Journal of Agricultural Science; Vol. 10, No. 10; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Growth and Physiology of Cherry Tomatoes Under Organic Fertilization in Different Environments

Letícia Kenia Bessa de Oliveira[1], Rafael Santiago da Costa[1], José Lucas Guedes dos Santos[2], Francisco Evair de Oliveira Lima[2], Aiala Vieira Amorim[2], Albanise Barbosa Marinho[2] & Rosilene Oliveira Mesquita[1]

[1] Department of Agronomy/Plant Science, Federal University of Ceará, Fortaleza, Ceará, Brazil

[2] Institute of Rural Development, University of International Integration of Afro-Brazilian Lusophony, Redenção, Ceará, Brazil

Correspondence: Letícia Kenia Bessa de Oliveira, Department of Agronomy/Plant Science, Federal University of Ceará, Fortaleza, Ceará, Brazil. E-mail: leticia.kbo7@gmail.com

Received: June 20, 2018 Accepted: July 21, 2018 Online Published: September 15, 2018

doi:10.5539/jas.v10n10p349 URL: https://doi.org/10.5539/jas.v10n10p349

Abstract

The cherry tomato is a vegetable that is gaining great prominence commercially and, for this reason, are being developed alternatives that aim to its production of more sustainable way. Among these alternatives are the use of organic fertilizers and barriers alive. The objective of this study was to evaluate the growth and gas exchange of cherry tomato plants (*Solanum lycopersicum* var. Cerasiforme) cultivated under different organic fertilizations in an environment with and without alive barrier. The experimental design was randomized blocks with split-plot to the variables leaf area, leaves dry mass and stem dry mass, relative index of chlorophyll, photosynthetic rate, stomatal conductance, transpiration and water use efficiency, being the plots defined by two environments (with or without barrier) and the subplots formed by the sources of organic fertilizer (chicken manure, bovine manure and without fertilization), with five repetitions. As for the variables plant height, stem diameter, used a split-split plot design with sub-subplots formed by the seven evaluation epochs (7, 14, 21, 28, 35, 42 and 49 days after transplanting). When cultivated in alive barrier environment and under fertilization with chicken manure, cherry tomato plants presented higher growth in height and stem diameter, with no difference between the leaf and stem dry masses. In contrast, the without alive barrier environment provided an increase in chlorophyll content and increases of 55.38%, 34.49% and 46.81% in stomatal conductance, photosynthesis and transpiration, respectively. For WUE, the environment with alive barrier was higher in 18.71%.

Keywords: alive barrier, biometry, gas exchange, *Solanum lycopersicum* var. Cerasiforme

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most produced vegetables in Brazil, both for its socioeconomic aspects and for its nutritional content (Souza, Moreira, Ferreira, & Matos, 2010). It stands out as being an extremely demanding in nutrient crop and influenced by climatic conditions (Carvalho, Bastos, & Alvarenga, 2004). Among the most cultivated varieties is the cherry type (*Solanum lycopersicum* var. Cerasiforme), due to its great acceptance in the market and compensating prices. Its production and commercialization have been boosted in the last years, since this fruit of sweetish taste and reduced size has become a versatile ingredient of modern gastronomy (Pinho et al., 2011).

However, in spite of all economic and social importance, its production faces very high costs, mainly due to the need for high dosages of fertilizers and the exacerbated application of agrochemicals (Souza, Moreira, Ferreira, & Matos, 2010), since it is a crop that has high nutritional requirement and is highly susceptible to pests and diseases.

However, alternatives aimed at reducing the use of these synthetic products in agriculture have been thought and developed in an attempt to mitigate the effects caused to the environment, minimize the costs of producers, as well as contribute to the maintenance of health and quality of life, both of who produces the fruits and of those who consume them (Preza & Augusto, 2012). Among these alternatives, the following stand out: use of resistant species, adoption of adequate irrigation management practices, crop rotation, cultivation in protected environments (Sousa et al., 2013), use of organic inputs and use of alive barriers (Harvey et al., 2003).

The use of organic inputs is configured as an easy obtain alternative that generates relatively low costs, since it can use natural inputs produced on the property of farmers, as is the case with animal manures. In addition, these fertilizers can promote benefits in improving the physical, chemical and biological properties of the soil (Cavalcante, Vieira, Santos, Oliveira, & Nascimento, 2010). Several authors have shown that their use can increase biometric and gas exchange variables in plants (Sousa et al., 2013; Viana et al., 2013). However, the limit of application of these inputs should be controlled, since high doses can cause reduction in production, toxicity, among others.

Regarding the living barrier, some studies show its efficiency in reducing pests in crops, in minimization impacts of winds, conservation and diversification the fauna and flora of agroecosystems, as well as establishing microclimates for the development of cultures (Tobar & Ibrahim, 2010; Ossa-Lacayo, 2013). However, there is a paucity of work in relation to its effects on the growth and physiology of agricultural crops.In this context, the objective of this study was to evaluate the use of alive barrier and the effects of different sources of organic fertilization on the growth and physiology of cherry tomato.

2. Material and Methods

The experiment was conducted during the period from May to September 2017 in two areas belonging to the Experimental Farm of the University of International Integration of Afro-Brazilian Lusophony (UNILAB), located in Redenção-CE, Brazil, at a latitude of 04º14′53″ S, longitude of 38º45′10″ W and average altitude varying between 240 and 340 m. According to Köppen (1923), the climate of the place is classified as Aw', that is, rainy tropical.

One of the areas was intended for the planting of cherry tomatoes under the protection of alive barrier composed of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.). The experimental area was 300 m^2, of which 228 m^2 were used for planting tomatoes, and the remainder destined for planting of the alive barrier. In the other environment, which did not use alive barrier, only 228 m^2 were occupied, an area destined for the planting of cherry tomatoes. The mean temperature during the experiment was 30.09 °C in the area with alive barrier and 31.21 °C in the area without alive barrier, while the average relative humidity was 59.97% and 57.10%, respectively.

The experimental design was randomized blocks in subdivided plot scheme, with five repetitions. For the variables plant height (PH) and stem diameter (SD), was used a scheme of split-split plot, the plots being defined by the two environments (with barrier and without alive barrier), the subplots formed by sources of organic fertilizer (chicken manure, bovine manure and without fertilization), and sub-subplots, by seven evaluation epochs (7, 14, 21, 28, 35, 42 and 49 days after transplanting-DAT). These variables were evaluated as a function of time for that could accompany the growth of the plants in the course of their vegetative stage. As for the other biometric variables and for the physiological variables, the scheme used was subdivided plots, being the plots defined by the two environments and the subplots by the three sources of organic fertilization.

For this study were used seeds of red cherry tomatoes of the brand TopSeed Garden, obtained in an agricultural store. Maize seeds, as well as cowpea seeds, were supplied by the seed bank of the Experimental Farm of UNILAB.

The seeds of maize and cowpea were sown in a position perpendicular to the direction of the wind forming alive barrier, in order to protect the crop of interest (tomato). In order to verify the direction of the wind, was used a windsock made by hand. It is noteworthy that both crops were planted 45 days prior to transplanting the tomato, using three seeds per pit.

The seedlings were obtained by planting cherry tomato seeds in polystyrene trays constituted of 100 cells, filled with substrate composed of earthworm humus (2:1, v:v). In each cell were seeded three seeds. To 15 days after sowing the tomatoes were thinned, leaving only one seedling per cell. The seedling transplanting to the field occurred when the seedlings presented size of 10 to 15 centimeters or three pairs of definitive leaves.

After transplanting, during the whole cycle of the tomato plants, the necessary cultural practices were carried out for the proper conduction of the crop, such as cutting, staking methods, cleaning of old leaves and weeds. The staking method used was vertical, where the plants were tied vertically in tutors such as wood stakes and wire. This type of tutoring confers better distribution of solar radiation and ventilation and greater efficiency of phytosanitary control (Wamser, Becker, Santos, & Mueller, 2008).

A composite sample of each environment (with and without alive barrier) was used, obtained by the homogenization of simple soil samples taken between the 0 and 20 cm layers of each area, collected through the method of walking in zig-zag. After being duly identified, they were referred to the Laboratory of Soil Chemistry and Fertility, Federal University of Ceará (UFC), to determine the main chemical attributes, the results of which can be observed in Table 1.

Table 1. Chemical soil attributes of environments with barrier (soil 1) and without alive barrier (soil 2), in the 0 to 0.20 m depth layer, where the cherry tomato plants were cultivated

Soil	C	N	OM	C/N	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$H^{+} + Al^{3+}$	Al^{3+}	S	T	P	pH
	--------- g kg^{-1} --------				------------------------------- $cmol_c$ kg^{-1} -------------------------------								mg kg^{-1}	
1	20.7	2.1	35.7	10	5.3	2.1	0.3	0.4	0.7	0.3	8.1	8.8	97	6.1
2	11.0	1.1	18.9	10	5.2	1.5	0.2	0.2	0.2	0.1	7.1	7.2	126	6.8

Source: Laboratory of Chemistry and Soil Fertility of the Federal University of Ceará.

According to Table 1, it can be seen that nutrient contents in the soils of both areas differ from one another, which was due to the fact of the historic of crops in these places. For this reason, rates of manure were calculated proportionally and taking into account these values.

With the tanning process of both manure already finished, samples of approximately 500 g were collected from each of them and sent to the Laboratory of Chemistry and Soil Fertility, UFC, for chemical analysis. The results can be seen in Table 2.

Table 2. Chemical composition of the manures applied to the soil for the cultivation of cherry tomato plants

Manures	N	P	P_2O_5	K	K_2O	Ca	Mg	Fe	Cu	Zn	Mn
	----------------------------------- g kg^{-1} -----------------------------------							---------------- mg kg^{-1} ---------------			
Bovine	9.2	4.2	9.5	3.04	3.7	18.8	16.0	1623.5	20.3	89.7	756.6
Chicken	24.1	16.4	37.6	19.58	23.9	25	16.5	507.6	151.7	637.7	391.6

Source: Laboratory of Chemistry and Soil Fertility of the Federal University of Ceará.

Analyzing Table 2, it can be observed that when comparing the nutrient contents of both manures, among them, they diverge in considerable amounts. This fact was also taken into account during fertilization calculations.Before the application of the fertilizers, the draw of the blocks was carried out, being considered useful plants (for evaluation purposes) those located in the central parts of each block. After that, the fertilization recommendation proposed by Tedesco et al. (2004) was used, being adapted proportionally to the conditions predicted in the soil analysis of the two cultivation areas, as well as to the nutritional need of the tomato for nitrogen, phosphorus and potassium.

In the area with alive barrier were applied per plant and according to the treatments, the amount of 1.15 kg of bovine manure and 0.18 kg of chicken manure; in the area without alive barrier, the amount applied was 1.18 kg of bovine manure and 0.18 kg of chicken manure, thus providing the amount of nutrients needed for the plants in the different areas.

In order to improve the use of fertilizers by the plants, their applications were parceled, being the foundation fertilization carried out 10 days prior to transplanting, where 1/3 of the total fertilization was applied, and the cover fertilization carried out 30 days after transplanting, where was applied 2/3 of total fertilization.

The irrigation of the cherry tomatoes was done by drip irrigation, with an emitter of mean flow rate of 4 L h-1 per plant, at a frequency of six times per week. The irrigation time used daily was calculated from the evaporation of the "Class A" tank. The irrigation of the plants that make up the alive barrier was performed by microsprinkler.

To 7, 14, 21, 28, 35, 42 and 49 days after transplanting (DAT) were carried out measurements of height (PH) and stem diameter (SD) of the five central plants of each block, using a measuring tape graduated in centimeters and a digital caliper graduated in millimeters, respectively. PH measurement was performed starting from stem base until the last leaf insertion, and the SD was measured at the stem base.

At the end of the experiment, 70 DAT (the time when the cherry tomatoes were emitting their flowers), the five central plants of each block were collected and the aerial part of each of them was fractionated in leaves and stems, being placed in paper bags properly identified. After that, the leaf area (LA) was determined by means of a surface meter (LI-3100, Area Meter, Li-Cor., Inc., Lincoln, 87 Nebraska, USA).

To determine stem (SDM) and leaves (LDM) dry mass, the separated plant organs were placed in a forced air circulation oven at 65 °C until reaching a constant mass (approximately for a period of 72 hours). After that, the vegetable materials were weighed on a precision scale of 0.1 grams to determine the dry mass in grams per plant.

To 70 DAT, measurements of the net photosynthetic rate (A), stomatal conductance (g_s) and transpiration rate (E) were performed on fully developed leaves of the middle third of the plants, between 9:00 a.m. and 12:00 p.m., using an infrared gas analyzer IRGA (portable model LI-6400xt, LI-COR Biosciences Inc., Lincon, Nebraska, USA), under saturated radiation, controlled CO_2 concentration (400 ppm) and under ambient temperature conditions. During the gas exchange measurements, the relative index of chlorophyll (RIC) was also estimated using the SPAD 502 portable meter (Minolta).

As the data obtained are of qualitative nature, they were submitted to analysis of variance and, later, when significant by the F test, submitted to Tukey's test at the 5% level of significance. For the statistical analysis the computational program "ASSISTAT 7.7 BETA" (Santos & Azevedo, 2016) was used.

3. Results and Discussion

The plant height (Figure 1A) and stem diameter (Figure 1B) as a function of the evaluation epochs were adjusted to the linear model, with determination coefficients of 0.93 and 0.95, respectively. Each increasing unit variation of the evaluation epochs resulted in an increase of 0.887 cm in height and 0.119 mm in the stem diameter of the plants, that is, there was a positive correlation between the age of the plants and their growth in height and diameter.

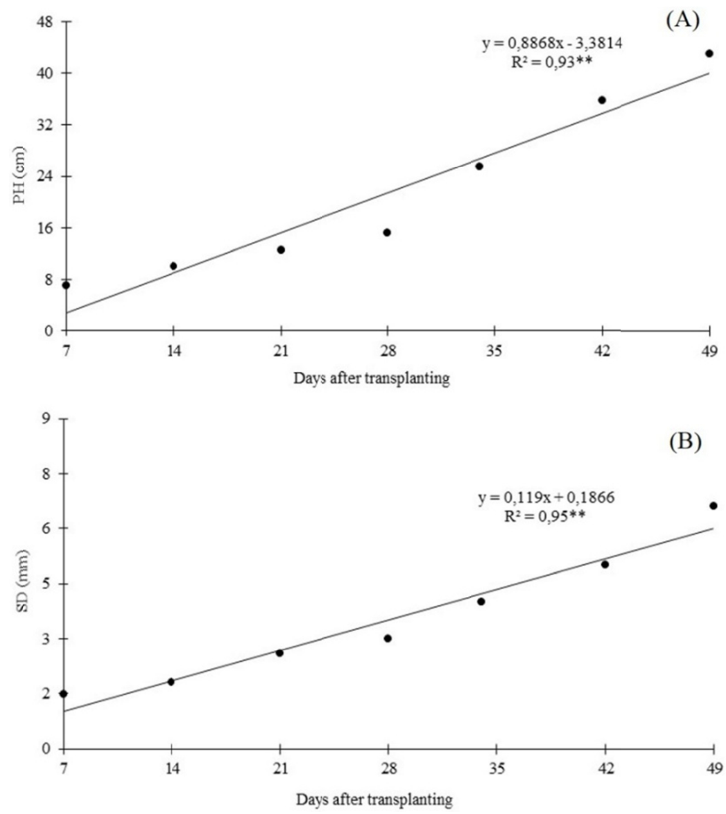

Figure 1. Height (PH) (A) and stem diameter (SD) (B) of cherry tomato plants as a function of the seven evaluation periods (7, 14, 21, 28, 35, 42 and 49 DAT). ** Significance at 1% probability by the Tukey test

These increasing responses in longitudinal length and in thickness, over time, are a characteristic of the vegetative growth, where the plants provide an increasing fraction of their biomass for their development. Results similar to these were found by Ribeiro et al. (2016), where working with pepper-rosemary (*Lippia origanoides* Kunth) submitted to epochs different and conditions of luminosity, the plants also presented increasing responses in height and stem diameter throughout the evaluation periods, both in the dry period and in the rainy season.

According to Camargo (2012), when plants receive nutrients in adequate amounts, they tend to show greater growth. In this sense, Almeida et al. (2014), working with *Bidens pilosa* under the influence of nutrient supply and evaluation epochs, verified that the greater the availability of nutrients, the greater the height and the diameter of the stem. Thus, the increasing results observed in the present study, besides being characteristic of plant growth, may have been influenced by the supply of organic fertilizers to the plants.

Concerning the interaction of the environment and fertilization in the PH and SD variables, it is observed that the best PH means were obtained in the environment with alive barrier and that the fertilization sources were statistically the same. However, for this same variable, in the environment without alive barrier, the treatment with chicken manure presented superior to the other fertilizations. Regarding the variable SD, the environment with alive barrier was superior to the one without barrier for the manure sources with chicken manure and bovine manure, and there was no significant difference between the environments for the treatment without fertilization. In relation to fertilizer sources, it was observed that the chicken manure presented better results than the bovine manure and the control in both the environments with barrier and the without barrier, statistically not differing from the treatment without fertilization (Table 4).

Table 4. Mean values of height (PH) and stem diameter (SD) in cherry tomato plants, in environments with and without alive barrier, submitted to three fertilization sources (chicken manure, bovine manure and without fertilization)

Environments	Fertilization Sources		
	Chicken Manure	Bovine Manure	Without Fertilization
PH (cm)			
With alive barrier	26.46 aA	23.31 aA	23.34 aA
Without alive barrier	22.43 bA	14.35 bC	18.05 bB
SD (mm)			
With alive barrier	4.20 aA	3.81 aB	3.50 aB
Without alive barrier	3.46 bA	2.70 bB	3.33 aA

Note. Means followed by the same lowercase letters in the column and uppercase letters in the row do not differ by Tukey test at the 5% probability.

The best PH and SD responses achieved in treatments under alive barrier (Table 4) may have been obtained due to the fact that the physical barrier possibly provided better conditions for acclimatization of cherry tomato shoots in the field. On the other hand, plants grown in the environment without alive barrier may have delayed their establishment in this environment due to the direct effects of temperature, humidity and luminosity (Reis, Souza, & Azevedo, 2009), resulting in lower growth.

Studies by Vásquez, Folegatti, Dias, and Silva (2005), with melon (*Cucumis melo* L.) in protected environment and open field, showed that solar radiation in the full sun was 26.8% higher than that of the protected environment and that in the behavior of the temperature happened the inverse, presenting internal temperature superior to the external one in 4%. In the case of this experiment, the plants that make up the alive barrier may have acted absorbing part of the heat coming from the radiation and its arrangement in the cultivation possibly contributed to the convective process of passage of hot air to the atmospheric environment (which does not occur in greenhouses), and this circulation of air and lower temperature could have contributed to the good establishment of the seedlings.

Concerning the fertilization sources employed, in both cultivation environments, it was observed that there was emphasis on fertilization with chicken manure in relation to the others. Similar results were obtained by Peixoto Filho et al. (2013) in the first cycle of lettuce (*Lactuca sativa* L.) cultivation, where the treatment that promoted the best results, in terms of shoot development, was that of chicken manure, to the detriment of those obtained with mineral fertilizer and bovine and sheep manure. This superiority may be related to the fact that there has been more rapid mineralization of chicken manure, promoting the release and greater availability of nutrients for the plants in this treatment, mainly in what refers to nitrogen (N), which has an essential role in the vegetative growth of plants, being required in larger quantities in the initial stages of its development (Jornada, Medeiros, Pedroso, Saibro, & Silva, 2008).

The variables leaf area (LA), leaf dry mass (LDM) and stem dry mass (SDM) were not significantly influenced by fertilization sources nor by the use of alive barrier. However, in Table 6, effect caused by the isolated environment factor in the variables AF, MSF and MSC is observed. In spite of not being significant, in absolute values, it can be seen that the environment without alive barrier was the one that presented the highest means for the variables LA, LDM and SDM, presenting a superiority of 5.63%; 22.47% and 13.01%, respectively.

Table 6. Mean values of leaf area (LA), leaves dry mass (LDM) and stem dry mass (SDM) of cherry tomato plants in environments with and without alive barrier

Environments	Variables		
	LA (cm^2)	LDM (g)	SDM (g)
With alive barrier	5208.53	29.44	48.75
Without alive barrier	5519.55	37.97	56.04

The trend of higher averages in the environment without alive barrier may have been a result of a higher direct incidence of solar radiation in cherry tomato plants, since in the alive barrier environment the plants around the crop may have acted promoting creating a milder microclimate, absorbing part of the incident radiation. Probably, as there was a greater intensity of light radiation on plants in the area without barrier, the growth and development were influenced by higher rates of photosynthesis, with consequently greater production of dry biomass in organs and expansion of leaf area (Taiz, Zeiger, Moller, & Murphy, 2017).

According to Miralles, Martínez-Sánchez, Franco & Bañón (2011), several growth variables can be altered according to the light intensity available. Among them, we highlight the allocation of dry biomass in root, stem, leaf and inflorescence, leaf area, total dry biomass and root/shoot ratio. This is explained by the fact that increased irradiance increases the production of photoassimilates and their availability for plant growth (Reis, Azevedo, Albuquerque, & Silva Junior, 2013).

Although not significant, Table 7 shows, in absolute terms, the effect caused by the fertilization sources in the LA, LDM and SDM variables. It can be noticed that fertilization with chicken manure provided the highest means of LA, LDM and SDM. For all variables, the treatment without fertilization was inferior.

Table 7. Mean values of leaf area (LA), leaves dry mass (LDM), stem dry mass (SDM) of cherry tomato plants according to the sources of fertilization

Fertilization Sources	Variables		
	LA (cm^2)	LDM (g)	SDM (g)
Chicken manure	6252.69	39.95	62.26
Bovine manure	5859.98	34.45	57.02
Without fertilization	3979.46	26.72	37.91

The highest absolute values were found when the plants were fertilized with chicken manure. However, contrary results were obtained by Viana and Vasconcelos (2008), who, when analyzing the effect of the use of bovine manure on lettuce plants, verified that this yielded better results in leaves dry mass (5.87 g $plant^{-1}$), when compared to treatment with chicken manure (3.83 g $plant^{-1}$) and control (1.27 g $plant^{-1}$). However, Costa, Rosal, Pinto, and Bertolucci (2008), working with organic and mineral fertilization on the production of biomass of lemon-grass (*Cymbopogon citratus* (DC.) Stapf.), observed that chicken manure was the one that produced the best results in the production of shoot dry biomass of lemon-grass plants.

With respect to the joint effect of the environment and fertilization on the variable RIC, it can be observed that the highest averages were obtained in the environment without alive barrier and that, in this and in the barrier environment, the types of fertilization did not present any difference between themselves (Table 9).

Table 9. Mean values of the relative index of chlorophyll (RIC) of cherry tomato plants in an environment with and without alive barrier, submitted to three fertilization sources (chicken manure, bovine manure and without fertilization)

Environments	Fertilization Sources		
	Chicken Manure	Bovine Manure	Without Fertilization
RIC			
With alive barrier	26.11 bA	28.82 bA	27.89 bA
Without alive barrier	36.50 aA	33.88 aA	34.64 aA

Note. Means followed by the same lowercase letters in the column and uppercase letters in the row do not differ by Tukey test at the 5% probability.

This higher RIC response to fertilization with chicken manure may be associated to the fact that this treatment has, in its composition, a high concentration of nitrogen. If this organic fertilizer was mineralized faster, there was greater availability of this nutrient to the plants (Corrêa et al., 2010). As nitrogen is one of the constituents of the chlorophyll molecule (Silva et al., 2012), it is believed that this was the factor that enabled this greater response.

Ferreira et al. (2006), working with tomato (*Solanum lycopersicum* L.) in function of nitrogen doses and organic fertilization with bovine manure, verified that the RIC increased as a function of N doses in the two fertilizations used. Similar results were also obtained by Pôrto et al. (2011), that when working with zucchini (*Cucurbita pepo* cv. Caserta) verified an increase of the RIC when the nitrogen rates of the soil were increased.

All gas exchange variables evaluated had a significant influence with regard to the environment factor. The cherry tomato plants, when cultivated in the environment without alive barrier, presented better responses regarding stomatal conductance (gs), photosynthetic rate (A) and transpiration rate (E), reaching averages of 0.65 mol H_2O m^{-2} s^{-1}, 21.95 µmol CO_2 m^{-2} s^{-1}, and 9.72 mmol H_2O m^{-2} s^{-1}, surpassing the rates of the area with alive barrier in 55.38%, 34.49% and 46.81%, respectively. However, with regard to water use efficiency (WUE), plants grown in the environment with alive barrier were the ones that stood out the most, presenting higher in 18.71% to plants grown in the area without alive barrier (Figure 2).

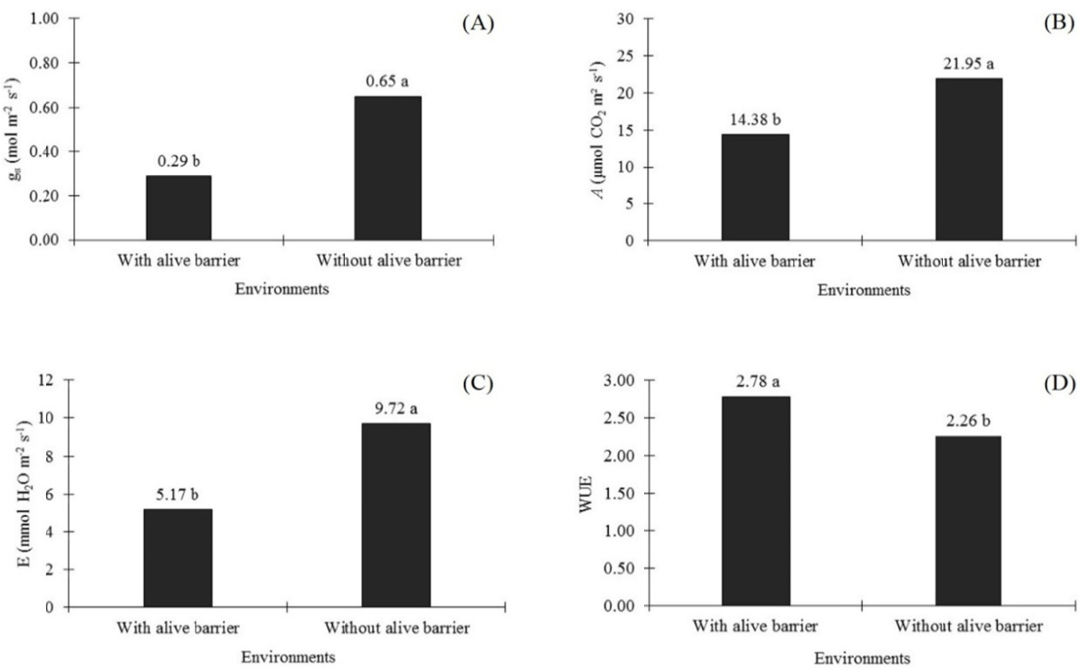

Figure 2. Stomatal conductance (g_s) (A), photosynthetic rate (*A*) (B), transpiration rate (E) (C) and water user efficiency (WUE) (D) in cherry tomatoes plants in function of the two types of environment (with and without alive barrier). ** Significance at 1% probability by the Tukey test (A, B and C); * Significance at 5% probability by the Tukey test (D)

The cherry tomato plants cultivated in the environment with alive barrier had a lower stomatal opening, which resulted in reductions in *A* and E. The alive barrier, in this case, may have acted reducing the effect of the winds on the crop, intensifying the resistance boundary air layer adjascent to leaves. This air layer, derived from the water vapor released by the stomata during the transpiration process, reduces the water potential gradient between the interior of the leaves and the atmosphere, causing slower transpiration. The thicker the boundary air layer, the greater the resistance to the gas exchanges carried out by the plants, that is, smaller the stomatal conductance. The lower the stomatal conductance, the lower the carbon increment in the biomass of the plants, as a consequence of the fall in photosynthesis.

Guimarães et al. (2017), working with cowpea (*Vigna ungiculata* var. Sesquipedalis) under staking systems and planting spacings, found that in larger densities there was an increase in the thickness of the boundary air layer. Already under conditions of greater spacing (lower densities) the plants were more subject to the interference of the wind, which acted to reduce this layer. This may justify the fact that the cherry tomato plants of the environment without alive barrier presented superior gas exchanges, since they were exposed to the action of the winds, causing the difference of water vapor between the leaf and the atmosphere to remain high, culminating in greater transpiration. The temperature may also have contributed because the greater exposure of the leaves to the solar radiation may have left them with temperatures higher than those that were under protection of the alive barrier, causing greater losses of water by transpiration.

The cherry tomato plants in the area without barrier presented major levels of chlorophyll and as we all know, this pigment is essential to photosynthesis, since it is responsible for the process of light assimilation and transformation into chemical energy for the plants (Jesus & Marenco, 2008) contributing to greater photosynthetic rates. Probably, this greater photosynthetic performance was also caused by the greater leaf area presented by plants, which provides increased capacity to take advantage of solar energy in order to carry out photosynthesis (González-Sanpedro, Le Toan, Moreno, Kergoat, & Rubio, 2008). Contrasting results were observed by Oliveira et al. (2006), working with coffee trees (*Coffea arabica* L.) in consortium with rubber trees (*Hevavea brasiliensis* L.), verified higher photosynthetic rates in an environment with lower radiation.

The best WUE responses obtained by plants cultivated in environment with alive barrier may be related to the fact that the alive barrier has promoted changes in the microclimate of the growing place, as previously mentioned. The lower temperatures and higher humidity recorded may have influenced a lower water loss by plants, which can be seen in the transpiration rate, directly influencing the water use efficiency. Guerra, Costa & Tavares (2017), when carrying out studies with lettuce under shading conditions, found that WUE was influenced by this cultivation condition, which provided lower temperature and higher humidity, occurring an increase of 21.94% in relation to full sun.

4. Conclusions

The environment with alive barrier provided a greater increase in the height and stem diameter variables in cherry tomato plants over time, as well as in the variable water use efficiency. When cultivated in an environment without alive barrier, cherry tomato plants showed an increase in stomatal conductance, net photosynthetic rate, transpiration and relative index of chlorophyll. Chicken manure showed to be more efficient in cherry tomato growing because of the increase in biometric variables.

Acknowledgements

To the University of International Integration of Afro-Brazilian Lusophony, for the availability of the area to conduct the experiment. To the teachers and students involved. To the Cearense Foundation to Support Scientific and Technological Development-Funcap, for the funding of the scientific initiation grant.

References

Almeida, M. D. O., Ferreira, E. A., Silva, D. V., Santos, J. B., Rodrigues, R. B., Souza, B. P., & Costa, S. S. D. (2014). Influência do tamanho do vaso e época de avaliação sobre o crescimento do picão preto em competição com milho e soja. *Bioscience Journal, 30*(5), 1428-1437.

Alvarenga, M. A. A. R. (2004). *Tomate: Produção em campo, em casa-de-vegetação e em hidroponia*. UFLA, Brazil.

Camargo, M. C. (2012). A importância do uso de fertilizantes para o meio ambiente. *Pesquisa & Tecnologia, 9*(2), 15-30.

Carvalho, J. G., Bastos, A. R. R., & Alvarenga, M. A. R. (2004). *Nutrição mineral e* Adubação. In M. A. R. Alvarenga (Ed.), *Tomate: Produção em campo, em casa de vegetação e em hidropônica* (pp. 61-120). Lavras: Ed. UFLA.

Cavalcante, L. F., Vieira, M. D. S., Santos, A. D., Oliveira, W. D., & Nascimento, J. D. (2010). Água salina e esterco bovino líquido na formação de mudas de goiabeira cultivar Paluma. *Revista Brasileira de Fruticultura, 32*(1), 251-261. http://doi.org/10.1590/S0100-29452010005000037

Corrêa, R. M., Pinto, J. E. B. P., Reis, E. S., Costa, L. C. B., Alves, P. B., Niculan, E. S., & Brant, R. S. (2010). Adubação orgânica na produção de biomassa de plantas, teor e qualidade de óleo essencial de orégano (*Origanum vulgare* L.) em cultivo protegido. *Revista Brasileira de Plantas Medicinais, 12*(1), 80-89. https://doi.org/10.1590/S1516-05722010000100012

Costa, L. C. B., Rosal, L. F., Pinto, J. E. B. P., & Bertolucci, S. K. V. (2008). Efeito da adubação química e orgânica na produção de biomassa e óleo essencial em capim-limão [*Cymbopogon citratus* (DC.) Stapf.]. *Revista Brasileira de Plantas Medicinais, 10*(1), 16-20.

Ferreira, M. M. M., Ferreira, G. B., Fontes, P. C. R., & Dantas, J. P. (2006). Índice SPAD e teor de clorofila no limbo foliar do tomateiro em função de doses de nitrogênio e da adubação orgânica, em duas épocas de cultivo. *Revista Ceres, 53*(305), 83-92.

González-Sanpedro, M. C., Le Toan, T., Moreno, J., Kergoat, L., & Rubio, E. (2008). Seasonal variations of leaf area index of agricultural fields retrieved from Landsat data. *Remote Sensing of Environment, 112*(3), 810-824. https://doi.org/10.1016/j.rse.2007.06.018

Guerra, A. M. N. M., Costa, A. C. M., & Tavares, P. R. F. (2017). Atividade fotossintética e produtividade de alface cultivada sob sombreamento. *Agropecuária Técnica, 38*(3), 125-132.

Guimarães, M. A., Lemos Neto, H. S., Araújo, R. B., Lima Neto, B. P., Silva, V. B., & Mesquita, R. O. (2017). Staking system and planting spacing in the asparagus bean production. *Horticultura Brasileira, 35*(4), 613-620. https://doi.org/10.1590/s0102-053620170422

Harvey, C. A., Villanueva, C., Villacis, J., Chacón, M., Muñoz, D., López, M., … Navas, A. (2003). Contribución de las cercas vivas a la productividad e integridad ecológica de los paisajes agrícolas en América Central. *Agroforestería en las Américas, 10*(39-40), 30-39.

Jesus, S. V., & Marenco, R. A. (2008). O SPAD-502 como alternativa para a determinação dos teores de clorofila em espécies frutíferas. *Acta Amazônica, 38*(4), 815-818. https://doi.org/10.1590/S0044-59672008000400029

Jornada, J. B. J., Medeiros, R. B., Pedroso, C. E. S., Saibro, J. C., & Silva, M. A. (2008). Efeito da irrigação, épocas de corte da forragem e doses de nitrogênio sobre a qualidade de sementes de milheto [*Pennisetum americanum* (L.) Leeke]. *Revista Brasileira de Sementes, Brasília, 30*(3), 10-15. https://doi.org/10.1590/S0101-31222008000300002

Köppen, W. P. (1923). *Die Klimate der Erde: Grundriss der Klimakunde*. Walter de Gruyter & Company.

Miralles, J., Martínez-Sánchez, J. J., Franco, J. A., & Bañón, S. (2011). *Rhamnus alaternus* growth under four simulated shade environments: Morphological, anatomical and physiological responses. *Scientia Horticulturae, 127*(4), 562-570. https://doi.org/10.1016/j.scienta.2010.12.005

Oliveira, C. R. M., Barbosa, J. P. R. A. D., Soares, A. M., Oliveira, L. E. M., & Macedo, R. L. G. (2006). Trocas gasosas de cafeeiros (*Coffea arabica* L.) e seringueiras (*Hevea brasiliensis* Muell. Arg.) em diferentes sistemas de cultivo na região de Lavras, MG. *Revista Árvore, 30*(2), 197-206. https://doi.org/10.1590/S0100-67622006000200006

Ossa-Lacayo, A. (2013). Cercas vivas y su importancia ambiental en la conservación de avifauna nativa. *Revista Colombiana de Ciencia Animal, 5*(1), 171-193.

Peixoto Filho, J. U., Freire, M. B. S., Freire, F. J., Miranda, M. F., Pessoa, L. G., & Kamimura, K. M. (2013). Produtividade de alface com doses de esterco de frango, bovino e ovino em cultivos sucessivos. *Revista Brasileira de Engenharia Agrícola e Ambiental, 17*(4), 419-424. https://doi.org/10.1590/S1415-43662013000400010

Pinho, L. D., Almeida, A. C., Costa, C. A., Paes, M. C. D., Glória, M. B. A., & Souza, R. M. (2011). Nutritional properties of cherry tomatoes harvested at different times and grown in an organic cropping. *Horticultura Brasileira, 29*(2), 205-211. http://doi.org/10.1590/S0102-05362011000200012

Pôrto, M. L., Puiatti, M., Fontes, P. C. R., Cecon, P. R., Alves, J. C., & Arruda, J. A. (2011). Índice SPAD para o diagnóstico do estado de nitrogênio na cultura da abobrinha. *Horticultura Brasileira, 29*(3), 311-315. http://doi.org/10.1590/S0102-05362011000300009

Preza, D. L. C., & Augusto, L. G. S. (2012). Vulnerabilidades de trabalhadores rurais frente ao uso de agrotóxicos na produção de hortaliças em região do Nordeste do Brasil. *Revista Brasileira de Saúde Ocupacional, 37*(125), 89-98. http://doi.org/10.1590/S0303-76572012000100012

Reis, L. S., Azevedo, C. A., Albuquerque, A. W., & Silva Junior, J. F. (2013). Índice de área foliar e produtividade do tomate sob condições de ambiente protegido. *Revista Brasileira de Engenharia Agrícola e Ambiental, 17*(4), 386-391. https://doi.org/10.1590/S1415-43662013000400005

Reis, L. S., Souza, J. D., & Azevedo, C. D. (2009). Evapotranspiração e coeficiente de cultivo do tomate caqui cultivado em ambiente protegido. *Revista Brasileira de Engenharia Agrícola e Ambiental, 13*(3), 289-296. http://doi.org/10.1590/S1415-43662009000300010

Ribeiro, M. S. S., Costa, R. S., Amorim, A. V., Lacerda, C. F., & da Silva Dias, N. (2016). Biometria e óleo essencial de alecrim pimenta cultivado em diferentes épocas e condições de luminosidade. *Revista Brasileira de Agricultura Irrigada, 10*(6), 1086-1095. http://doi.org/10.7127/rbai.v10n600539

Santos, F. A., & Azevedo, C. A. V. (2016). The Assistat Software Version 7.7 and its use in the analysis of experimental data. *African Journal of Agricultural Research, 11*(39), 3733-3740. https://doi.org/10.5897/AJAR2016.11522

Silva, M. A. G., Mannigel, A. R., Muniz, A. S., Porto, S. M. A., Marchetti, M. E., Nolla, A., & Bertani, R. M. A. (2012). Ammonium sulphate on maize crops under no tillage. *Bragantia, 71*(1), 90-97. http://doi.org/10.1590/S0006-87052012000100014

Sousa, G. G., Viana, T. V. A., Braga, E. S., Azevedo, B. M., Marinho, A. B., & Borges, F. R. (2013). Fertirrigação com biofertilizante bovino: efeitos no crescimento, trocas gasosas e na produtividade do pinhão-manso. *Revista Brasileira de Ciências Agrárias, 8*(3). http://doi.org/10.5039/agraria.v8i3a2288

Souza, J. A. R., Moreira, D. A., Ferreira, P. A., & Matos, A. T. (2010). Avaliação de frutos de tomate de mesa produzidos com efluente do tratamento primário da água residuária da suinocultura. *Engenharia na Agricultura, 18*(3), 198-207. https://doi.org/10.13083/reveng.v18i3.77

Taiz, L., Zeiger, E., Moller, I. M., & Murphy, A. (2017). *Fisiologia e Desenvolvimento Vegetal* (6th ed.). Porto Alegre: Artmed.

Tedesco, M. J., Gianello, C., Anghinoni, I., Bissani, C. A., Camargo, F. A. O., & Wietholter, S. (2004). *Manual de adubação e de calagem para os estados do Rio Grande do Sul e de Santa Catarina*. Porto Alegre, Sociedade Brasileira de Ciência do Solo, Núcleo Regional Sul.

Tobar, D. E., & Ibrahim, M. (2010). Las cercas vivas ayudan a la conservación de la diversidad de mariposas en paisajes agropecuarios? *Revista de Biología Tropical, 58*(1), 447-463. http://doi.org/10.15517/rbt.v58i1.5221

Vásquez, M. A., Folegatti, M. V., Dias, N. S., & da Silva, C. R. (2005). Efeito do ambiente protegido cultivado com melão sobre os elementos meteorológicos e sua relação com as condições externas. *Engenharia Agrícola, 25*(1), 137-143. https://doi.org/10.1590/S0100-69162005000100015

Viana, E. M., & Vasconcelos, A. C. F. (2008). Produção de alface adubada com termofosfato e adubos orgânicos. *Revista Ciência Agronômica, 39*(2), 217-224.

Viana, T. V. A., Santos, A. P., Sousa, G. G., Pinheiro Neto, L. G., Azevedo, B. M., & Aquino, B. F. (2013). Trocas gasosas e teores foliares de NPK em meloeiro adubado com biofertilizantes. *Revista Brasileira de Ciências Agrárias, 8*(4), 595-601. http://doi.org/10.5039/agraria.v8i4a3260

Wamser, A. F., Becker, W. F., Santos, J., & Mueller, S. (2008). Influência do sistema de condução do tomateiro sobre a incidência de doenças e insetos-praga. *Horticultura Brasileira, 26*, 180-185. https://doi.org/10.1590/S0102-05362008000200010