</td></tr>
<tr><td rowspan="14">Fruit</td><td>Green shoulder (before ripening)</td><td colspan="5">Present</td></tr>
<tr><td>Green shoulder size (before ripening)</td><td colspan="2">Small</td><td>Medium</td><td>Small</td><td>Medium</td></tr>
<tr><td>Green stripes (before maturity)</td><td colspan="2">Present</td><td>Absent</td><td colspan="2">Present</td></tr>
<tr><td>Size</td><td colspan="2">Medium</td><td colspan="2">Large</td><td>Small</td></tr>
<tr><td>Length / diameter ratio</td><td colspan="2">Medium</td><td>Moderately compressed</td><td>Medium</td><td>Moderately compressed</td></tr>
<tr><td>Longitudinal shape</td><td>Circular</td><td colspan="4">Flattened shape</td></tr>
<tr><td>Ridge in the peduncular area</td><td>Absent/very weak</td><td>Weak</td><td>Medium</td><td colspan="2">Weak</td></tr>
<tr><td>Peduncle scar size</td><td colspan="2">Very small</td><td colspan="2">Large</td><td>Medium</td></tr>
<tr><td>Pistil scar size</td><td colspan="4">Very small</td><td>Medium</td></tr>
<tr><td>Color (at maturity)</td><td colspan="5">Red</td></tr>
<tr><td>Pulp color (at maturity)</td><td>Pink</td><td colspan="4">Red</td></tr>
<tr><td>Color of the cuticle</td><td>Pale yellow</td><td colspan="4">Uncolored</td></tr>
<tr><td>Firmness</td><td>Firm</td><td colspan="4">Medium</td></tr>
<tr><td rowspan="2">Phenology</td><td>Days to flowering</td><td>35</td><td>43</td><td>39</td><td>47</td><td>43</td></tr>
<tr><td>Days to harvest</td><td>81</td><td>90</td><td>95</td><td>99</td><td>94</td></tr>
</table>

The analysis showed that the highest yield was obtained in Variety 3 submitted to chemical control, thus surpassing the rest of varieties submitted to either chemical or biological control method. It was followed by Variety 2 submitted to any control method as well. The effect of interactions is noticeable when observing that Variety 3 was the best when using chemical control but one of the lowest yielding when receiving biological control (Table 3). In other words, in this variety the chemical control favored the yield increase.

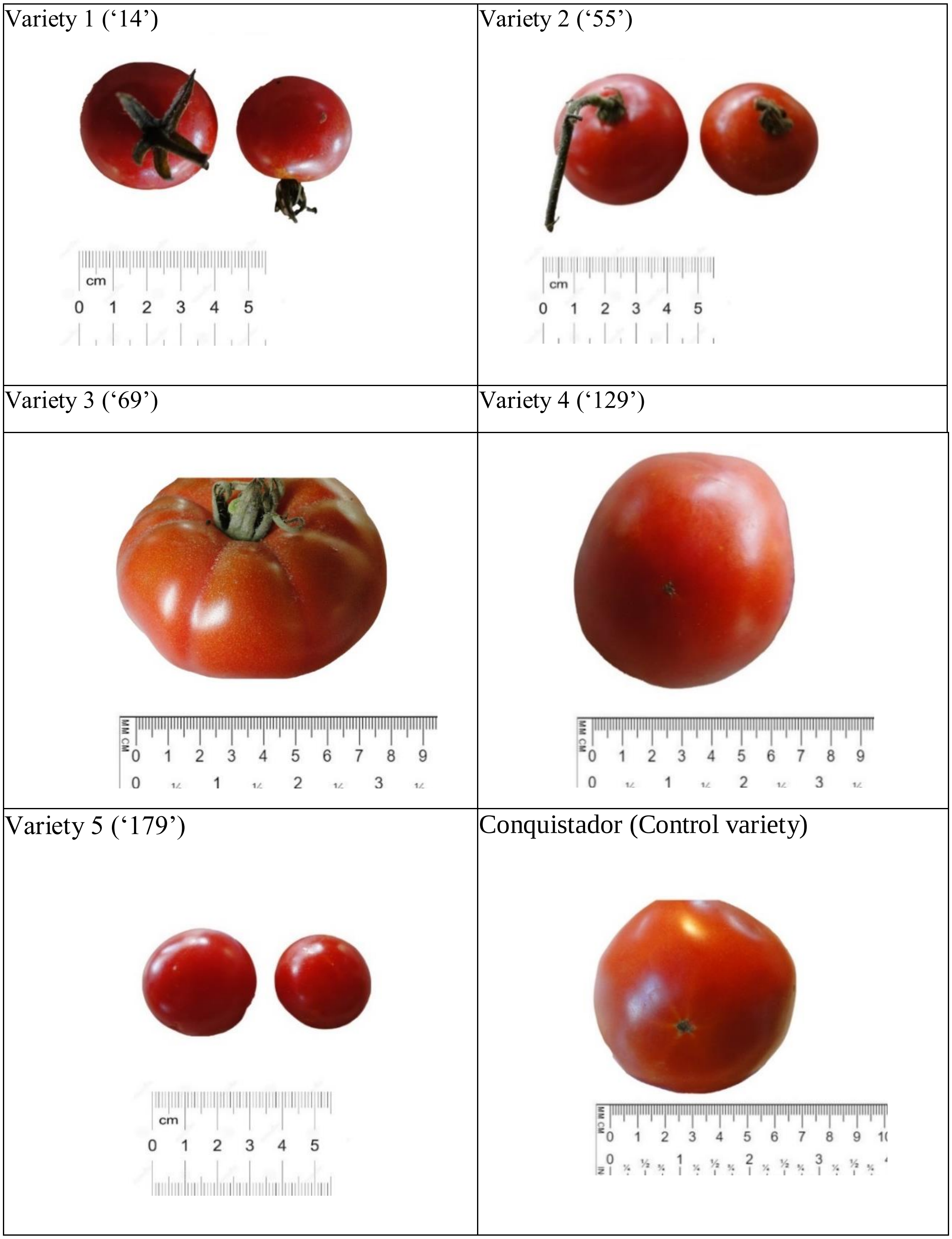

Figure 1. Representative images of the tomato fruits produced at harvest by the F_6 genotypes studied in this research, and the control variety

Of the genotypes tested, Variety 2 (cherry size) and Variety 3 (large size) should be taken in consideration for large-scale cultivation due to their high yield and resistance to pests and diseases.

The yield of the five tomato genotypes, candidates to become varieties, clearly surpassed that of the control variety, when using either chemical or biological pest control (Table 3), which is mainly attributed to the fact that they have incorporated genes for resistance to pests and diseases from wild Ecuadorian species.

The use of resistant varieties developed with native germplasm (wild species) is a highly effective method to control pests and diseases, also decreasing the pesticides usage (Benavides et.al, 2011). The resistance has been evaluated by morpho agronomical and molecular means during the development of the breeding materials and new varieties (Morales et al., 2014; Pérez et al., 2016).

Table 3. Interaction effect on yield (kg·ha^{-1}) of five candidate varieties and a variety control subjected to two control methods against pests in the province of Loja, Ecuador

Variety	Pest control method	
	Chemical	Biological
1	49,870 de	42,920 ef
2	70,770 b	61,400 c
3	81,280 a	29,900 hi
4	55,980 cd	30,600 hi
5	43,040 ef	40,220 fg
Control	34,070 gh	23,190 i

*Different letters indicate statistical differences in the mean yield according to Tukey test (P≤0.05)

This research has taken advantage of being located near the tomato center of origin and diversification, in a region where the closest wild relatives to the cultivated commercial varieties are yet found, allowing the introduction of important genes for resistance to pests and diseases.

Most varieties reacted adequately in both chemical and biological technology, although with advantage in yield with chemicals. Nonetheless, in our research the application of chemical products was minimal, proving that 3 to 4 applications suffice compared to the 40 applications that are currently applied in traditional crop cultivation in Ecuador. And, on the other hand, the fact that the use of biological control also resulted in acceptable values, suggests the possibility to produce non-chemically-treated tomatoes, highly beneficial for the health of the producer, consumers and environment

CONCLUSION

The morphological characterization of five tomato populations was performed.

Regarding their progenies, candidate genotypes to be varieties, it is concluded that based on their yield, Variety 3 (large size) under chemical pest control, and Variety 2 (cherry size) under either control method can be considered for large-scale cultivation, in Loja, Ecuador.

LITERATURE CITED

1. Álvarez, M., C. Moya, M. Florido y D. Plana. 2003. Resultados de la mejora genética del tomate (*Lycopersicon esculentum* Mill.) y su incidencia en la producción hortícola de Cuba. Cultivos Tropicales 24(2): 63-70.
2. Bai, Y. y P. Lindhout. 2007. Domestication and breeding of tomatoes: What have we gained and what can we gain in the future? Annals of Botany 100(5): 1085-1094.
3. Benavides, A., J. Cisne, D. Querol y J.C. Moran. 2011. Germoplasma de tomate silvestre (*Lycopersicum* spp.) en la reserva de recursos genéticos de Apacunca (RRGA), Chinandega. Revista Científica La Calera 11(17): 33-40.
4. Carrilho Santos, N., G. Repeza Marquez, G. Mascarenhas Maciel, L. Medeiros Pereira, H.G. Peres and J.V. Miranda Peixoto. 2020. Resistance of round tomato genotypes with determinate growth habit to two-spotted spider mites and silver leaf white fly. Bioagro 32(1): 15-22.
5. Chirinos, D.T., R. Castro, J. Cun, J. Castro, S. Peñarrieta, L. Solis y F. Geraud-Pouey. 2020. Los insecticidas y el control de plagas agrícolas: la magnitud de su uso en cultivos de algunas provincias de Ecuador. Ciencia y Tecnología Agropecuaria 21(1): e1276.
6. FAO (Food and Agriculture Organization). 2022. FAOSTAT statistical database. http://www.fao.org/faostat/en/#home (retrieved March 15, 2022].
7. IPGRI. 1996. Descriptors for tomato (*Lycopersicon* spp.). International Plant

Genetic Resources Institute, Roma, Italia. 44 p. https://n9.cl/7qno3 (retrieved March 15, 2022).

8. Labate, J.A. y L.D. Robertson. 2012. Evidence of cryptic introgression in tomato (*Solanum lycopersicum* L.) based on wild tomato species alleles. BMC Plant Biology 12(1): 133.
9. Morales, M.N., G. Espinoza, R. Morales, B. Sánchez, A. Jimenez y Y. Milián-García. 2014. Morphological characterization and resistance evaluation to *Fusarium oxysporum* in wild species of *Solanum* genera *Lycopersicon* section. Revista Colombiana de Biotecnología 16(1): 62-73.
10. Moya, C., M. Álvarez, D. Plana, M. Florido y C.J.B. Lawrence. 2005. Evaluación y selección de nuevas líneas de tomate (*Lycopersicon esculentum* Mill) con altos rendimientos y frutos de calidad. Cultivos Tropicales 26(3): 39-43.
11. Nowicki, M., M.R. Foolad, M. Nowakowska y E.U. Kozik. 2012. Potato and tomato late blight caused by *Phytophthora infestans*: an overview of pathology and resistance breeding. Plant Disease 96(1): 4-17.
12. Peralta, I.E., S. Knapp y D.M. Spooner. 2006. Nomenclature for wild and cultivated tomatoes. Tomato Genetics Cooperative Report 56(1): 6-12.
13. Pérez-Almeida, I., R. Morales, R. Medina, G. Rosales, A. Dascon y T. Solano. 2016. Evaluación molecular de genotipos de tomate por su resistencia a *Melodoigyne incognita*, *Fusarium oxysporum* y *Ralstonia solanacearum* con fines de mejoramiento. Bioagro 28(2): 107-116.
14. Ramírez-Ojeda, G., I.E. Peralta, E. Rodríguez-Guzmán, J.L. Chávez-Servia, J. Sahagún-Castellanos y J.E. Rodríguez-Pérez. 2021. Climatic diversity and ecological descriptors of wild tomato species (*Solanum* sect. *Lycopersicon*) and close related species (*Solanum* sect. Juglandifolia and sect. Lycopersicoides) in Latin America. Plants 10(5): 855.
15. Tanksley, S.D. 2004. The genetic, developmental, and molecular bases of fruit size and shape variation in tomato. Plant Cell 16 (Suppl.): S181–S189.
16. Tigchelaar, E.C. 2001. Botánica y cultivo. In: Jones J.B. et al. (eds.). Tomato pests and diseases. The American Phytopathological Society. Mundi-Prensa: Madrid. pp. 2- 4.
17. Valarezo, O., E. Cañarte, B. Navarrete y M. Arias. 2003. *Prodiplosis longifila* (Diptera: Cecidomyiidae) principal plaga de tomate en Ecuador. INIAP. p. 95. https://n9.cl/imc14 (retrieved March 15, 2022).