Cultivos Tropicales, 2020, vol. 41, no. 2, e06
ISSN impreso: 0258-5936
ISSN digital: 1819-4087

abril-junio
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas

http://ediciones.inca.edu.cu

Original article

Hydrosustainable study in tomato cultivation, its effect on fruit yield and quality

Jesús Rodríguez-Cabello[1*]

Aymara Pérez-González[1]

Loreilys Ortega-García[1]

Mayra Arteaga-Barrueta[2]

[1]Instituto Nacional de Ciencias Agrícolas (INCA), carretera San José-Tapaste, km 3½, Gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba. CP 32 700

[2]Universidad Agraria de La Habana “Fructuoso Rodríguez Pérez”, carretera a Tapaste y Autopista Nacional. San José de las Lajas. Mayabeque, Cuba

[*]Author for correspondence: jesusr@inca.edu.cu

ABSTRACT

Tomato is the most consumed vegetable in the world. In Cuba, most sowings are concentrated in the months of lower rainfall, so the application of high volumes of water for irrigation is needed. The evolution of Cuban agriculture and the effects of climate change, makes it necessary to study the water needs of crops in each environment, and a new focus on their determination. The objective of this study is to evaluate different irrigation variants in tomato cultivation and its effect on fruit yield and quality. The research was carried out in organoponic, using eight treatments that ranged between 100 and 10 % of the volume of water applied daily. Descriptors related to the components of plant growth, yield and fruit quality were evaluated. The response of the plants was characterized by the induced effect due to the different levels of irrigation. In the first 40 days after planting, no differences were observed between treatments. The water needs of the plants became evident from flowering. In the treatments of greater water stress, the organoleptic quality of the fruit was superior. The results indicate the possibility of reducing the water supply to the tomato crop to 10 %

until pre-flowering and 60 % in the following phases, to obtain quality fruits, without affecting the components of plant growth and yield.

Key words: tomato, growth, fruiting, water stress, yield, fruit quality

INTRODUCTION

The tomato (*Solanum lycopersicum* L.) is the most consumed vegetable in the world; its demand increases continuously and with it its cultivation, production and trade (1–3). Consumers prefer these fruits for their high levels of lycopene, beta-carotene, flavonoids, vitamin C and hydroxycinnamic acid derivatives (4–6).

Tomatoes occupy the eleventh place in the list of most produced species worldwide (7,8). The annual increase in production in recent years is mainly due to the increase in yield, and to a lesser extent to the increase in planting area (9).

In Cuba, tomato cultivation represents 50 % of the total area dedicated to vegetables and production ranges around 750,000 t (10). However, most plantings are concentrated between October and January, where rainfall differs from the water requirements of the plants, which coincide with the optimal stage of the species, so the application of high volumes of water is needed to irrigation (11).

Irrigation in agriculture is responsible for spending 70 % of the water available worldwide and one of the main causes of the irrational use of this resource. Two thirds of the water used in irrigation is lost in drainage and runoff, and approximately 30 % is lost in storage and transportation (12,13).To achieve irrigation optimization, it is necessary to guarantee that water use is efficient, with high productivity for each drop of water available, using a method that contributes to increasing economic performance (14).

The evolution of Cuban agriculture and the effects of climate change, makes it necessary to study the water needs of crops in each environment, as well as a new approach in its determination, if we consider that water is an essential resource, but increasingly scarce (15–17). In this sense, urban agriculture is considered one of the solutions to the adaptation of climate change, is related to the environment of cities, because it improves the climate, stimulates the recycling of organic waste and reduces energy consumption (13).

Proper water management is necessary to increase the nutritional value of food from agriculture, which contributes to the health of the population, social equity and the health of ecosystems (13,18,19). For all the aforementioned, the present study aims to evaluate different irrigation variants in tomato cultivation, to assess sustainable production with minimal impact on fruit yield and quality.

MATERIALS AND METHODS

The experiment was developed in the Department of Plant Physiology and Biochemistry of the National Institute of Agricultural Sciences (INCA), located at km 3 ½ of the San José to Tapaste highway, San José de las Lajas municipality, Mayabeque province. It is located at 23° 00’ north latitude and 82° 12’ west longitude and 138 m a.s.l.

The research was carried out under organoponic conditions, in eight concrete containers with a 1.67 m^3 capacity (0.250m x 0.6m x 0.44m) each. These contained gravel at the bottom to facilitate drainage and a mixture of leached Red Ferralitic soil, degraded (20) and decomposed cachaça in a 3:1 v/v ratio of substrate. Tomato 'Mara' seeds with germination power greater than 90 % were used.

A completely randomized experimental design with eight treatments (one for each container) and ten repetitions was used. Throughout the crop cycle and in the morning, different levels of irrigation per plant were according to the percentage required in the treatment carried out (Table 1), according to the needs of the crop (21). The rest of the cultural services were performed according to the recommendations of the technical instructions for cultivation (22).

Table 1. Description of the irrigation variants in the experiment

Treatments	Daily water needs/plant (L)	Daily applied water volume/plant (L)	Percentage of water applied daily/plant (%)
T1	1.5	1.50	100
T2	1.5	1.12	75
T3	1.5	0.90	60
T4	1.5	0.75	50
T5	1.5	0.60	40
T6	1.5	0.45	30
T7	1.5	0.30	20
T8	1.5	0.15	10

Evaluated descriptors

Growth rate of plants at 40, 60 and 75 days after planting (dap)

Height (cm): with a ruler, from the root neck to the axilla of the youngest leaf. Stem diameter (cm): with a vernier (vernier caliper) from two centimeters above the root neck. Number of leaves per plant: visual count. Dry mass of the plants (g): five plants for each treatment, oven drying (BrBOXUN) at 70 ºC until constant mass and weighing on the analytical balance (*Sartorius*).

Components of quality and performance

Fruiting percentage: the determinations of the percentage were to arcsen √n for statistical analysis converted and informed of their real value. Polar (DP) and equatorial (DE) diameter of the fruit at 60, 75 and 90 DAP: it was measured with a vernier (three fruits per plant were taken as a sample). Fruit color: performed on 10 mature fruits per treatment, four days after harvest: a Minolta model CR-200 colorimeter (Instruments Inc. (Highland Industrial Park, England) was used. Data were expressed in L * values. (Luminosity), a* and b* (color coordinates), from the CIELAB scale (23).

Number of fruits per plant: by visual count. For the analysis of the data, the normality and homogeneity of the variance were verified using the Kolmogorov-Smirnov test and the Cochran C, Hartley, Bartlett test. Average fruit mass (g). Yield: by dividing the total mass of fruits in the treatment by the number of total fruits. Total soluble solids (ºBrix): they were determined by means of a digital refractometer model NR-151 Instruments Inc. (Highland Industrial Park, England). Titratable acidity: the methodology proposed in COVENIN standard No. 1151-77 was used, by means of direct titration with NaOH (0.1 N).

For the analysis of the data, an ANOVA and analysis of variance of simple classification were used. The resulting means were compared with the Duncan Multiple Range Test (24) or Tuckey for p≤ 0.05 when there were significant differences between treatments, processed using the statistical package for Windows Statistical Package for the Social Science (SPSS Inc.) version 21 (25).

RESULTS AND DISCUSSION

Plant growth rate at 40, 60 and 75 days after planting

The result of the Variance Analysis shows the growth behavior of the \`Mara´ tomato plants at 40, 60 and 75 dap, subjected to different irrigation variants (Table 2). Exponential growth was observed that was not vigorous in the first 40 days, but then increased significantly up to 75 dap, at which time the plants bear fruit and use their reserves for this physiological function (26).

Table 2. Assessment of growth rates (heights and stem diameter) of tomato plants (*Solanum lycopersicum* L.) \`Mara´ at 40, 60 and 75 dap, subjected to different variants of organoponic irrigation

Treatments	Height of plants			Stem diameter			Leaves number	Dry mass
	40 dap	**60 dap**	**75 dap**	**40 dap**	**60 dap**	**75 dap**	**40 dap**	**40 dap**
T-1	21.0	52.6 ab	77.9 a	0.56 ab	1.36 a	1.58 a	6.8	2.24 ab
T-2	21.9	58.2 a	73.0 a	0.62 a	1.20 b	1.34 bc	7.6	2.36 a
T-3	19.6	50.8 b	71.4 ab	0.54 ab	1.10 bc	1.38 bc	2.7	2.16 b
T-4	19.1	52.8 ab	63.2 bc	0.56 ab	1.22 b	1.42 b	6.8	2.12 b
T-5	19.3	45.8 bc	57.8 cd	0.50 b	1.00 cd	1.08 d	6.4	2.30 ab
T-6	20.3	46.0 bc	55.9 cd	0.60 a	0.96 cd	1.18 d	6.8	2.12 b
T-7	19.4	39.4 c	54.6 cd	0.56 ab	0.94 d	1.24 cd	7.4	2.13 b
T-8	21.7	41.8 c	51.8 d	0.56 ab	1.00 cd	1.16 d	7.2	2.14 b
E. est. X	**2.70 NS**	**7.54 ***	**11.15 ***	**3.05 ***	**7.54 ***	**1.24 ***	**1.43 NS**	**0.08 ***

*Statistically significant difference. NS there is no statistically significant difference. Means with equal letters do not differ from each other, by Duncan's Test ($p \leq 0.05$)

There were no differences in the height of the plants and the number of leaves between the treatments evaluated at 40 dap. Similar behavior, regarding differences between treatments, was observed in the stem diameter and dry mass, with the exception of T2 and T5 that differed from each other in the first and T2 that did not differ from T1 and T5 in the second. Result related to the present was obtained in \`INCA 9 (1)´ evaluated in Spain (27).

It is estimated that in optimal climatic conditions for cultivation, an adult plant requires between 0.6 and 1.8 L of water daily (21). However, tomato roots are superficial in the first stage of growth, which is why the daily supply of 0.15 L of water per plant in the morning is sufficient to maintain its turgidity and optimal growth prior to phenological phase of flowering.

Keep in mind the content of organic fertilizer applied to the substrate, which contributed to the retention of water in the soil and the development of the roots, which was not affected after the first month after planting as there was no transplant due to the direct sowing. These are aspects to consider for efficient irrigation management, because the crop responds to the water available in the root zone and when it is applied, not all the water is retained in the area that allows the roots to take it.

The physiological response appreciated between the treatments in this phenological phase is because the plants demand low water levels given their reduced foliage. The leaves constitute the fundamental organ for the photosynthetic process and the formation of dry mass of the vegetable. Hence, after this phenological phase, the foliage increases, which implies a greater leaf area and abundant accumulation of dry mass in the organ itself, which favors its physiological activity.

At 60 days, the affectations in the growth of the plants began from the treatments where it watered below 50 %. The highest plants corresponded to the first four treatments and the smallest to the last two. Treatments T5 and T6 maintained an intermediate behavior, differing only from T2. The differences between the treatments in this phenological phase are given by the development of the plants. By increasing the leaf area, plants increased transpiration levels with higher water demand, due to changes in photosynthesis and respiration processes (13). The critical phase for cultivation is considered to occur between 38 and 80 days after transplanting, which coincides with flowering and the first stage of fruit ripening (28).

The differences in the height of the plants were accentuated at 75 dap, from T4 with respect to the treatments from T1 to T3 with the highest growth. It is inferred that when the water deficit is applied slowly, there are changes in development processes that have various effects on growth. Limiting leaf expansion is one of the most affected processes under these conditions, because photosynthesis depends on it (29).

The largest stem diameter corresponded to T1, irrigated with 100 % of the water required by the plant at 60 and 75 days, followed by T2 at T4 (75–50 %) of water. Water deficit of less than 50 % affected the diameter of the stem of the plants. The least thick stems corresponded to T8 (10 %) of the irrigation water. However, these did not differ from T5 to T7.

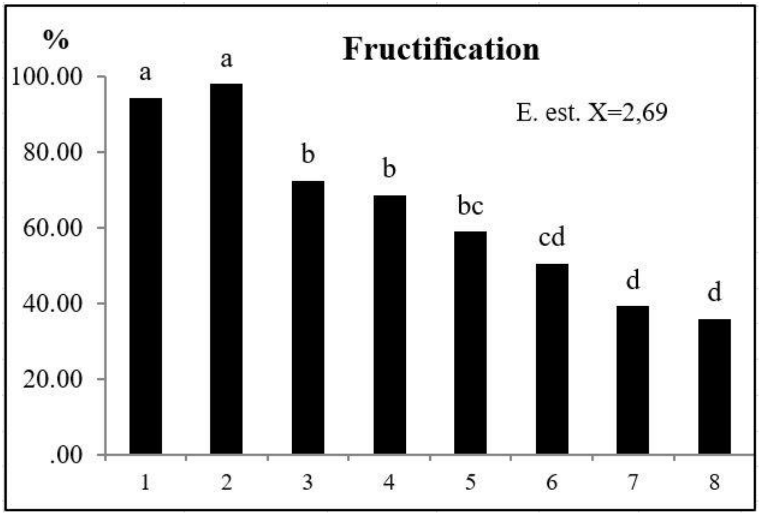
According to the results shown, the water requirements may differ between the phenological stages. The response of the plant depends on the stage of development of the plant at the time of stress and its duration and severity. In addition, the genotype and the environmental factors that cause it (30).

Yield components

Fructification

The fruiting percentage showed differences according to the irrigation variants applied (Figure 1). The first two treatments showed a better percentage, while treatments T7 and T8, with less irrigation levels, reached the lowest values, less than 40 %. In studies carried out on this species, it was shown that water consumption increased considerably during the fruiting stage, attributable to the increase in the physiological needs of plants at this stage (31).

Treatments T3 to T6 with irrigation between 60 and 40 %, achieved fruiting percentages between 73 and 50 %. This result demonstrates the susceptibility of plants to irrigation in this phenological phase. For this reason, this component is used as an index of stress tolerance, based on the differential behavior of accessions in stressful and non-stressful environments (32).

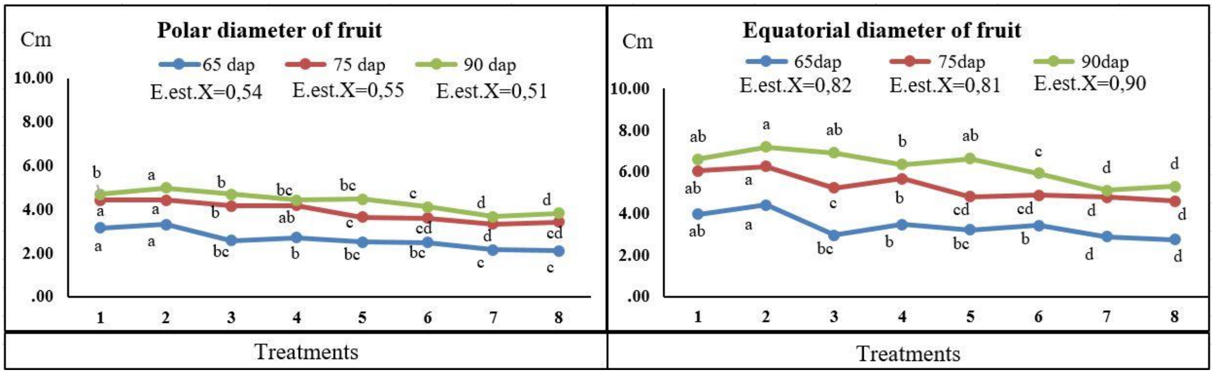


Means with equal letters do not differ from each other, by Duncan's Test (p≤0.05)

Figure 1. Effect of irrigation on the fruiting of the tomato (*Solanun Lycopersicum* L.) `Mara´, subjected to different variants of organoponic irrigation

Dimensions of the fruit

The growth of the fruits at 60, 75 and 90 dap, subjected to different irrigation variants are shown in Figure 2. It was appreciated that the diameter of the fruits was decreasing as the water stress increased. Both the polar (DP) and equatorial (DE) diameter of the fruits were greater in the first two treatments. Treatments T7 and T8 obtained the smallest diameter fruits at all times evaluated. However, at 60 dap in the PD they only differed from the T1, T2 and T4 treatments.



Means with equal letters do not differ from each other, by Duncan's Test ($p \leq 0.05$)

Figure 2. Polar and equatorial diameter of tomato fruits (*Solanum Lycopersicum* L.) `Mara´, subjected to different variants of organoponic irrigation

As has been seen, water deficit stress, however slight, affects the size of the fruit. It can be positive for its quality in parameters such as firmness, flavor and shelf life, but with smaller fruits.

Fruit color

The color of the fruits four days after harvest is shown in Table 3. The luminosity (L*) was higher in the T1 and T2 treatments with respect to the rest of the treatments, which did not differ from each other. In both coordinates the values were positive and lower in a* coordinate with respect to the b* coordinate, which indicated that the tone angles are intermediate between light and dark, away from gray.

In a* coordinate, the highest values corresponded to treatments from T8 to T6, although the latter only differed from T1 and T2, which yielded the lowest values. In the b* coordinate, T5 was similar to the treatments with greater water stress. These values correspond to the most intense red color with respect to treatments T1 to T3, which showed light red colors.

Enzymes that are highly dependent on ethylene, which regulate the synthesis of lycopene, b-carotene, and the breakdown of chlorophyll (33), control changes in fruit color. Similar results to the present were obtained in cherry tomato subjected to water deficit (34).

Table 3. Color of tomato fruits (*Solanum Lycopersicum* L.) \`Mara´ four days after harvest, subjected to different variants of organoponic irrigation

	Fruit color 4 days after harvest		
Treatments	**L***	**a***	**b***
1	45.1 a	12.5 c	35.2 a
2	44.7 ab	14.9 c	37.7 a
3	42.0 bcd	18.6 b	34.0 b
4	41.5 cd	19.3 b	33.4 bc
5	40.8 d	19.9 b	31.1 cd
6	41.6 cd	21.5 ab	31.6 cd
7	41.9 cd	24.4 a	31.4 cd
8	40.6 d	23.7 a	30.9 d
E. est. X	**2.4**	**3.6**	**3.0**

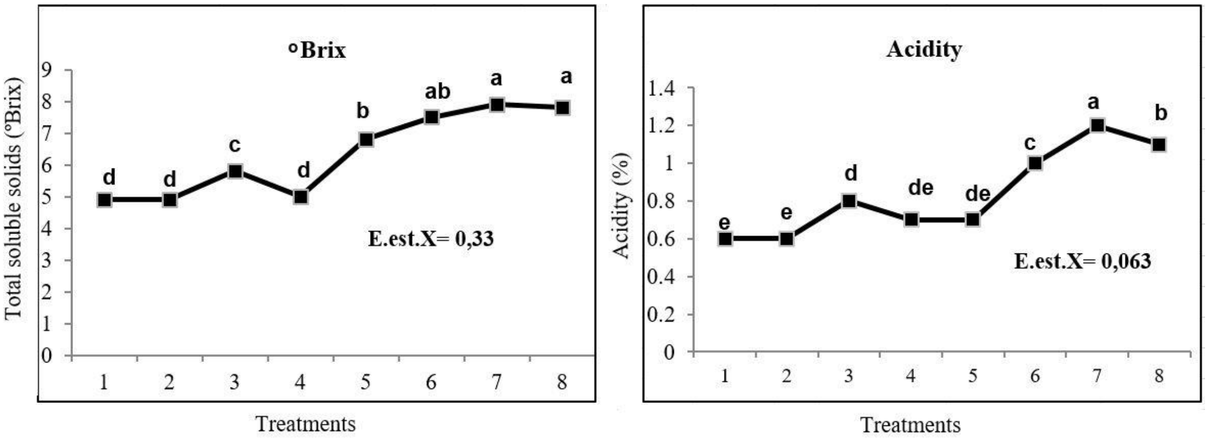
Means with equal letters do not differ from each other, by Duncan's Test ($p \leq 0.05$)

The intense red color appreciated in the treatments of greater water stress reveals a greater content of lycopene, which is significant for agriculture, food, nutrition, health, among others. The market for these compounds as food ingredients is continually growing. On the other hand, many studies conclude that appropriate levels in the diet can be positive in the protection against diseases due to its antioxidant properties (35).

Internal quality of the fruit

The average values of ºBrix and titratable acidity in \`Mara´ are shown in Figure 3. Variability and similarity were observed between these indicators and the increase in stress due to water deficit in plants with differences between treatments.

The ºBrix showed the lowest values for the treatments where it watered above 50 % (T1 to T4). Similar results were obtained in 15 tomato cultivars evaluated in Spain (36). In other studies, values equal to or greater than 4.0 ºBrix were achieved, which are considered significant, since there is a direct relationship between soluble solids and fruit firmness (37).



Means with equal letters do not differ from each other by the Duncan´s test (p≤0,05)

Figure 3. Bromatological evaluation in fruits of tomato (*Solanum Lycopersicum* L.) `Mara´ 4 days after the harvest subjected to different irrigation variants in organoponic

In the rest of the treatments, T6 to T8 stood out, with greater water stress. ºBrix is the index with the greatest influence on industrial performance and more than the varietal character, there are environmental factors that determine the content of soluble solids, especially temperatures and water during the ripening period, which can cause them to vary for fruits of the same cultivar between 4 and 7 % (37).

Acidity also achieved the highest percentages in the treatments with the highest water stress, while treatments from T1 to T5 reached values between 0.5 and 0.7 %. Similar results were obtained in Cuba (38). The author stated that even when the values are relatively high; it does not affect the organoleptic properties of the fruits, which, on the contrary, is a desired characteristic when the fruits are destined for industry.

Total acidity is due to the presence of various organic acids (tartaric, malic, acetic, citric, succinic, glutamic, among others). Citric acid predominates and usually ranges from 0.35 to 0.40 g/100 ml of juice (36). Values above 0.5 % are recognized as good (37).

Reducing sugars and total acidity influence the flavor of the fruit. In studies carried out on cherry tomato, it was shown that with the reduction of more than 50 % of the irrigation water, the fruit maintained its commercial, nutritional and functional quality (35).

Yield

The result of the analyzes of variance carried out for the yield showed a correspondence between the most productive treatments and the irrigation levels applied in the different descriptors (Table 4). The treatments T1 to T3 excelled in the number of fruits and the average fruit mass per plant, which led to a higher yield. Related values for this cultivar were obtained under field conditions in Cuba, with an average of 12 fruits per plant and a mass of 94 g (5).

Treatments T7 and T8 showed the lowest number of fruits per plant, while treatments from T4 to T6 reached higher values than these, with no differences between them for this descriptor. However, the average fruit mass and yield was lower from the T6 treatment. It has been shown that when the quantity of water necessary for the plant is not supplied, the crop yield is affected (39). However, studies in tomato plants subjected to water deficit revealed that, in most cases, the decrease in irrigation applied to plants did not have a negative effect on the yield and its components (6).

In ball-type tomatoes grown under greenhouse conditions, the response of the plants with respect to the growth, yield and fruit mass was positive as the amount of water applied was reduced with respect to the maximum recommended volume (40). Also, when studying the effects of regulated deficit irrigation strategies, applied in different phenological phases of tomato, higher fruit quality and water productivity were found when irrigation was applied with a cultivation coefficient (Kc of 0.8). However, when a Kc of 0.6 was applied in the flowering and fruit development stages, significant yield losses were obtained (4).

Table 4. Evaluation of the yield and its components in tomato (*Solanum Lycopersicum* L.) `Mara´, subjected to different variants of organoponic irrigation

Treatments	**Fruits per plant**	**Fruit Mass (g)**	**Yield (kg/plant)**
1	11.6 a	96.8 a	1.1 a
2	11.9 a	91.7 a	1.1 a
3	11.4 a	94.7 a	1.1 a
4	8.8 b	86.8 b	0.8 b
5	8.5 b	86.9 b	0.7 b
6	8.1 b	65.5 c	0.5 c
7	7.0 d	63.4 c	0.4 c
8	7.1 d	66.9 c	0.5 c
E. est. X	**0.20**	**1.83**	**0.03**

Means followed by the same letter do not differ from each other by the Tukey test (p≤0.05)

CONCLUSIONS

The response of tomato plants, grown under organoponic conditions, is characterized by an induced effect due to different levels of irrigation. The results indicate the possibility of reducing the water supply to the tomato crop to 10 % from planting to pre-flowering and to 60 % in the following phases, to obtain better quality fruits, without affecting the components of growth and yield of the organoponic plants.

BIBLIOGRAPHY

1. Florido Bacallao M, Álvarez Gil M. Aspectos relacionados con el estrés de calor en tomate *Solanum lycopersicum* L. Cultivos Tropicales. 2015;36:77–95.
2. González B, Fortis H, Preciado R, Segura C, Salazar Sosa E, García H, et al. Calidad fitoquímica de tomate Saladette producido con sustratos orgánicos bajo condiciones de invernadero. Phyton (Buenos Aires). 2016;85(1):71–8.
3. Allende M, Salinas L, Rodríguez F, Olivares N, Riquelme J, Antúñez A, et al. Manual de cultivo del tomate bajo invernadero. INIA. Santiago de Chile-Chile. 2017;112.
4. López L. Manual Técnico del cultivo de tomate *Solanum lycopersicum*L. Innovación para la seguridad alimentaria y nutricional en Centroamérica y Panamá. Costa Rica. Instituto Nacional de Innovación y Transferencia en Tecnología …; 2017. 130 p.
5. Moya-López CC, Orozco-Crespo E, Mesa-Fleitas ME. Ferias de agro-biodiversidad cubanas: vía para la selección de variedades de tomate. Agronomía Mesoamericana. 2016;27(2):301–10.
6. Dell’Amico-Rodríguez JM, Guillama R, González MC. Respuesta de cinco líneas de tomate *Solanum lycopersicum* L. cultivadas en dos variantes de riego, en condiciones de campo. Cultivos Tropicales. 2018;39(4):78–85.
7. FAOSTAT. Crops [Internet]. 2016 [cited 24/03/2020]. Available from: http://www.fao.org/faostat/en/#data/QC.
8. Coyago Cruz E del R. Estudio sobre el contenido en carotenoides y compuestos fenólicos de tomates y flores en el contexto de la alimentación funcional. [Internet]. De Sevilla; 2017 [cited 24/03/2020]. 238 p. Available from: https://idus.us.es/handle/11441/77389
9. Arcauce Lozano M. Aplicación de técnicas de riego deficitario en tomate para industria y sus efectos sobre la producción y calidad de la cosecha. Universidad de Sevilla. 2015;68.

10. Terry Alfonso E, Falcón Rodríguez A, Ruiz Padrón J, Carrillo Sosa Y, Morales Morales H. Respuesta agronómica del cultivo de tomate al bioproducto QuitoMax®. Cultivos Tropicales. 2017;38(1):147–54.
11. González MC, Mukandama JP, Fuentes JL, Sevillano E. Nuevos mutantes de tomate para uso industrial tolerantes a bajos insumos hídricos. Cultivos Tropicales. 2007;28(3):89–90.
12. FAO. Evaluación de los Recursos Hídricos Renovables. [Internet]. 2016 [cited 24/03/2020]. Available from: http://www.fao.org/aquastat/en/
13. Aguilar CCRB. El manejo integrado del agua en la agricultura: necesidad de implementación y aspectos vinculados. Revista Científica Agroecosistemas. 2017;5(2):40–54.
14. Kadasiddappa MM, Rao VP, Reddy KY, Ramulu V, Devi MU, Reddy SN. Effect of irrigation (drip/surface) on sunflower growth, seed and oil yield, nutrient uptake and water use efficiency-A review. Agricultural reviews. 2017;38(2):152–8.
15. Aurín R. Agua y desarrollo sostenible. Aplicación de los objetivos de desarrollo sostenible relacionados con el agua. La relevancia de la tecnología. Revista Iberoamericana agua. 2015;2(1):104.
16. Alaña Castillo TP, Capa Benítez LB, Sotomayor Pereira JG. Desarrollo sostenible y evolución de la legislación ambiental en las MIPYMES del Ecuador. Revista Universidad y Sociedad. 2017;9(1):91–9.
17. Puebla JH. Estudio de las necesidades de agua de los cultivos, una demanda permanente, un nuevo enfoque. Revista Ingeniería Agrícola. 2017;5(1):52–7.
18. Brown Manrique O, Gallardo Ballat Y, Correa Santana A, Barrios García S. El cambio climático y sus evidenciasen las precipitaciones. Ingeniería hidráulica y Ambiental. 2015;36(1):88–101.
19. López-Seijas T. Matrices integradoras de acciones para la implementación de medidas de adaptación al cambio climático a escala local. Revista Ingeniería Agrícola. 2017;6(4):23–31.
20. Hernández Jiménez A, Cabrera Rodríguez A, Borges Benítez Y, Vargas Blandino D, Bernal Fundora A, Morales Díaz M, et al. Degradación de los suelos Ferralíticos Rojos Lixiviados y sus indicadores de la Llanura Roja de La Habana. Cultivos Tropicales. 2013;34(3):45–51.

21. Merino Ruiz GAM. Producción de semillas híbridas de tomate *Solanum lycopersicum* L. determinados o indeterminados en el valle de Cañete. 2017;78.
22. MINAGRI. Instructivo técnico para organopónicos y huertos intensivos. Minagri La Habana; 1998. 74 p.
23. McGuire RG. Reporting of objective color measurements. HortScience. 1992;27(12):1254–5.
24. Duncan DB. Multiple range and multiple F tests. Biometrics (International Biometric Society). 1995;11(1):1–42.
25. SPSS. Manual de usuario del sistema básico de IBM SPSS Statistics. Vol. 21. IBM USA; 2011. 484 p.
26. Alemán Pérez RD, Domínguez Brito J, Rodríguez Guerra Y, Soria Re S. Indicadores morfológicos y productivos del cultivo del tomate en Invernadero con manejo agroecológico en las condiciones de la Amazonía Ecuatoriana. Centro Agrícola. 2016;43(1):71–6.
27. Dell Amico JM, Fernández F, Nicolás Nicolás E, Sánchez-Blanco M de J. Crecimiento, relaciones hídricas y aprovechamiento nutricional en el tomate inoculado con un inoculante micorrízico en soporte líquido. Cultivos Tropicales. 2015;36(4):77–85.
28. García C. Manejo del riego en el cultivo de tomate industria. Revista INIA. 2007;12:26–9.
29. Nilsen ET, Orcutt DM. Physiology of plants under stress. Abiotic factors. Physiology of plants under stress. Abiotic factors. 1996;
30. Cattivelli L, Rizza F, Badeck F-W, Mazzucotelli E, Mastrangelo AM, Francia E, et al. Drought tolerance improvement in crop plants: an integrated view from breeding to genomics. Field Crops Research. 2008;105(1–2):1–14.
31. Peña-Casadevalls MS, Vargas-Rodríguez P. Tecnología del riego por succión para la producción de tomate *Lycopersicon esculentum* L. en condiciones controladas. Revista Ciencias Técnicas Agropecuarias. 2018;27(2):1–9.
32. Florido Bacallao M, Bao Fundora L, Lara Rodríguez RM, Álvarez Gil M, Dueñas Hurtado F, Shagarodsky Scull T. Evaluación de la tolerancia a la sequía en tomate *Solanum lycopersicum* L. utilizando los índices de tolerancia. Cultivos Tropicales. 2016;37(1):128–35.
33. Martínez-González ME, Balois-Morales R, Alia-Tejacal I, Cortes-Cruz MA, Palomino-Hermosillo YA, López-Gúzman GG. Poscosecha de frutos: maduración y cambios bioquímicos. Revista mexicana de ciencias agrícolas. 2017;8(19):4075–87.

34. Matsuzoe N, Zushi K, Johjima T. Effect of soil water deficit on coloring and carotene formation in fruits of red, pink, and yellow type cherry tomatoes. Journal of the Japanese Society for Horticultural Science. 1998;67(4):600–6.
35. Coyago-Cruz E, Corell M, Stinco CM, Hernanz D, Moriana A, Meléndez-Martínez AJ. Effect of regulated deficit irrigation on quality parameters, carotenoids and phenolics of diverse tomato varieties *Solanum lycopersicum* L. Food Research International. 2017;96:72–83.
36. Ciruelos-Calvo A, De la Torre R, González-Ramos C. Parámetros de calidad en el tomate para industria. La agricultura y la ganadería extremeñas, http://eia. unex. es/EIIAA/P ortals/0/L a. 2008;13(31):157.
37. Cabello JR. Obtención de híbridos F1 de tomate *Solanum lycopersicon* L. Estimación de parámetros genético-estadísticos del rendimiento y sus componentes. UNIVERSIDAD DE LA HABANA; 2006. 83 p.
38. Dell´Amico J. Comportamiento de plantas de tomate (Solanum lycopersicum L.) ante condiciones de abastecimiento hídrico del suelo. [ISAAC]; 1992. 27 p.
39. Guerra DD, Grajales LC, Rojas LR. Efecto del riego y la fertilización sobre el rendimiento y la calidad de la fruta de lima ácida Tahití Citrus latifolia Tanaka *Rutaceae*. Corpoica. Ciencia y Tecnología Agropecuaria. 2015;16(1):87–93.
40. Macías-Duarte R, Grijalva-Contreras RL, Robles-Contreras F. Efecto de tres volúmenes de agua en la productividad y calidad de tomate bola *Lycopersicon esculentum* Mill. bajo condiciones de invernadero. Biotecnia. 2010;12(2):11–9.
41. Nangare DD, Singh Y, Kumar PS, Minhas PS. Growth, fruit yield and quality of tomato *Lycopersicon esculentum* Mill. as affected by deficit irrigation regulated on phenological basis. 2016;171:73–9.