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RESPONSE OF FIVE TOMATO LINES (*Solanum lycopersicum* L.) GROWN IN TWO IRRIGATION VARIANTS, UNDER FIELD CONDITIONS

Respuesta de cinco líneas de tomate (*Solanum lycopersicum* L.) cultivadas en dos variantes de riego, en condiciones de campo

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ABSTRACT. The tomato crop, for its biological benefits, is an excellent model for basic and applied research programs. In addition, due to its nutritional properties it has reached a considerably high popularity worldwide. On the other hand, the drought stress currently aggravated by global warming limits the crops productivity throughout the world. Therefore, it is essential to obtain cultivars with greater water use efficiency. The work consisted to evaluating the behavior of five tomato lines under field conditions and cultivated in two irrigation variants. The seedlings were planted in blocks of 1000 m^2 each in a leached red ferralitic soil. Two soil moisture treatments (T1 and T2) were established, which were differentiated by their arrangement of the drip irrigation lines. T1 where the humidity was maintained in a range between 22 % and 36 % (well supplied) and T2 where the humidity was between 14 and 22 % during the experiment time (stress treatment). Evaluations of Volumetric Soil Water Content (CVA) and stomatal conductance (gs) were made at 23, 30, 39, 44 and 51 DDT and the yield and its components. The results showed a differentiated effect of the treatments on soil moisture, which induced significant differences of the gs in favor of the plants cultivated in T1. The decrease of the irrigation applied to the plants of the different lines cultivated with T2, in most of the cases did not have a negative effect on the yield and their components.

Key words: yield, water plant relations, soil moisture

RESUMEN. El cultivo del tomate, por sus bondades biológicas, constituye un excelente modelo para programas de investigaciones básicas y aplicadas. Además, por sus propiedades nutricionales ha alcanzado una popularidad considerablemente elevada a nivel mundial. Por otra parte, el estrés por sequía agravado actualmente por el calentamiento global, limita la productividad de los cultivos en todo el mundo. Por ello, resulta imprescindible obtener cultivares con mayor eficiencia del uso del agua. El trabajo consistió en evaluar el comportamiento de cinco líneas de tomate en condiciones de campo y cultivadas en dos variantes de riego. Las posturas se plantaron en bloques de 1000 m^2 cada uno en un suelo Ferralítico Rojo lixiviado. Se establecieron dos tratamientos de humedad (T1 y T2) del suelo, diferenciados por su disposición de las líneas de riego por goteo. El tratamiento T1 donde la humedad se mantuvo entre el 22 y 36 % (bien abastecido) y T2 donde la humedad estuvo entre 14 y 22 % (estrés). Se realizaron evaluaciones de contenido volumétrico del agua en el suelo (CVA) y conductancia estomática (gs) a los 23, 30, 39, 44 y 51 DDT y del rendimiento y sus componentes. Los resultados, evidenciaron un efecto diferenciado de los tratamientos en la humedad del suelo, que indujeron diferencias significativas de la gs a favor de las plantas cultivadas en T1. La disminución del riego a las plantas de las líneas cultivadas con T2, en la mayoría de los casos, no tuvo un efecto negativo en el rendimiento de las plantas y sus componentes.

Palabras clave: rendimiento, relaciones planta agua, humedad del suelo

INTRODUCTION

Tomato is considered a protective food, due to its particular nutritional value, since it provides important nutrients such as lycopene, beta-carotene, flavonoids, and vitamin C and hydroxycinnamic acid derivatives. In addition, this crop has achieved a colossal popularity,

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especially in recent years, with the discovery of the antioxidant activities of lycopene and its anticancer functions (1).

Due to its biological exclusivity, it is an excellent model for programs, both basic and applied research. This is because it has a number of useful characteristics, such as the possibility of growing under different growing conditions, a relatively short life cycle, seed production capacity, relatively small genome (950 Mb), lack of gene duplication, high self-fertility and homozygosity, easy way to control pollination and hybridization, capacity for asexual propagation by grafting and possibility of regenerating plants of different explants (2,3).

Drought is among the most devastating abiotic stresses that limit the productivity of crops worldwide. Global warming has worsened this situation in most agricultural regions, so it is imperative to develop crops with more efficient use of water that can minimize yield losses induced by drought. In addition, tolerance to drought stress can not only improve the productivity of the land that is in use, it can also allow the exploitation of arable land with limited water supplies (4).

Achieving high irrigation efficiency in the cultivation of tomato (*Solanum lycopersicum* L.) grown under different conditions is of great importance, if we consider that water is an essential resource, but unfortunately increasingly scarce. (5).

Taking into account the evolution of Cuban agriculture and the need for greater precision in water balances, given the challenge of a future shortage motivated by increased demand associated with an increase in the areas to be irrigated and the effects of possible changes climatic, it seems necessary to update knowledge about the water needs of crops in the Cuban environment; which will require, in addition to a new focus in its determination (6).

The participation of the research group in this work was with the objective of evaluating the response of five lines of tomato grown in two variants of irrigation and directed, in addition, to the generation of knowledge about the ecophysiology of the efficiency of water use by the plants, to know much better the key processes for the production, the weight of the climatic and edaphic variations on the efficiency of these processes and also to identify varieties of greater efficiency in the use of the water.

MATERIALS AND METHODS

The work was carried out in the National Institute of Agricultural Sciences of the Mayabeque-Cuba province, the area of the agroclimatic unit was approximately one hectare of a leached Red Ferralitic soil (7). Five tomato lines (*Solanum lycopersicum*) that were transplanted on February 20, 2017 were planted in two blocks of approximately 1000 m^2 each, with a planting density of 44 444 plants per hectare (0.90 m between rows and 0, 25 m between plants). Of the five lines, those identified with numbers 20, 22 and 45 are of salad type and 24 and 28 of industry type, all were kept in optimum conditions of agronomic management and cultural attention until harvest (April 20th, 2018).

Irrigation was carried out by means of a drip system with a weekly frequency and two soil moisture treatments (T1) and (T2) were established with standards of approximately 200 and 100 m^3 ha^{-1}, respectively. Both treatments were differentiated by their arrangement of irrigation lines (T1) where the humidity of the same was maintained in a range between 22 and 36 % (well supplied) and (T2) where the humidity was between 14 and 22 % during the whole culture (stress treatment), establishing a sample design consisting of two blocks of 28 rows of 40 m long, seven rows corresponding to each tomato line.

The volumetric moisture of the soil was determined at a depth of 16 cm, using a HD2 Precise Moisture Measurement instrument equipped with a TRIME®-PICO TDR Technology Moisture Sensor, Germany, calibrated with the internal calibration No. 2 of the probe itself.

An automatic meteorological station (IMETOS) was installed in the central part of the cultivated area and meteorological data (solar radiation (Mj m^{-2} s^{-1}), air temperature (ºC), precipitation (mm) and relative humidity (%) were measured simultaneously at five minute intervals.

Contenido Volumétrico del Agua en el Suelo (CVA) y conductancia estomática (GS) Volumetric Content of Water in the Soil (CVA) and stomatal conductance (GS)

The CVA (%) evaluations were made from the 23 (DAT), 15 measurements were made in each irrigation treatment, between two plants in the row, at 23, 30, 39, 44 and 51 DDT. Also, the gs (mmol H_2O m^{-2} s^{-1}) was measured between 11:00 and 11:30 am (maximum hour), in leaves of the upper third of the plants, well developed and totally exposed to the sun in five plants of each line in (T1) and (T2), respectively.

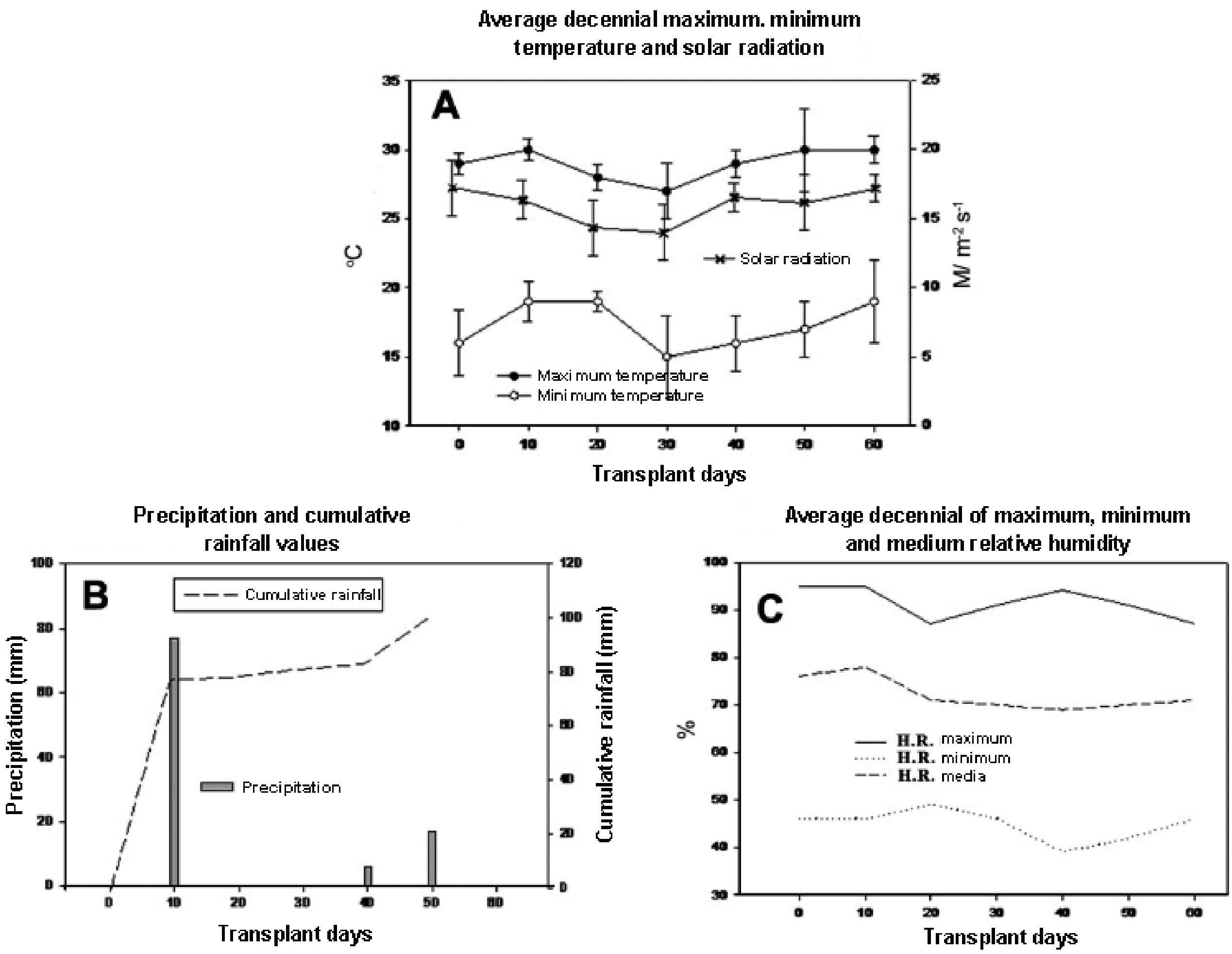
The yield and its components were evaluated in ten randomly selected plants in each of the moisture treatments and the five lines studied.

For the processing of the data, the comparison of means and the calculation of the confidence interval, the Statistical Program SPSS 19.0 for Windows was used. The graphing of the results was done through the SIGMA PLOT 11.0 program.

RESULTS AND DISCUSSION

The variations of the meteorological variables occurred during the experiment are presented in Figures 1A, 1B and 1C. The average decadal values of the air temperatures (1A) the average values of the maximum were 28 ºC (maximum of 31 ºC and minimum of 25 ºC). The minimums varied more than the maximums and were in the order of 17 ºC as average (maximum values of 22 ºC and minimum of 11 ºC). In terms of solar radiation, the values were on average 16 Mj m^{-2} s^{-1} (maximum values of 19 and minimum values of 9 Mj m^{-2} s^{-1}). These values, in a general way, indicate that the days were relatively warm and the nights cool.

During the period only three rain events were recorded (Figure 1B), in the first five DAT there were 77 mm of precipitation, at 41 DAT there were six mm and between 57 and 58 DAT occurred 17 mm, giving rise to an accumulated rain of 100 mm in the 60 days of the experiment, which would correspond to approximately 1.7 mm of precipitation per day. It is noteworthy that there was a period of 30 days, between 10 and 40 DAT without rain and that between 10 and 50 DAT only six mm were recorded. Therefore, the experimental period can be considered as dry, since the highest rainfall occurred at the beginning of the experiment.

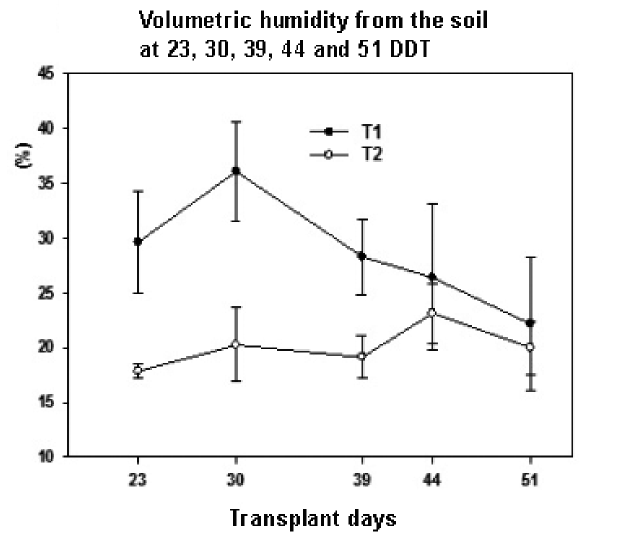


Maximum and minimum air temperatures and solar radiation (A), precipitation and accumulated rainfall (B) and maximum, minimum and average relative humidity (C) occurred during the experiment
The bars above the mean values represent the confidence interval of the means (α=0.05)

Figure 1. Decennial average values of climatic variables

The maximum, minimum and average relative humidity (RH) values are shown in Figure 1C, where it can be seen that the maximum HR was in the range between 90 and 100%, the minimum between 40 and 50 % and the means between 70 and 80%, values that are typical of the locality at this time of the year.

Figure 2 shows the variations of soil CVA, where it was observed that in the irrigation treatments (T1) and (T2) this variable showed statistical differences (α=0.05) between both at 23, 30 and 39 DAT. In (T1) average maximum values of 36 % were reached at 30 DAT and minimums of 22 % at 51 DAT. In (T2), the average maximum value (22 %) was presented at 44 DAT, without difference with (T1) at that time and the minimum of 17 % at 23 DAT. These results show the effect of irrigation treatments applied to the crop. Several studies have shown that TDR technology can be used to analyze the temporal and spatial variability of water content in the soil at a fine resolution scale (8).



The bars above the mean values represent the confidence interval of the means (α=0.05)

Figure 2. Seasonal variation of soil CVA in treatments at 16 cm depth

Stomatal conductance estimates the gaseous exchange rate and transpiration (ie, the absorption of CO_2 and water loss) through the stomata of the leaves, according to the degree of opening or closing of the same and, therefore, the physical resistance to the movement of gases between the air and the interior of the sheet. Therefore, it is a function of the density, size and degree of opening of stomata (9) and soil moisture, since stomatal control is basically conditioned by the availability of water in the root zone, water reserve that decreases at a rate directly proportional to the stomatal opening (10).

The gs values of the five evaluated lines are presented in Figure 3, where a differentiated behavior of the plants was observed before the soil moisture conditions imposed by the treatments, in such a way that the plants corresponding to line 20 presented statistical differences (α = 0.05) between treatments only at 23 and 30 DAT, those on line 22 at 23, 30 and 39 DAT, line 24 at 39 and 44 DAT, 28 at 30 and 44 DAT and finally, line 45 at 23, 30, 39 and 44 DAT. These results indicate that the variations of the gs, are associated to the characteristics of the plants of each line or cultivate in particular and that they depend on the density, size and degree of stomatal opening that characterizes them.

In this sense, in other investigations, working with different models of photosynthesis and stomatal conductance linked to soil moisture (11), it has been pointed out that no method completely replicates the observed response of stomata to soil water stress and there are doubts about of the way in which soil moisture stress works, when it comes to explaining the physical and physiological transport of water, through the hydraulic continuous soil-plant-atmosphere (10-13).

In general, the plants corresponding to (T2), of all the lines, presented average values of gs below 300 mmol m^{-2} s^{-1}, unlike those of (T1) whose values were always equal to or greater than this.

In works carried out with two varieties of Cuban tomatoes in field conditions and with limited irrigation (14), it was found that one of the variables that most correlated with gs, in the morning hours, was soil moisture. It should be noted that in lines 24, 28 and 45 to 44 DAT there were statistical differences in the gs of the plants of both treatments, in favor of those corresponding to (T1), even though the soil CVA values did not differ statistically This behavior can be associated, fundamentally, with the presence of some remnant of abscisic acid (ABA) in the leaves, which caused a lower gs, due to the stomatal closure induced by the presence of this hormone, since the ABA content in the leaf it increases due to the decompartamentalization and redistribution from the chloroplasts of mesophilic cells and to the synthesis and transport from the roots, being released to the apoplast to reach the cells stored through the transpiratory current (15).

In works carried out in field conditions, it is indicated that the tomato, in these conditions, showed the ability to survive in periods of severe water deficit in the soil, with values of gs that hovered around 0.09 mol m^{-2} s^{-1} (90 mmol m^{-2} s^{-1}) (16).

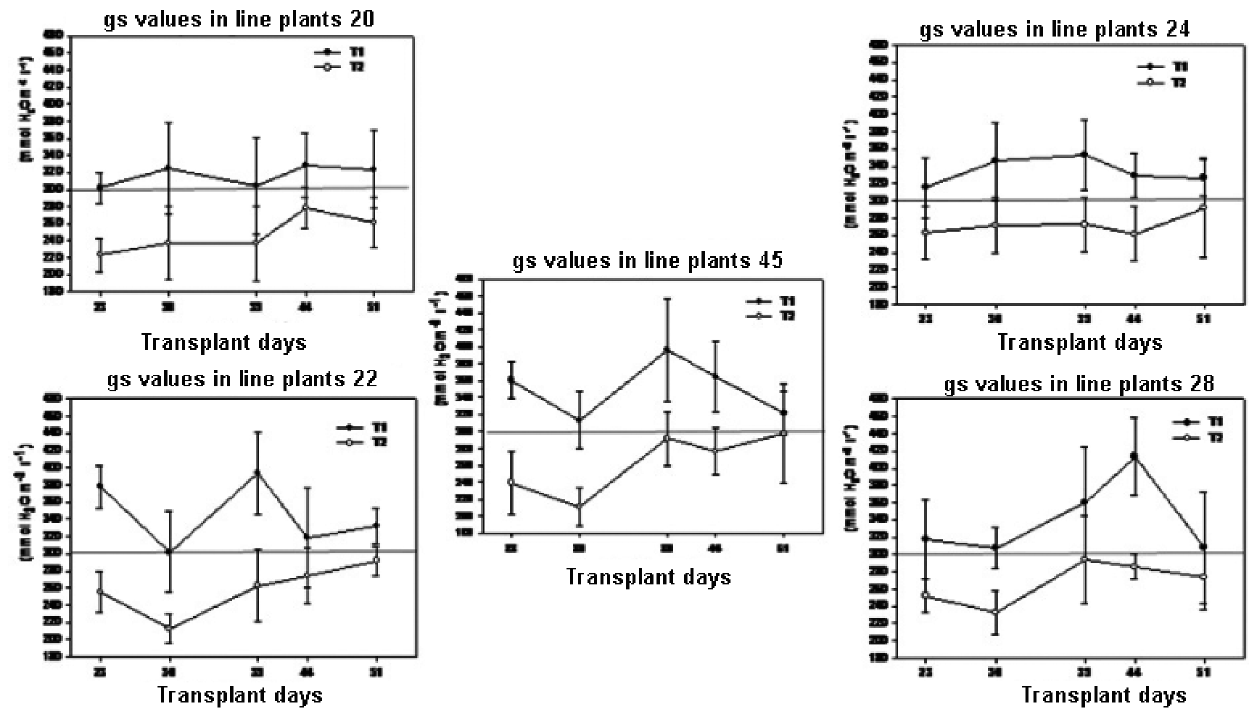


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Figure 3. Mean values of gs at 23, 30, 39, 44 and 51 DAT in each of the lines evaluated in two irrigation treatments

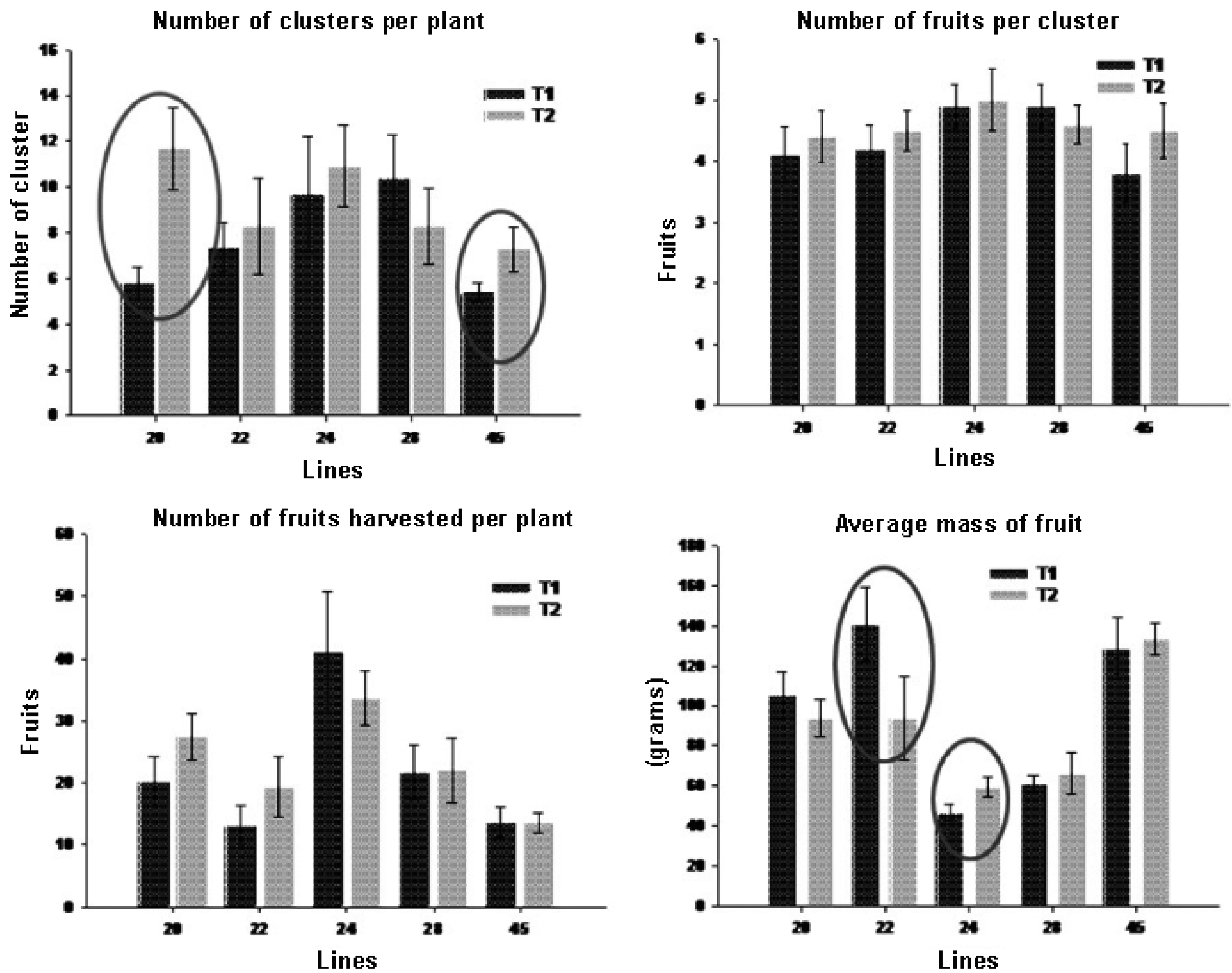
On the other hand, in the cultivation of wheat (*Triticum aestivum* L.) other studies indicate that the typical values for irrigation trials are between 300-700 mmol m^{-2} s^{-1}; and for tests with light water stress are between 80-300 mmol m^{-2} s^{-1} (9). Based on these results, it is evident that soil moisture conditions, induced by the application of irrigation treatment (T2), corresponded to a light water stress for the plants. It is also noted that at the physiological level, stomatal closure constitutes a fundamental mechanism of tolerance to water stress, as these are responsible for the highest proportion of water loss in plants (17).

In Figure 4, the values corresponding to the variables related to the yield components of the different lines under study are presented, where it was found that both in the number of bunches per plant, and in the average fresh mass of the fruits, was where there were statistical differences (α = 0.05) between the plants of the two treatments. In the case of the number of bunches, line 20 in (T2) doubled the value of this component (100 % increase) and 45 showed an increase of 35 %, with respect to its similar in T1.

In the average mass of the fruits, the plants of line 22 presented the highest value with the T1 treatment with an increase of 33% ; while line 24 with T2, increased the mass of the fruits by 28 %. Neither in the number of fruits per cluster, nor in the number of harvested fruits did statistical differences (α = 0.05) appear between the plants of both treatments.

The results of the average yield per plant and the values of the equatorial and polar diameters of the fruits of the tomato lines under study, are presented in Figure 5, where it can be seen that, as in the number of fruits per bunch and the number of fruits harvested per plant, there were no significant differences (α = 0.05) between the plants of the treatments applied.

The results in this sense indicate that the decrease in irrigation applied to the plants of the different lines cultivated with T2, in most cases, did not have a negative effect on the yield of the plants and their components.



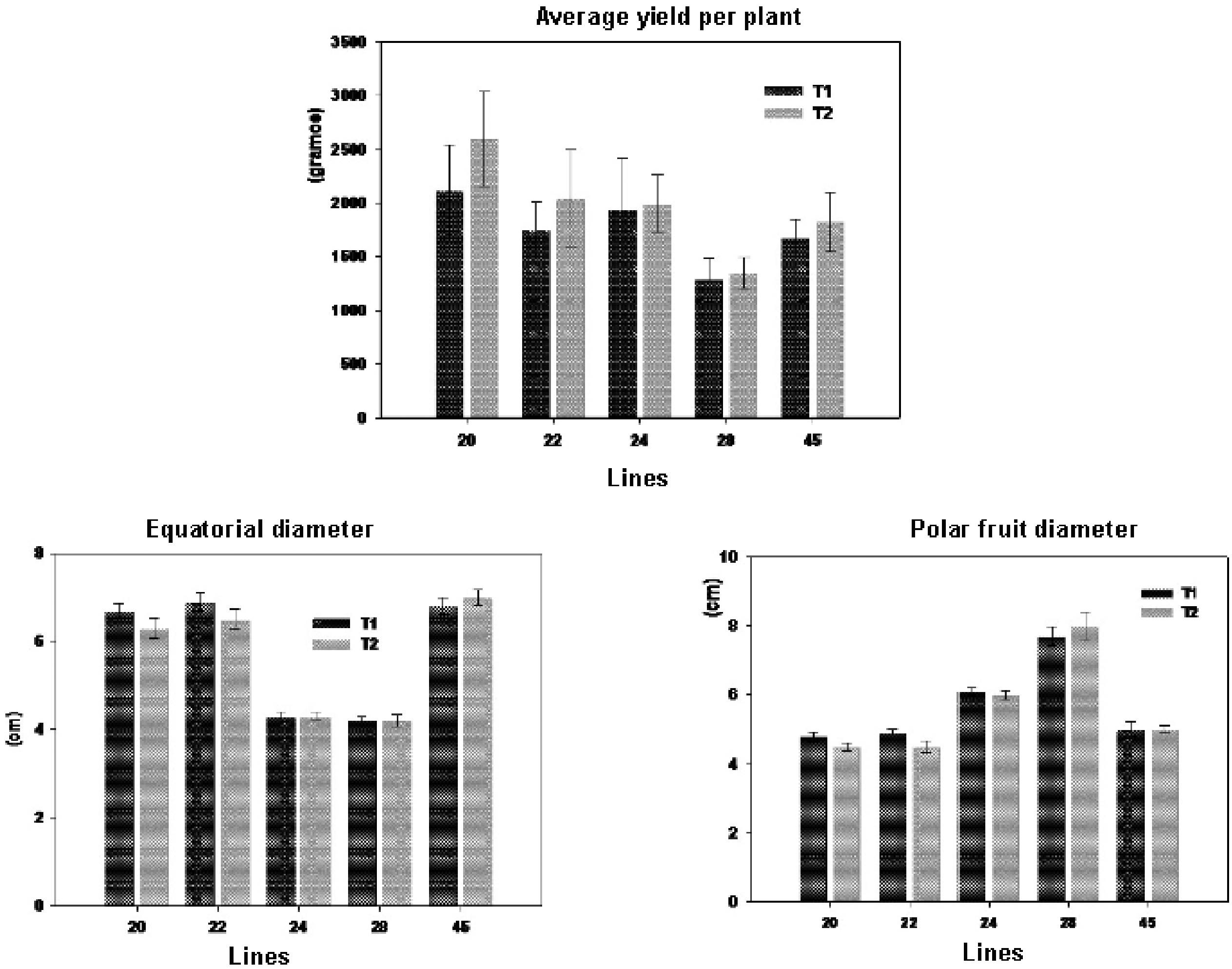
The bars above the mean values represent the confidence interval of the means (α = 0.05)

Figure 4. Performance components of five tomato lines grown under two soil moisture conditions

Similar results have been reported in tomato type ball, grown under greenhouse conditions, where the growth of the plants, the yield and the weight of the fruits presented a positive response as the amount of water applied was reduced (18).

In work done, when studying the effects of regulated deficit irrigation strategies, applied in different phenological phases of the tomato (19), higher fruit quality and water productivity were contracted when irrigation was applied with a crop coefficient (19). Kc of 0.8). However, when a Kc of 0.6 was applied in the stages of flowering and fruit development, significant yield losses were obtained.

On the other hand, it has been shown that excess water in tomato roots (radical hypoxia) reduces the production of dry biomass, especially in fruits and roots and with the increase in the duration of waterlogging, symptoms such as chlorosis and falling basal leaves, in addition to the epinasty and red foliar coloration, as well as the formation of adventitious roots (20).



The bars above the mean values represent the confidence interval of the means (α=0.05)

Figure 5. Average yield per plant and equatorial and polar diameter of the fruits of five tomato lines grown in two soil moisture conditions

CONCLUSIONS

As a conclusion, it can be considered that the response of the five tomato lines grown in two irrigation variants, under field conditions, was mediated by a differentiated effect on soil CVA, induced by the irrigation treatments (T1 and T2), which caused, in general, higher values of stomatal conductance in plants cultivated with good water supply (T1) and greater average mass of fruits in plants of line 24. However, the reduction of water supply to plants (T2) favored a greater number of bunches per plant in lines 20 and 45 and greater average mass of fruits in line 24 and did not cause negative effects in the morphology of the fruits.

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