English Version

Ecophysiological behavior of maize and bean-string under different culture conditions

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Abstract:

The environmental effects are based on factors prevalent in plant development, since they determine the conditions for sustaining life. Therefore, the objective was to evaluate the ecophysiological behavior of early stage of maize and cowpea in different culture environments: greenhouse with greenhouse transparency of 50% and the external environment in the field. The experiment was conducted during September to November 2008; it was conducted in an area of the meteorological station of the Federal University of Ceará, using a randomized design in a 2x2 factorial design with four replications. The variables evaluated in both culture environments were: wind speed (U), global photosynthetically active radiation (PAR), internal CO2 concentration, transpiration, stomatal conductance, and rate of photosynthesis. The results were submitted to analysis of variance (ANOVA) and comparison of means by Tukey test in both experiments. It was concluded that the values of wind speed and global photosynthetically active radiation inside the greenhouse were always lower than the values obtained in the external environment. There were changes both morphological and physiological for both cultures studied.

Key words: *Vigna unguiculata* (L) Walp.; *Zea mays* L.; protected environment; gas exchange

Introduction

Among the various compounds of the environment, light is prior to plant growth, not only to provide energy for photosynthesis but also for providing signs which regulate their development through receivers sensitive to different light intensities. Thus, modifications of light levels to which a species is adapted may condition different physiological responses in their biochemical, anatomic and growth characteristics (ATROCH et al., 2001).

For Braun et al. (2007), the adaptation of plant to the light environment depends on the adjustment of its photosynthetic apparatus, using efficiently the environmental luminosity, and through that it occurs an adaptation which will be observed through its global growth.

According to Costa and Marenco (2007) the functioning of stomata and leaf area influence the vegetal yield. The first factor because it controls the CO_2 absorption and the second because it determines the light interception. The same authors affirm that the decrease in stomatal conductance is linked to the reduction in the photosynthesis in hottest hours.

Plants reduce the degree of stomata opening, reducing, thus, the stomatal conductance, to reduce the water loss and maintain the water equilibrium. This happens because the higher the water deficiency, the smaller the degree of stomata opening and, consequently, the higher will be the input of atmospheric CO_2 (KERBAUY, 2004).

Paiva et al. (2005), when studying the stomatal conductance in bean, observed that plants which were better irrigated presented higher values, probably due to the better plant water condition. They still observed that in plants submitted to smaller availability of water in soil presented smaller mean values.

In maize it can be observed that to plants properly irrigated it occurs an increase in the stomata opening with the increase of the photosynthetically active irrigation. Plants with water stress present a

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slower response to the incident radiation and values of stomata conductance of approximately a fifth of those found in non stressed plants. Reducing the velocity of stomata opening or letting them less opened can be a form or reduce the water losses through transpiration (BONO et al., 2001).

For Bergonci and Pereira (2002), transpiration is largely dependent on the stomata conductance and it decreases in function of the fraction of water available to the plant and the incidence of radiation photosynthetically active. When plants are supplied by water quantities, in quality and quantity for consumption, the flux of transpiration is basically determined by its leaf area and the meteorological elements which command the evaporative demand (DALMAGO et al., 2006).

Concerning the internal concentration of CO_2, C_4 plants need lower concentrations to make the photosynthesis saturated comparing to C3 plants. The better performance of C_4 plants may be due to several factors, among them it can be cited the efficiency of PEPcase carboxylation, combined with the inhibition of the photorespiration provided by the C_4 mechanism of CO_2 internal concentration together with the active cycle of Rubisco (KERBAUY, 2004).

According to Chavarria et al. (2008), when analyzing the cultivation of vineyard with woven plastic sheeting, transparent, coated with low density polyethylene, the variables photosynthesis, transpiration and stomata conductance present values superior to those cultivated without this cover.

Seeing the importance of the influence of different environmental effects over the plants, the present work aimed trough the field research, to study the physiological behavior of initial phase of the maize and cowpea crop in different cultivation environments: protected environment (screenhouse with shading screen) and in environmental conditions.

Material and methods

The experiment was installed in an area of the meteorological station of the Federal University of Ceará, Pici *Campus*, Fortaleza, Ceará, Brazil (3° 45' S; 38° 33' W and altitude of 19 meters in relation to the sea level). According to the Köppen classification, the area of the experiment is located in a region of Aw' climate, tropical rainy, with precipitations from October to Summer and mean temperature higher than 18 °C during the entire year. The experiment lasted sixty days, and was conducted in the months from September to November 2008. The seeds used were: cowpea [*Vigna unguiculata* (L) Walp.] cultivar Setentão and maize (*Zea mays* L.) hybrid AG 1051.

Plants were submitted to different crop conditions, corresponding to the following treatments: protected environment with screenhouse/shading screen 50% transparency and external environment, in which the average temperature of the months of September, October and December 2008, corresponded to 26.84 ºC, 27.12 ºC e 27.12 ºC and the average of relative humidity in the same period corresponded to 62.09%, 62.36% e 63.30%, respectively.

The experimental design used in the experiment was completely randomized, following a factorial arrangement (2 x 2), correspondent to two crops and two treatments with four replications, totaling 16 experimental plots.

Initially it was prepared the vessels where it was put approximately 10 kg of sieved soil coming from an area of Argissolo Vermelho Amarelo, located in the Laboratory of Hydraulics and Irrigation of the Federal University of Ceará, whose main physical and chemical characteristics are presented in Table 1. In each vessel it was added 300 g of organic compound and 1.1 g of urea, 8.0 g of superphosphate and 1.5 g Potassium chloride. The fertilization was made according to the soil analysis performed.

It was distributed 30 plastic vessels in the protected environment with an area of 38.15 m^2 and 30 plastic vessels outside this environment located beside the screenhouse/shading screen. The selected seeds were placed to germinate in the vessels inserting a vessel with six cowpea seeds and a vessel with six maize seeds. The vessels were disposed with spacing 0.8 m between vessel lines and 0.3 m between vessels, with the same spacing for both crops. After establishing the seedlings, it was made a thinning (14 days after planting), leaving two plants per vessel.

The irrigation was daily and the volume of water applied to plants was estimated according to the principle of lysimeter drainage (BERNARDO et al. 2005), maintaining the soil in the field capacity.

For occasion of the thinning and at 14, 21, 28 and 35 days after germination (DAG) eight cowpea plants and eight maize plants were collected, constituting the first sampling.

The physiological parameters were evaluated due to each sampling, and it was calculated the measure of photossintetically active radiation, net photosynthetic rate, transpiration rate and stomatal conductance in fully expanded leaves using a portable system of infrared gas analysis (ADC System, Hoddesdon, UK), in an open system with airflow of 300 mL min-1.

During the study it was performed the measure of the wind speed, using a Digital Hygro-Thermo-Anemometer-Light meter - THAL 300, with the data collected at a height of 1.0 from the base of the vessel. It was estimated the daily length of the global solar radiation (GR) and the wind speed (U), through a correlation of the data collected by the meteorological station and in IRGA (portable system of infrared gas analysis), the values of radiation and wind speed inside and outside the protected environment, for all the days in which the experiment was conducted, were obtained by an automatic meteorological station located in the Meteorological Station of the Federal University of Ceará, Pici Campus, Fortaleza.

The results were submitted to the analysis of variance at the level of 5% probability and regression analysis. As tool auxiliary to the statistic analysis, it was used the procedure of the program SAEG/UFV (RIBEIRO JÚNIOR, 2001).

Results and discussion

Wind speed (U) and global photosynthetically active radiation (PAR)

The average values of wind spend, measured in the interior and exterior of the protected environment, over the initial cycle of cowpea and maize are represented in Figure 1.

It can be observed that the wind speed inside the protected environment, during all day, is always lower then the values observed outside. According to Vasquez et al. (2005), this behavior is justified by the screens which constitute the walls of the protected environment, besides reducing the values of evapotranspiration of the evaluated cultures.

By analogy, even though in environments

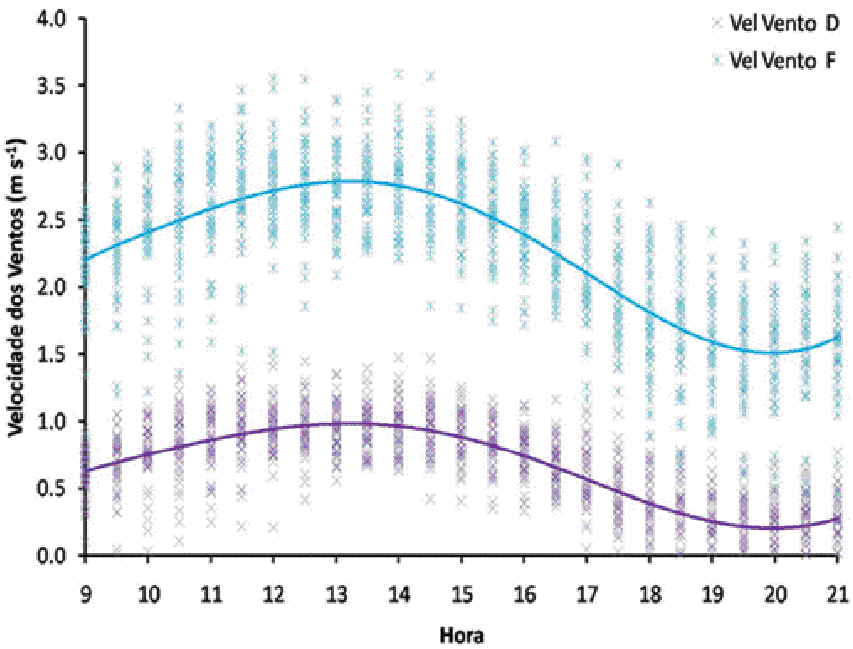

Figure 1. Values of Wind speed (U) in the protected environment and outside, in months from September to November 2008. UFC, Fortaleza – Ceará, 2008.

protected with screen it may occur passage of air, the wind speed must be reduced in relation to outside, which is the reason why plastic sheeting used in construction of screen houses may be used as wind breaker in different crops according to Vieira et al. (2004). The wind intensity may cause in plants favorable reactions, as the redistribution of heat inside the culture and dispersal of pollens, and unfavorable, as excessive transpiration and flower fall. The factors affected by intense winds in crops are: elimination of the pollinator insect, increase in the transpiration, stomata closing, and reduction of the leaf area, among others.

It can be observed than the mean square values of the parameter PAR expressed in Table 1 confirm the effect expected of the environment in the distribution of radiation over the studied cultures. On the other hand, it was not verified effect of the collection period, which can be explained by the fact that the study was performed in the dry season, when the presence of clouds and ranges in the radiation intensity are lower over the time.

It was observed that plants cultivated inside the protected environments received lower values of PAR compared to the cultures cultivated outside (Figure 2), i. e., at full sun, since in the internal environment the global radiation was reduced, proving, thus, that the screen enables the passage of only 50% of the solar radiation.

These results can be justified by Buriol et

Table 1. Values of the mean squares of the PAR inside protected environment and outside, in the months from September to November 2008. UFC, Fortaleza – Ceará, 2008.

Source of Variation	Mean square
Environment	0.11E+08**
Culture (Cult)	100489.0ns
Collecting (Col)	133322.1ns
(Col) * (Cult)	29653.1ns
Residue	55377.36
CV (%)	18.558

**Significant by F test at 5% ** Significant by F test at 5% ns Non significant*

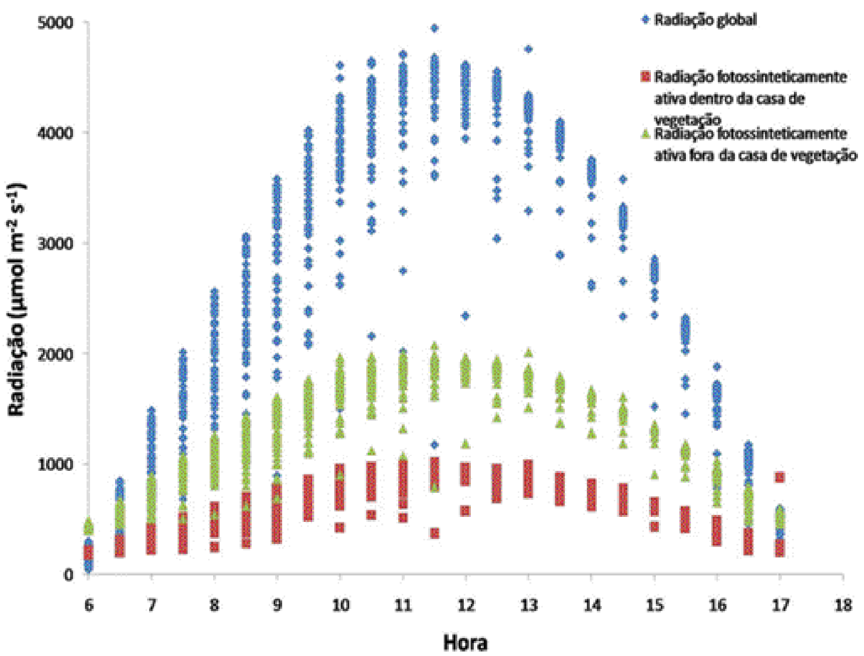

Figure 2. Values of the global and photossynthetically active radiation inside and outside the protected environment, in the months from September to November 2008. UFC, Fortaleza – Ceará, 2008.

al. (2005), who affirms that inside the protected environments and the density of solar radiation flux is lower than outside, in function of the reflectance and the absorptance of the cover material. Giuselini et al. (2004) agree, affirming that the protected environments affect the meteorological elements reducing the global and photosynthetically active solar radiation. The values of PAR, which, even outside of inside the protected environment followed the same behavior of the global radiation, and the values obtained inside it were always lower than those obtained outside it. Similar values with global radiation, inside and outside the protected environment were observed by Vásquez et al. (2005).

Gas exchanges

The analysis of variance presented in Table 2 shows that the environment had a significant effect, in the variables, for the studied treatments and crops with an exception of the behavior of internal concentration of CO_2, which did not present significant differences.

In Figure 3 it is presented the average of leaf temperature for the cowpea and maize; it is observed that the lower values are those from plants cultivated outside. This can be explained by the

Table 2. Values of the mean square of the gas exchange of the studied cultures inside and outside the protected environment, in the months from September to November, 2008. UFC, Fortaleza – Ceará, 2008.

Source of Variation	Mean Squares				
	Stomata conductance	Photosynthesis rate	Internal concentration of CO_2	Transpiration	Leaf temperature
Environment	0.265**	963.40**	17822.25**	18.30**	5581406*
Culture	0.24**	1696.10**	5148.06ns	1.60**	605576.6**
Col * Cul	0.35**	140.16**	14582.02**	12.05**	7236823**
Residue	0.17E-01	13.38	1392.66	0.14	0.8610258
CV(%)	29.90	14.47	19.01	6.98	25.059

*Significant by F test at 5% ** Significant by F test at 5% ns Non significant

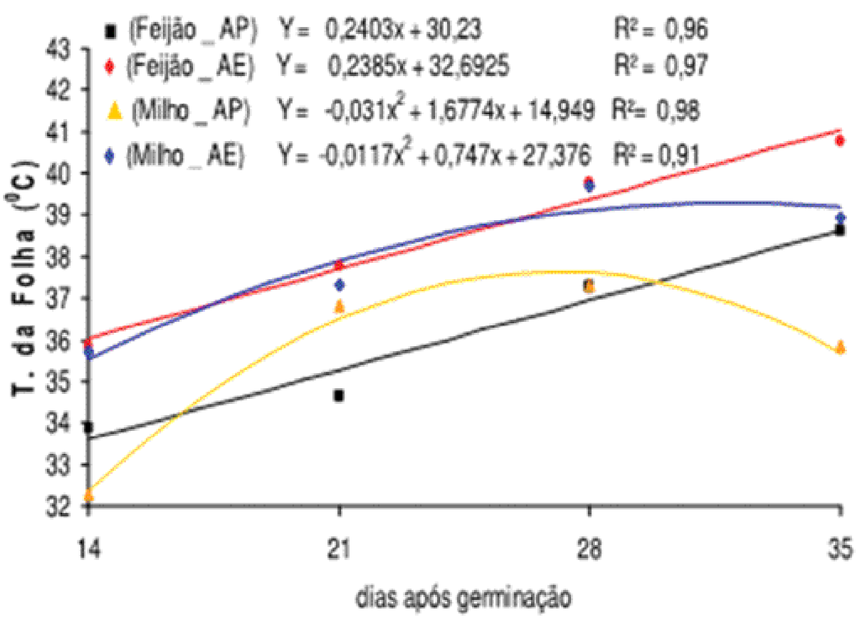

Figure 3. Values of leaf temperature in the studied cultures inside and outside the protected environment, in the months from September to November 2008. UFC, Fortaleza – Ceará, 2008.

higher incidence of solar radiation in plants which were outside the protected environment. The lower incidence of radiation is a characteristic of the shading screen, which usually is used to reduce the exterior temperature to protect cultures sensitive to the excess of radiation. Freitas et al. (2003), when studying the influence of different levels of shading in the physiological behavior of coffee cutivars, observed that the highest leaf temperatures were maintained at full sun followed by the level 30% and 50% shade, and the lowest with the highest shading of 70% shade.

The stomata conductance in maize was higher in the protected cultures (Figure 4), and this may be explained by a higher intensity of radiation outside, leading to a faster loss of water, causing loss of water potential in plant leaves, reducing their turgor and stomatal conductance. The stomatal conductance decreases while the water potential in leaf becomes lower (BONO et al., 2001). It is known that the leaf water potential is one of the major factors which affect the functioning of stomata.

It is important to emphasize that the fluctuations of the meteorological conditions, as the wind speed, or if the sun has few clouds, and others, may in some way affect the stomata conductance, since, for similar levels of PAR, different conductances are found.

The values of stomata conductance obtained, for the cultures inside the protected environment can be considered low when comparing to the values of conductance which are typical to maize. Some factors may have influenced these values: maybe, the most important is the fact that the experiment was conducted without the best condition to the maize development.

Cowpea had a very similar behavior during the evaluation period, in which the highest difference between the values of stomata conductance appeared in the end of the experiment, with the best response inside the protected environment. Paiva et al. (2005), studying the effect of stomata conductance in leaves of bean in different regimes of irrigation, observed that the plant under the best water condition during the vegetative stage presented highest stomata conductance.

It can be verified in Figure 5 that, either to cowpea or maize culture the photosynthesis rate was higher in the external environment of both cultures. Maize was more efficient in relation to the photosynthesis rate, since it is a C_4 plant, different from cowpea which is a C_3 plant. The highest net photosynthesis rates in C_4 plants are due to the capacity to concentrate CO_2 in the action site of Rubisco, which reduces the loss in the

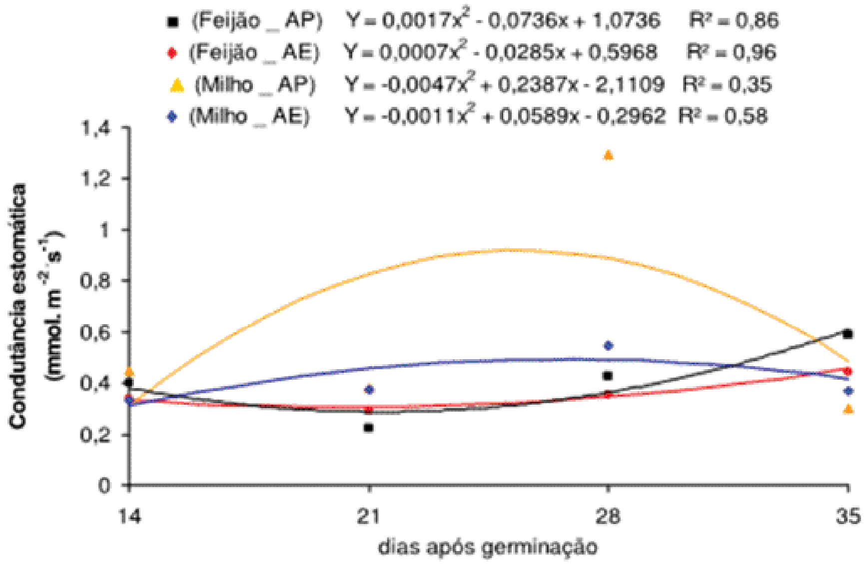

Figura 4. Valores da condutância estomática das culturas estudadas no ambiente protegido e externo, nos meses de setembro a novembro de 2008. UFC, Fortaleza – Ceará, 2008.

photorespiration process, which is elevated in C_3 plants (TAIZ e ZEIGER, 2004).

Casaroli et al. (2007), when studying the solar radiation and the physiological aspects of the soybean crop observed that, since it is a C_3 species, it is not so effective in the use of solar energy when compared to C_4 species.

This occurs, probably, due to the fact that the photorespiration is a process almost absent in these plants, i.e., the net photosynthesis is not inhibited by the high concentration of O_2 in high temperatures and irradiances due to the lower loss of Carbon by photorespiration.

The decrease in the photosynthesis rate in the protected environment may be a response of the cultures to the lower quantity of solar radiation, linked to photochemical and biochemical factors. In experiments made in individual leaves it was found that the increase of the solar radiation flux results in a lower rate of Carbon assimilation, i.e., photosynthesis (BERNADETE, 2002).

Regarding to transpiration in both cultures (Figure 6), the graphic showed higher index for the cultures exposed to external conditions, once the cultures are submitted to higher temperatures. According to Taiz and Zeiger (2004), transpiration is a process which involves the water evaporation from the surface of the cells from the mesophyll to the leaf intercellular spaces and diffusion of water vapor from leaves to the medium.

Regarding to the internal concentration of CO_2 to the cowpea culture, it was observed higher values to the cultures cultivated in protected environment. To maize, the internal concentration of CO_2 was higher in the beginning of the experiment, having a better behavior in the culture in protected environment, and in the end it was observed that, the highest internal concentration of CO_2 to maize belonged to cultures in external environment.

The behavior of the Figure 7 may be explained by Machado and Lagoa (1994), who, when studying the gas exchanges and stomata conductance in three grass species, affirm that the increase in the photosynthesis rate causes a decrease in the internal concentration of CO_2, having strong retroactive effect, and can, consequently, cause a decrease in the photosynthesis rate. The results obtained in the present study showed that the highest values of internal concentration of CO_2 in the plants cultivated in protected environments (Figure 7) are related to the lowest values of photosynthesis rate, namely in the cowpea leaves (Figure 5).

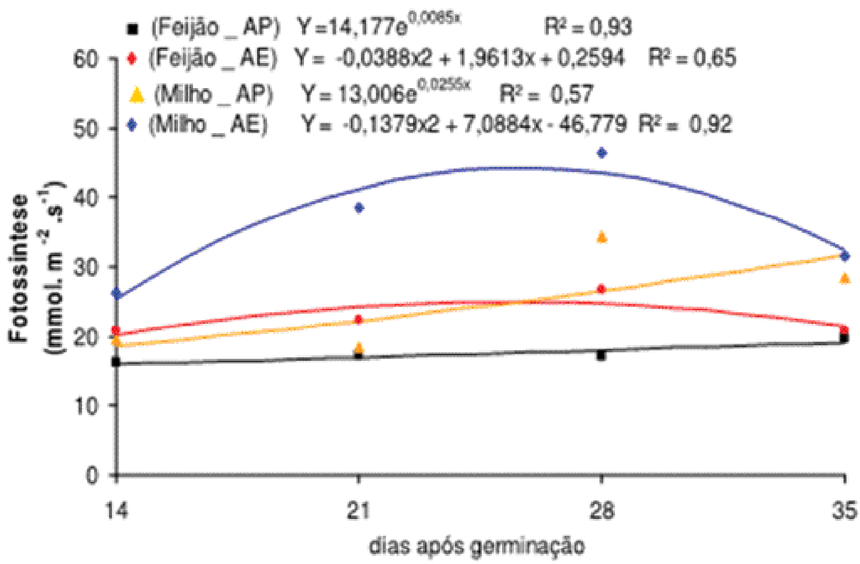

Figure 5. Values of the photosynthesis rate (A) of the studied cultures inside and outside the protected environment in the months from September to November 2008. UFC, Fortaleza – Ceará, 2008.

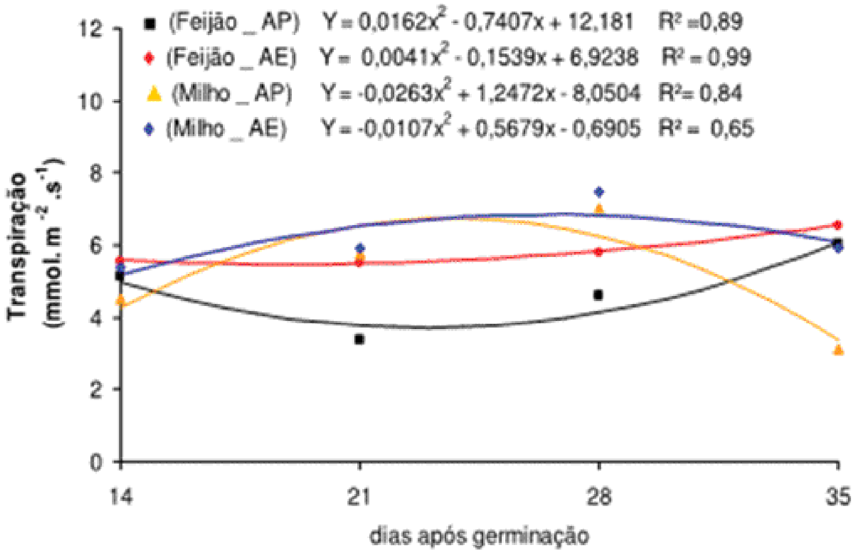

Figure 6. Values of transpiration (E) of the cultures studied inside and outside protected environment, from the months of September to November 2008. UFC, Fortaleza – Ceará, 2008.

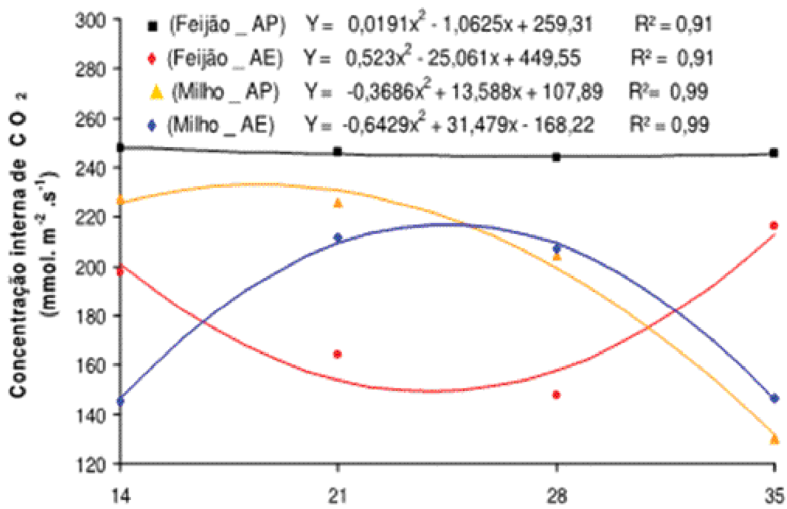

Figure 7. Values of the internal concentration of CO_2 of the cultures inside and outside protected environment, from the months of September to November 2008. UFC, Fortaleza – Ceará, 2008.

Conclusions

The use of shading screen which enable the passage of 50% of global radiation caused different reactions in the cultures studied.

The values of wind speed (U) and photosynthetically active radiation (PAR) inside the protected environment were always lower that those obtained in the exterior environment.

There were changes either morphological or physiological to both cultures studied. These changes had the objective of making the plant as acclimatized as possible to the adverse conditions.

References

ATROCH, E. M. A. C.; SOARES, A, M.; ALVARENGA, A. A. DE; CASTRO, E. M. DE. Crescimento, teor de clorofilas, distribuição de biomassa e características anatômicas de planas jovens de *Bauhinia forficata Link* submetidas a diferentes condições de sombreamento. **Ciência Agrotecnologia**, Lavras, v.25, n.4, p.853-862, 2001.

BERGONCI, J. I.; PAREIRA, P. G. Comportamento do potencial da água na folha e da condutância estomática do milho em função da fração de água disponível no solo. **Revista Brasileira de Agrometeorologia**, Santa Maria, v.10, n.2, p.229-235, 2002.

BERNADETE, R.; **Eficiência do uso da radiação fotossinteticamente ativa pelo tomateiro cultivado em diferentes ambientes**. 2002. 127f. Tese (Doutorado em Fitotecnia). Universidade Federal do Rio Grande do Sul.

BONO, L.; BERGAMASCHI, H.; ROSA, L. M. G.; FRANÇA, S.; RADIN, B.; SANTOS, A. O. S.; BERGONCI, J. I. Alterações no padrão de resposta à luz da condutância estomática do milho causadas pelo déficit hídrico. **Revista Brasileira de Agrometeorologia**, Santa Maria, v.9, n.1, p.27-34, 2001.

BRAUN, H.; ZONTA, J. H.; SOUZA LIMA, J. S. de.; REIS, E. F. de.; Produção de mudas de café 'conilon' propagadas vegetativamente em diferentes níveis de sombreamento. **IDESIA**, Chile, v.25, n.3, 2007.

BURIOL, G. A.; LAGO, I.; HELDWEIN, A. B.; SCHNEIDER, F. M.; ANDRIOLO, J. L. Disponibilidade de radiação solar para hortaliças cultivadas em ambiente protegido no período invernal no Estado do Rio Grande do Sul. **Revista Brasileira de Agrometeorologia**, Santa Maria, v.13, n.1, p.21-26, 2005.

CASAROLI, D.; FAGAN, E. B.; SIMON, J.; MEDEIROS, S. P.; MANFRON, P. A.; NETO, D. D.; LIER, Q. de J. V.; MULLER, L.; MARTIN, T. N. Radiação solar e efeitos fisiológicos na cultura d soja. **Revista da FZVA**, Uruguaiana, v.14, n.2, p.102-120, 2007.

CHAVARRIA, G.; SANTOS, H. P. dos.; FELIPPETO, J.; MARODIN, G. A. B.; BERGAMASCHI, H.; CARDOSO, L. S.; FIALHO, F. B. Relações hídricas e trocas gasosas em vinheto sob cobertura plástica. **Revista Brasileira de Fruticultura**. Jaboticabal, v.30, n.4, p.1022-1029, 2008.

COSTA, G. F. da.; MARENCO, R. A. Fotossíntese, condutância estomática e potencial hídrico foliar em árvores jovens de andiroba (*Carapa guianensis*). **Acta amazônica**, v.37. n.2. p.229-234. 2007.

DALMAGO, G. A.; HELDWEIN, A. B.; NIED, A. H.; GRIMM, E. L.; PIVETTA, C. R. Evapotranspiração máxima da cultura de pimentão em estufa plástica em função da radiação solar, da temperatura, da umidade relativa e do déficit de saturação do ar. **Ciência Rural**, v.36, n.3, p.785-792, 2006.

FREITAS, R. B.; OLIVEIRA, L. E. M. da.; FILHO, N. D.; SOARES, A. M. Influência de diferentes níveis de sombreamento no comportamento fisiológico de cultivares de café (*coffea arábica* L.). **Ciências agrotecnologia**, Lavras, v.27, n.4, p.804-810, 2003.

GUISELINI, C.; SENTELHAS, P. C.; OLIVEIRA, R. C. de. Uso de malhas de sombreamento em ambiente protegido II: efeito sobre a radiação solar global e a fotossinteticamente ativa. **Revista Brasileira de Agrometeorologia**, Santa Maria, v.12, n.1, p.19-26, 2004.

KERBAUY, G. B. **Fisiologia Vegetal**. 1ª ed. Rio de Janeiro. 2004. 452 p.

MACHADO, E. C.; LAGOA, A. M. M. A. Trocas gasosas e condutância estomática em três espécies de gramíneas. **Bragantina**, Campinas, v.52, n.2, p.141-149, 1994.

PAIVA, A. S.; FERNANDES, E. J.; RODRIGUES, T. J. D.; TURCO, J. E. P. Condutância estomática em folhas de feijoeiro submetidos a diferentes regimes de irrigação. **Engenharia Agrícola**, Jaboticabal, v.25, n.1, p.161-169, 2005.

PILAU, F. G.; BONNECARRERE, R. A. G.; NETO, D. D.; FANCELLI, A. L.; MARTIN, T. N.; PEREIRA, C. R.; MANFRON. P. A. Transpiração e condutância foliar à difusão de vapor de Transpiração feijoeiro irrigado em função da temperatura da folhagem e variáveis Ambientais. **Acta Science Agronomic**, Maringá, v.29, n.1, p.127-131, 2007.

TAIZ, L.; ZIEGER, E. **Fisiologia vegetal.** Trad. SANTARÉM, E. R., 3° ed., Porto Alegre: Artemed, 2004. 719p.

VÁSQUEZ, M. A. N.; FOLEGATTI, M. V.; DIAS, N. da S.; SILVA, C. R. da. Efeito do ambiente protegido cultivado com melão sobre os elementos meteorológicos e sua relação com as condições externas. **Engenharia Agrícola**, Jaboticabal, v.25, n.1, p.137-143, 2005.

VIEIRA, M. R.; CORREA L. de S.; CASTRO T. M. M. G de; SILVA, L. F. S. da, MONTEVERDE, M. de S. Efeito do cultivo do mamoeiro (*Carica papaya* L.) em ambiente protegido sobre a ocorrência de ácaros fitófagos e moscas-brancas. **Revista Brasileira de Fruticultura**, Jaboticabal - SP, v.26, n.3, p.441-445, 2004.