

Comportamento metabólico na alocação de biomassa de cultivares de melão sob condições de déficit hídrico

Metabolic behavior in the allocation of biomass of melon cultivars under water deficit conditions

Comportamiento metabólico en la asignación de biomasa de melones en condiciones de déficit hídrico

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Resumo

Buscando compreender os mecanismos de tolerância de plantas de melão sob déficit hídrico, este estudo teve como objetivo avaliar o comportamento bioquímico de cultivares de melão e a alocação de biomassa sob déficit hídrico. Os dois experimentos foram conduzidos em

ambiente sombreado na área experimental da Universidade Estadual da Bahia, Juazeiro / BA; o primeiro foi realizado em 2015 e o segundo em 2016. O delineamento experimental foi em blocos casualizados, replicados três vezes, com parcelas subdivididas; as parcelas consistiram em quatro taxas de aplicação de água (50, 75, 100 e 125% da evapotranspiração das culturas), as subparcelas de duas cultivares de melão 'Amarelo' e 'Piel de Sapo'. As sub-subparcelas foram os períodos de amostragem: 15; 30 e 45 dias após o transplante. No primeiro experimento foi avaliado: açúcares solúveis totais, açúcares redutores, proteínas totais. No segundo experimento, além das análises bioquímicas, foi avaliada a alocação de biomassa de folhas, galhos, raízes, frutos e razão raiz/ parte aérea. No final de ambos os experimentos foi avaliado prolina da raiz e parte aérea. Ambas as cultivares apresentaram comportamento bioquímico semelhante, exceto pelo acúmulo de prolina obtido na cultivar 'Piel de sapo', que permitiu maior alocação de biomassa para o fruto do que a cultivar 'Amarelo'.

Palavras-chaves: Ajuste osmótico; *Cucumis melo L.*; Manejo da irrigação.

Abstract

Seeking to understand the mechanisms of tolerance of melon plants under water deficit, this study aimed to evaluate the biochemical behavior of melon cultivars and the allocation of biomass under water deficit. Two experiments were conducted in a shaded environment in the experimental area of the State University of Bahia, Juazeiro / BA; the first was carried out in 2015 and the second in 2016. The experimental design was in randomized blocks, replicated three times, with subdivided plots; the plots consisted of four water application rates (50, 75, 100 and 125% of the crop evapotranspiration), the subplots of two melon cultivars 'Yellow' and 'Piel de Sapo'. The sub-subplots were the sampling periods: 15; 30 and 45 days after transplantation. In the first experiment it was evaluated: total soluble sugars, reducing sugars, total proteins. In the second experiment, in addition to biochemical analyzes, the allocation of biomass of leaves, branches, roots, fruits and root / shoot ratio was evaluated. At the end of both experiments, root proline and aerial part were evaluated. Both cultivars showed similar biochemical behavior, except for the accumulation of proline obtained in the cultivar 'Piel de sapo', which allowed greater biomass allocation to the fruit than the cultivar 'Amarelo'.

Key words: Osmotic adjustment; *Cucumis melo L.*; Irrigation management.

Resumen

Buscando comprender los mecanismos de tolerancia de las plantas de melón bajo déficit hídrico, este estudio tuvo como objetivo evaluar el comportamiento bioquímico de los

cultivares de melón y la asignación de biomasa bajo déficit hídrico. Se realizaron dos experimentos en un entorno sombreado en el área experimental de la Universidad Estatal de Bahía, Juazeiro / BA; la primera se realizó en 2015 y la segunda en 2016. El diseño experimental fue en bloques aleatorizados, replicados tres veces, con parcelas subdivididas; las parcelas consistieron en cuatro dosis de aplicación de agua (50, 75, 100 y 125% de la evapotranspiración del cultivo), las subparcelas de los dos cultivares de melón 'Amarillo' y 'Piel de Sapo'. Las subparcelas secundarias fueron los períodos de muestreo: 15; 30 y 45 días después del trasplante. En el primer experimento se evaluó: azúcares solubles totales, azúcares reductores, proteínas totales. En el segundo experimento, además de los análisis bioquímicos, se evaluó la asignación de biomasa de hojas, ramas, raíces, frutos y la relación raíz / brote. Al final de ambos experimentos, se evaluó la prolina de raíz y la parte aérea. Ambos cultivares mostraron un comportamiento bioquímico similar, excepto por la acumulación de prolina obtenida en el cultivar 'Piel de sapo', que permitió una mayor asignación de biomasa a la fruta que el cultivar 'Amarelo'.

Palabras clave: Ajuste osmótico; *Cucumis melo* L.; Manejo del riego.

1. Introduction

The semi-arid region is characterized by drought, high temperatures and low relative humidity, which greatly limits agriculture, restricting cultivation to irrigated areas. However, according to (Obermaier and Rosa, 2013), the worsening of environmental conditions in the semiarid regions of Brazil and the world is expected in the coming years, caused mainly by the effects of climate change.

Climate change contributes to increasing the effects of water scarcity and, consequently, decreasing the production of plants in the affected areas, hindering the development of several plant species, mainly melon, due to the decrease in plant health, decreasing the size of the plants, fruits and quality, as well as yield (Colman et al., 2014; Pires et 2013; Farias et al. 2015).

Many melon hybrids are known to be sensitive to water deficit. Therefore, it is essential to carry out studies on the biochemical behavior and allocation of biomass for the fruit, in order to subsidize the choice of productive hybrids in conditions of water deficit, assisting in decision making on the amount of water to be use by the plant that does not have a marked impact reduction in growth, development and productivity of plant fruits.

Osmotic adjustment helps the plant to withstand or tolerate adverse conditions due to drought, minimizing damage caused by water retention and keeping the turgor of adjacent cells at adequate levels, producing and accumulating organic compounds such as sugars, proline and organic acids and others (Pereira et al., 2012; Souza et al., 2014).

This biochemical adjustment may favor a greater allocation of biomass for fruit formation, allowing the plant to be more efficient in converting photo-assimilates under limited water conditions.

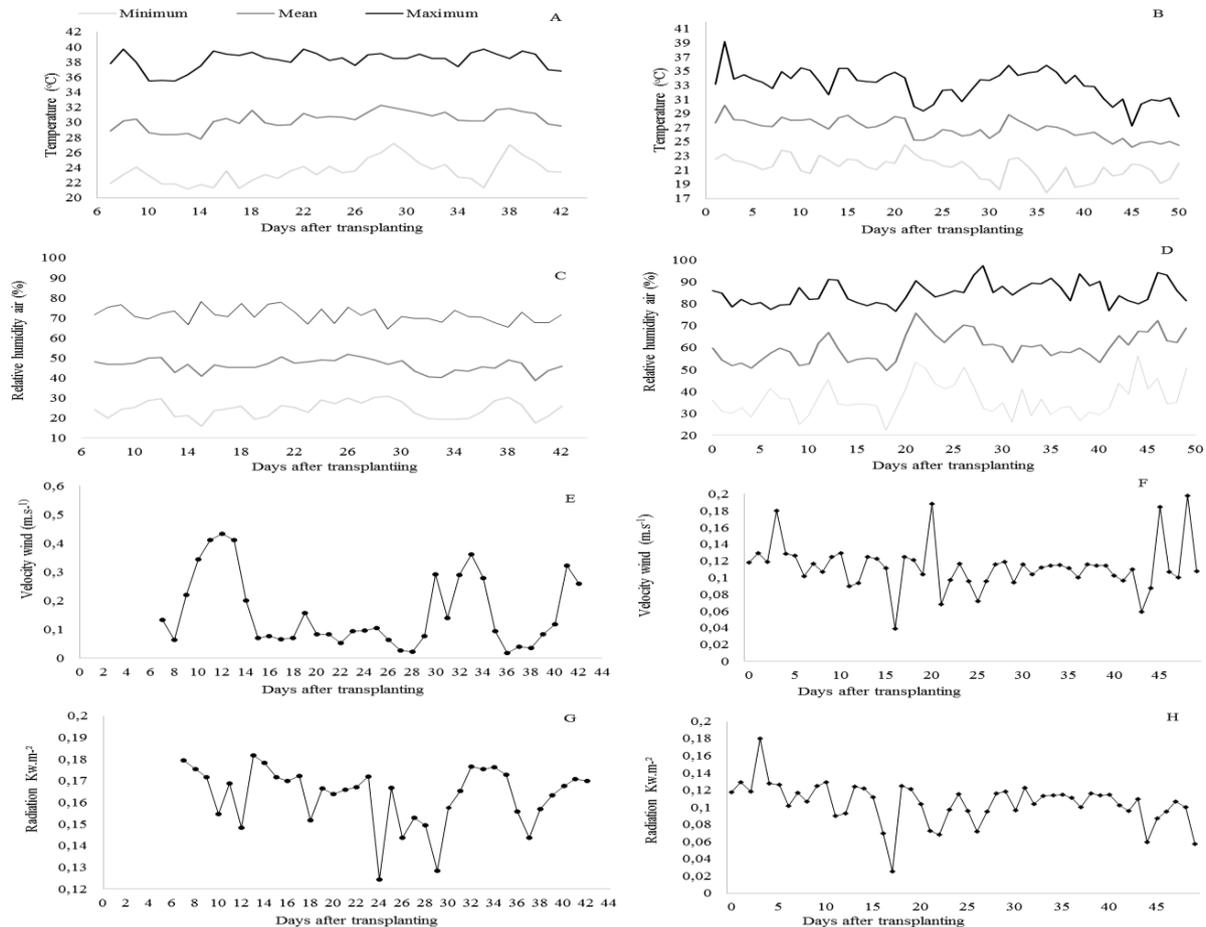
The biochemical change of the melon is expect under conditions of water deficit; Based on this information, this study aims to evaluate biochemical variations throughout the cultivation cycle of two melon hybrids and biomass allocation under water deficit conditions in the São Francisco River valley, in the São Francisco sub-center.

2. Material and Methods

Two experiments were conduct in shaded environments with 40% of solar reduction. The first experiment was carried out from October to December, 2015 and the second experiment was performed in the period ranging from May to June, 2016.

Climatic conditions were measure at a meteorological station inside the shaded environment. The data acquired were temperature (Figure 1A and B), air speed (Campbell Anemometer, 03002-L45 model) (Figure 1C and D), air humidity (Campbell Thermo-hygrometer, HMP45CL45-PT model), (Figure 1 E and F), and overall solar radiation (LP02-L12-PT Pyranometer) (Figure 1 G and H). These pieces of equipment were interconnected to a data collector and store (Campbell Datalogger, CR800 model); readings were performed over an interval of 1 second and mean values were stored every 15 minutes.

Figure 1. A and B) Temperature. C and D) Air (wind) speed. E e F) Relative air humidity. G and H) Solar radiation inside the shaded environment in the cultivation season, respectively, in the first and second cultivation period (October to December, 2015 and May to June, 2016).



Source: Survey data.

The experimental design was in randomized blocks with subdivided plots, with three replications. The plots were composed by four irrigation rates (50, 75, 100 and 125% of the evapotranspiration of cultures-ETc); the subplots were the hybrids 'Juazeiro' and 'Mandacaru', representing the types of cultivars 'Piel de Sapo' and 'Amarelo', respectively, and the sub-plots were represented by sampling at 15, 30 and 45 days after transplantation.

To perform biochemical analyzes, three samples were taken, at 15, 30 and 45 days after transplanting the seedlings, and the following variables were characterized: total soluble sugar content (Yemm and Willis, 1954); reduced sugar content (Miller, 1959); and soluble proteins (Bradford, 1976). At the end of the experiment, leaves, branches and roots of melon were collected and dried in an oven at 60°C for 72h for analysis of proline (Bates et al.,

1973). The design used to evaluate the content of proline in the aerial parts and roots. In the second experiment, the biomass allocation of the leaf, branch, fruit and root / aerial part consisted of subdivided plots, as the analysis was performed at the end of the experiment, when the plots consisted of irrigation rates and the subplots consisted of types of melon.

The seeds were inserted in polyethylene trays with commercial substrate and, when the plants had two pairs of definitive leaves, they were transferred to 5-liter pots. After an acclimatization period of 10 days after transplantation, the four irrigation rates were differential: 50, 75, 100 and 125% of the crop evapotranspiration. Irrigation was performed daily using an automated drip system.

The plants were fertilized weekly using Hoagland's nutrient solution (Hoagland and Arnon, 1950); in experiment I, the fertilization recommendation followed for hydroponic conditions. In the second experiment, a qualitative change in the nutrient solution used was necessary; therefore, the dry biomass of the aerial parts was estimated for a new calculation of the nutrients used (Table 1).

The data were subject to a normality test, when normal, to an analysis of variance; when the results were significant, they were submitted to the means test and regression analysis.

Table 1. Amount of fertilizers applied to protected-grown melon plants in both experiments.

Experiments	Solution A			Solution B	
	MA P*	Ca(NO ₃) ₄ *	KN O ₃ *	MgS O ₄ *	Conmicr os*
Experiment 1	1L (Dilution of 5mL ⁻¹)			400 mL (Dilution of 2mL ⁻¹)	
	34,0 g	208, 0g	110, 0g	49,0 g	50,0g
Experiment 2	10 L (N\D)			400 mL (N\D)	
	340, 0g	1.03 7,0g	1.10 0,0g	49,0 g	50,0g

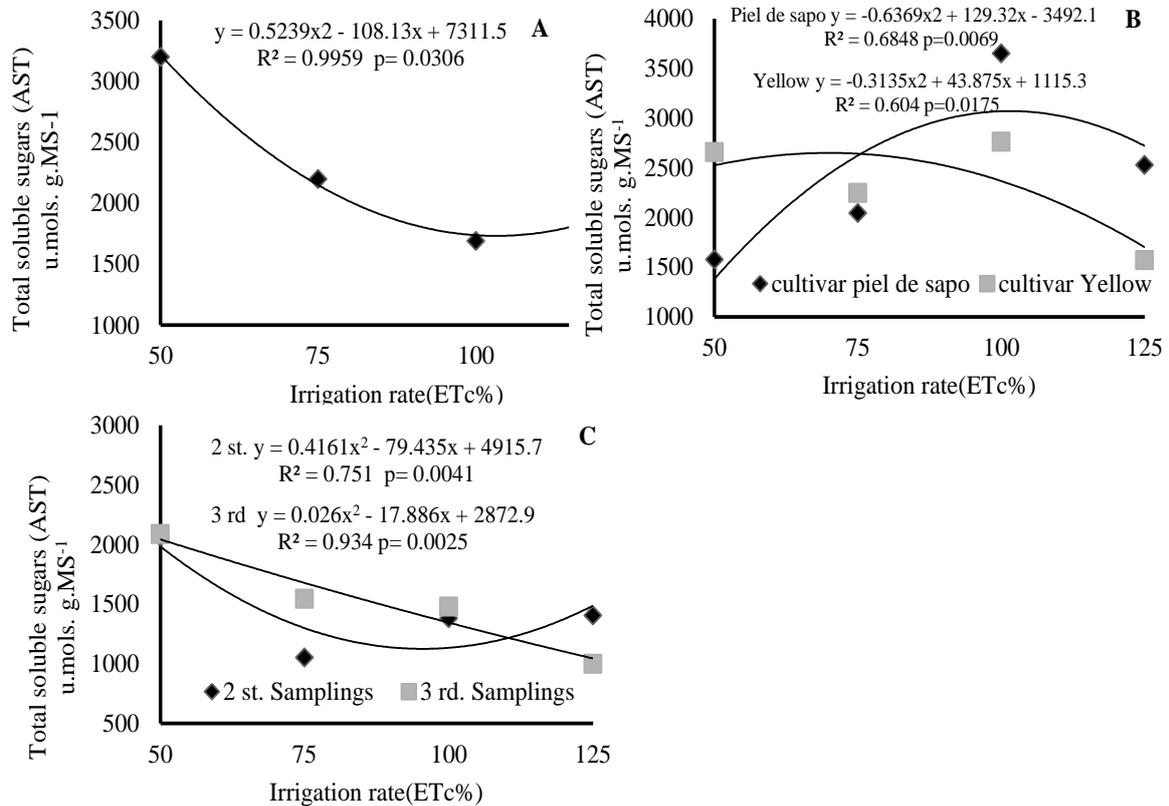
* MAP - Monoamonic phosphate, Ca(NO₃)₄ – Calcium nitrate, KNO₃ – Potassium nitrate, MgSO₄ – Magnesium sulphate, Conmicros - Micronutrient Fertilizer. N\D – No dilution.

Source: Survey data.

3. Results and Discussion

Regarding the content of total soluble sugars, in the first sampling (15 days after transplantation) the cultivar 'Piel de Sapo' (Figure 2A) responded significantly in terms of irrigation rates. The water deficit applied with the 50% slide (ETc) contributed to increase the total content of soluble sugars, in order to tolerate this adverse condition.

Figure 2. Total soluble sugar content: triple interaction between irrigation rates (crop evapotranspiration: ETc%) with the 1st sampling (15 days after transplant) and 'Piel de Sapo' (A); Triple interaction: irrigation rates with the 2nd sampling (30 days after transplant) and the cultivars 'Piel de Sapo' and 'Yellow' in the first experiment (B); Irrigation rates and 2nd (30 days after transplant) and 3rd sampling (45 days after transplant) (C) in the second experiment.



Source: Survey data.

In the 2nd sampling (30 days after transplant) there was a triple interaction between the sampling time, the melon cultivars and the levels of irrigation rate shown in Figure 2 (B), being adjusted to the quadratic polynomial regression models. The cultivars showed similar behavior, the condition of 100% water availability showed higher values in relation to water availability.

The 'Piel de Sapo' had the opposite behavior in relation to the 1st sampling with the 2nd, due to the decrease in the total content of soluble sugar under water deficit conditions, and these sugars accumulated in the first moment may have been directed by the flow of the phloem to others plant organs. One of the acclimatization responses to the condition of water deficit.

The osmotic adjustment mechanism, increasing the total soluble sugar content observed in 'Piel de sapo' in the 1st sample, was corroborated by Ouzounidou et al. (2014), who evaluated the effects of drought and salinity on beans and observed an increase of 53% in the sugars of the aerial parts, which indicates their involvement in the response to the deficit.

In the second experiment, from May to July 2016, the results showed that there was a significant difference in the bidirectional interaction between samples and cultivars. Using the Tukey test, the total soluble sugar content in the 'Piel de Sapo' showed no significant difference between the samples, but the 'Yellow' melon showed interaction between the three samples.

At 15 days after transplant, in the vegetative phase when the plant needs high production of photoassimilates to induce its growth and development and in the fruiting stage, the melon showed the highest values (15 and 45 days after transplant) (2004.37 and 1376.7 $\mu\text{.mols.g MS}^{-1}$) did not differ from each other and, at 30 days (1204.17 $\mu\text{.mols.g MS}^{-1}$) after transplantation, there was a lower value than the others, because at this stage photosynthesis products are being used to meet the energy demands of the vegetative phase.

The results are corroborate by the work of Koch (2004), since the carbon balance in the plant is variable for each stage of development of the plant. There was a bidirectional interaction between the irrigation rates and the 2nd and 3rd samples (Figure 2C), which were adjusted to the quadratic polynomial regression models. In the 2nd sampling, there was a higher content in the application rate of 50%, with a drop closer to the rate of 75%.

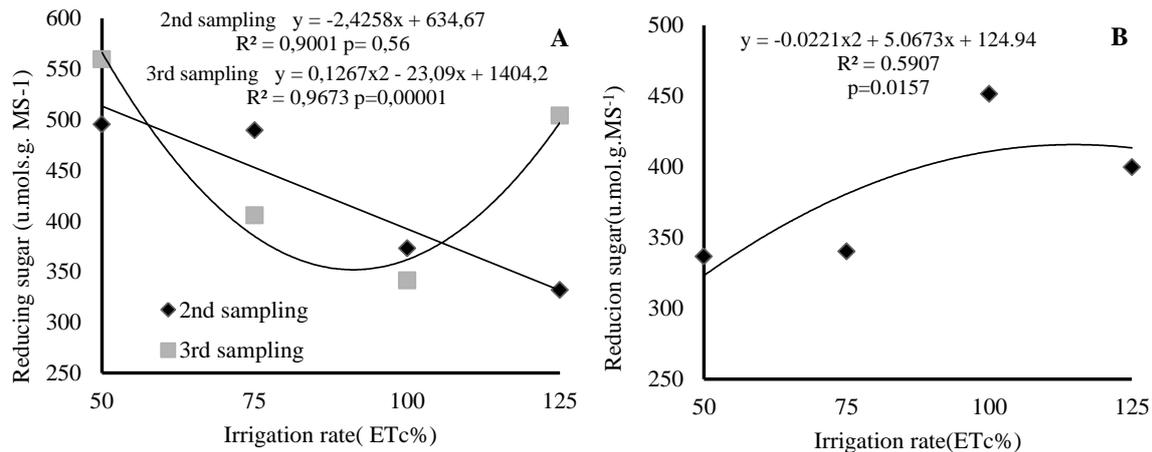
The accumulation of sugar allows the plant to absorb water from the soil, even in dry conditions, as carbohydrates work directly in osmotic balance. The increase in the total content of soluble sugars under water deficit occurs due to natural changes in the metabolism of plant cells (Waseem et al., 2011; Pereira et al., 2012). Accumulation of carbohydrates in leaves with deficit, also observed by Lobo et al. (2015) and Ribeiro et al. (2017), it may be due to the low demand for carbohydrates, since plants with water deficit generally show less growth and accumulation of dry matter.

This is corroborated by Moura et al. (2016), evaluating the organic solutes in young plants of *Jatropha curcas* L. under different water regimes, in the condition of 120 days after planting, a 60% reduction in water condition showed the highest value of total soluble sugars.

Regarding the reduction of sugar content, there was no difference between cultivars in the first experiment. There was no difference in the 1st sampling, but there was significance and bidirectional interaction between the 2nd and 3rd samplings and each irrigation rate

(Figure 3A). The reduction in sugar content was greater due to the lower availability of water in the 2nd sampling.

Figure 3. Change in reducing sugars between irrigation rates (Crop evapotranspiration: ETC) and the 2nd and 3rd samplings (30 and 45 days after transplanting) in the first experiment (A). Interaction between Irrigation rates (Crop evapotranspiration: ETc) and the 3rd sampling in the second experiment (B).



Source: Survey data.

When comparing the 2nd and 3rd samples, we observed a convex parabolic function with its minimum point between 75% and 100% and an increasing trend after this interval. In the second experiment, there was no statistical difference between samplings or types, but there was a difference between irrigation rates (Figure 3B). The water deficit caused a reduction in the sugar content.

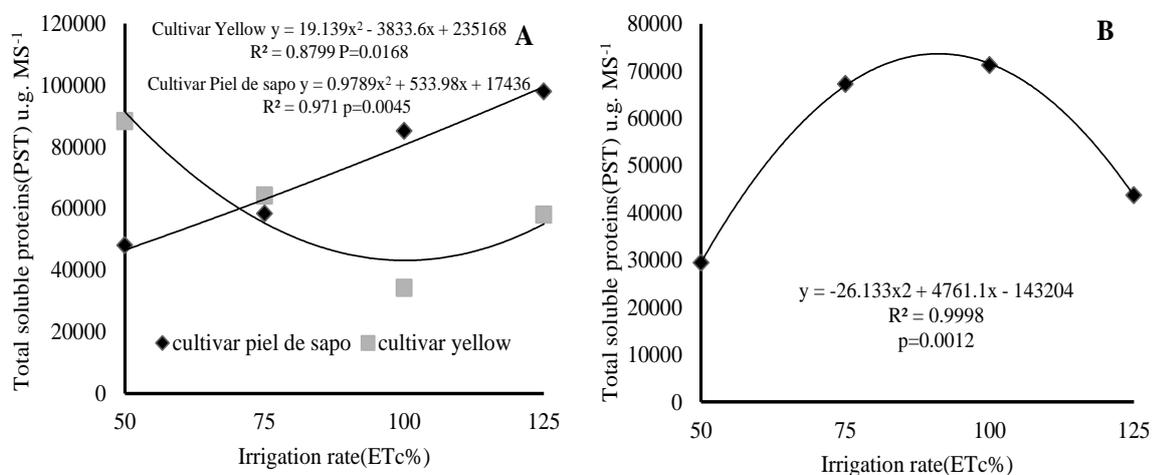
Change in total soluble proteins in the interaction between Irrigation rates (Crop evapotranspiration: ETc), the 1st sampling (15 days after transplanting), and 'Piel de sapo' and 'Amarelo' types (A); interaction between Irrigation rates the 2nd sampling (30 days after transplanting) and 'Piel de Sapo' (B) in the first experiment.

The decrease in reducing sugars is associated with the consumption of these molecules to maintain the survival and development of plants, since the nutritional and environmental conditions allowed the use of reducing sugars in metabolic processes, directly influencing the development of plants.

Regarding total soluble proteins, the results of the first experiment showed that there was no significant difference between cultivars, but in isolation, there was a triple interaction

between cultivars and irrigation rates in the 1st sampling, we obtained the best fit for the model of quadratic polynomial regression (Figure 4A). 'Yellow' reduced the content with increased water availability, differing from 'Piel de Sapo', which obtained a higher content of total soluble proteins with increased irrigation rate.

Figure 4. Change in total soluble proteins in the interaction between Irrigation rates (Crop evapotranspiration: ETc), the 1st sampling (15 days after transplanting), and 'Piel de sapo' and 'Amarelo' types (A); interaction between Irrigation rates the 2nd sampling (30 days after transplanting) and 'Piel de Sapo' (B) in the first experiment. Juazeiro-BA, UNEB, 2017.



Source: Survey data.

The Figure (4B) shows that there was a triple interaction between the 2nd sampling (30 days after transplant), 'Piel de Sapo' and the irrigation rates, adjusted to the linear regression model. The prolonged water deficit caused an adjustment behavior, since the 50% rate showed a higher total content of soluble proteins, decreasing gradually as the irrigation rates increased.

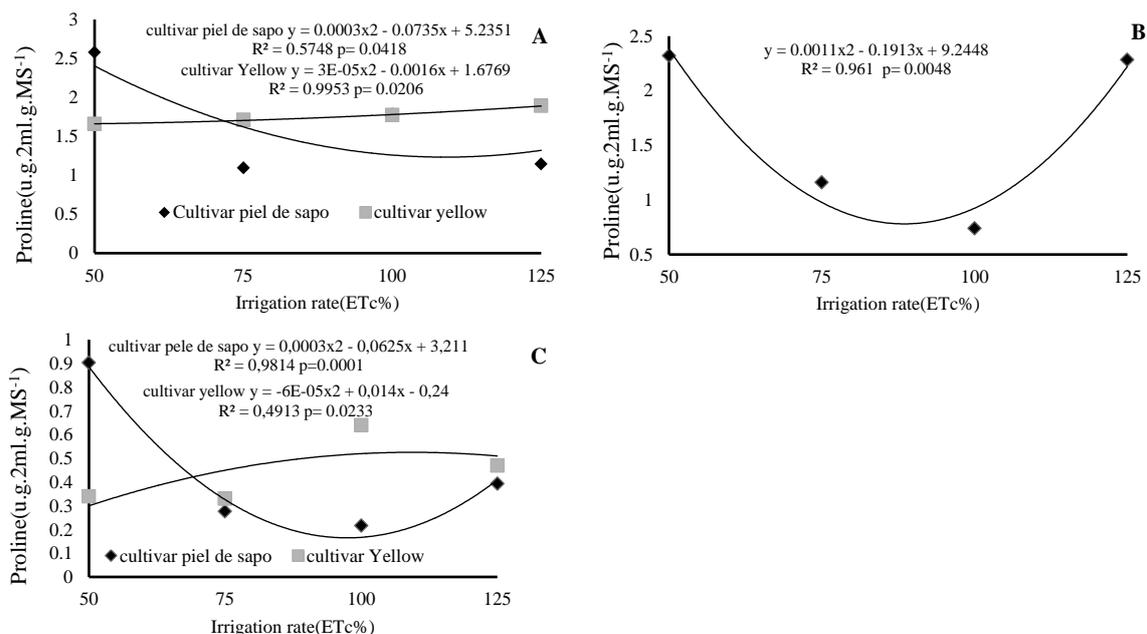
In the second experiment, with more favorable climatic conditions, as (Figure 1) there was no statistical difference between the irrigation rates and the two cultivars, as the evapotranspiration demand was generally lower due to the fact that the temperature and solar radiation were lower and higher relative humidity, reducing water loss. These factors are decisive so that the water deficit does not alter the total content of soluble proteins. The evaluation samples showed a significant difference, differing from the first experiment, according to the quadratic polynomial regression model.

The results of the present study are corroborated by Alves et al. (2016), who evaluated the genotypic variability of peanuts in response to water deficit based on chemical descriptors. They observed that total soluble proteins increased 43% in dry conditions in only two of the six strains studied, showing an independent behavior for each genotype.

The results obtained in the cultivar 'Yellow' are corroborated by Ferreira et al. (2016) for demonstrating that the highest levels of total soluble proteins as the irrigation rates increased.

Following the evaluated variables, the one that has great importance in terms of osmotic adjustment is the amino acid proline, in the first experiment, there was a significant difference and bidirectional interaction, between cultivars and irrigation levels, shown in (Figure 5A); there is a downward trend as irrigation rates increase for 'Piel de Sapo'. The behavior of the 'Yellow' cultivar differs in that it presents a reduction in the content of proline in the aerial part with increased water availability, being indicative that this cultivar presents less osmotic adjustment.

Figure 5. Change in aerial part proline in the interaction between rates (Crop evapotranspiration: ETC) and types ('Piel de sapo' and 'Yellow') (A) in the first experiment; interaction between irrigation rates and 'Piel de Sapo' in the second experiment (B). Change in root proline content in the interaction between rates (Crop evapotranspiration: ETC) and cultivars ('Piel de sapo' and 'Amarelo') in the first experiment(C).



Source: Survey data.

In the second experiment, the aerial part of the proline showed no statistical difference between the rates of irrigation and 'Piel de Sapo' (Figure 5B). It was evident that, in conditions of more severe deficit, alongside the rate of 50% (drought condition) and the rate of 125% (excessive watering), the proline content increased to maintain plant development and metabolic processes .

In the study by Barzegar et al. (2017), they evaluated the effect of water stress on yield, antioxidant activity, proline content of four Iranian melon genotypes ("Khatooni", "Suski-Sabz", "Zarde-Tabriz" and "Shiari"). The lower availability of water resulted in an accumulation of proline, corroborating our results for 'Piel de Sapo' in the two experiments and for 'Amarelo' in the first, because the lower availability of water led to a higher concentration of proline.

The accumulation of proline is a well-known response in plants in deficit conditions, since its synthesis is increased and in the same way that its degradation is inhibited. It is one of the ways in which plants use it as a reserve to recover the ideal condition of development to serve as a nitrogen source for resuming plant development (Szal and Podgórska, 2012). It is known that proline has an osmoprotective function when the plant is under the influence of water deficit over time (Moura et al., 2016).

In relation to root proline in the first experiment (Figure 5C), 'Piel de Sapo' and 'Yellow' had a higher content with an irrigation rate of 50% than in the others, showing behavior similar to that of aerial parts. According to some authors, plants tolerant to physiological stresses due to the deficit of water and salt synthesize a greater amount of proline (Pereira et al., 2012).

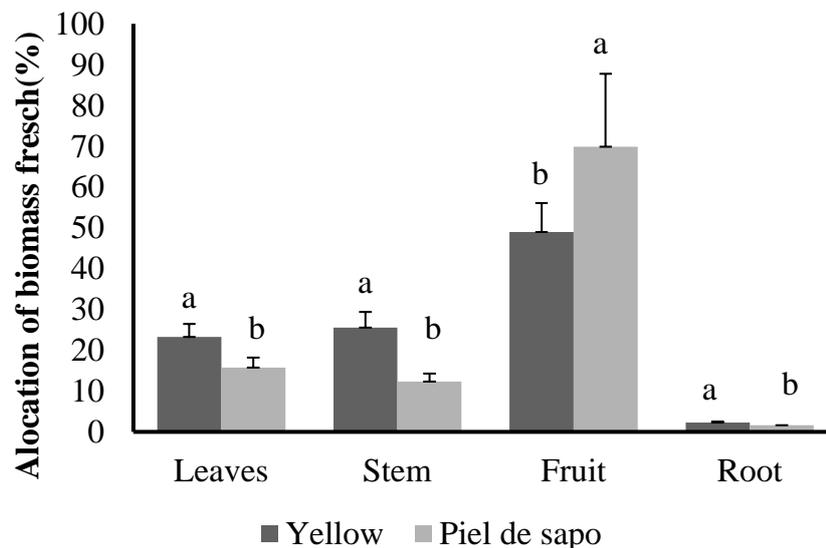
Aerial part proline accumulation was higher than in the root in both types of melon plants, which is corroborated by (Pereira et al., 2012). Water deficit affects the transfer of photoassimilates from the aerial part to the root, as the root system is the first organ to be harmed, and consequently, there is higher accumulation in the aerial part. Our results are also corroborated by Souza et al. (2014), who evaluate nitrogen compounds, proteins, and amino acids in maize under different silicon levels and drought and observed that drought conditions also reduced the activity of the enzyme in leaf tissue. Based on the biochemical results found and its relationship with the plant's osmotic adjustment, it is possible to notice the influence on the accumulation and allocation of plant biomass.

The accumulation and allocation of biomass is the result of the balance between the incident photosynthetically active radiation and that absorbed by the leaves. Abiotic stresses such as lack of water and salinity can alter the distribution of biomass so that the plant can

survive this condition (Nóbrega et al., 2020). The average conversion efficiency of the absorbed radiation in dry mass and its partition between the light-collecting parts, the leaves, and the rest of the plant to form organs of interest mainly to the fruit (Pereira et al., 2015; Tei et al., 1996).

With regard to the allocation of biomass, according to (Figure 6.) it was possible to notice that the cultivar `Piel de sapo was more efficient in the allocation of photosimilars for the fruit than the cultivar Melon Yellow, which presents greater allocation of leaf, stem and root at the expense of fruit formation and weight.

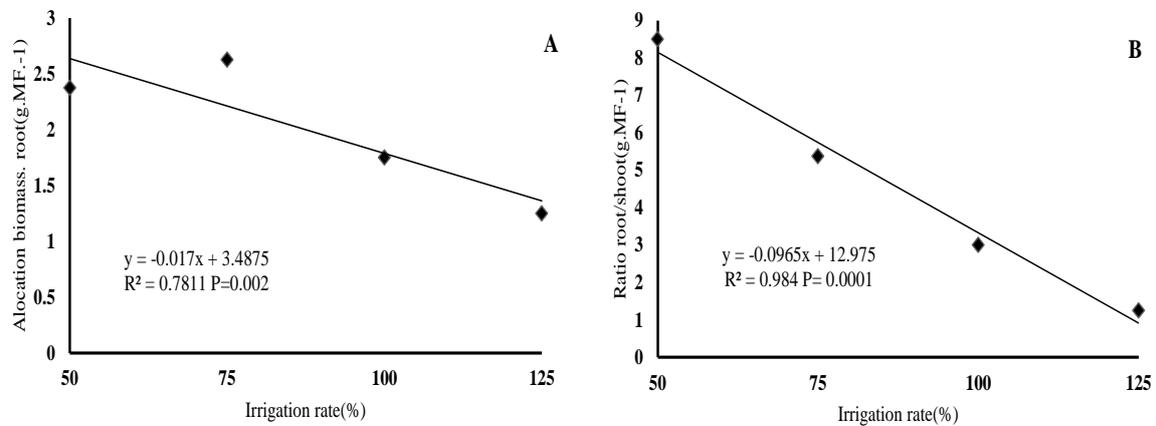
Figure 6. Allocation of biomass fresh (%) of leaves, stem, fruits and roots in Yellow and Piel de sapo cultivars in the second experiment. The values followed by the same letter do not show differences according to the Tukey test $P \leq 0.05$.



Source: Survey data.

The root biomass allocation variables (Figure 7A) and the root / shoot ratio (Figure 7B) showed a significant difference for irrigation rates. The adjustment was due to linear regression and with a tendency to decrease when water availability was increased. These results are consistent, since with less water availability, both cultivars invested in root biomass to obtain greater efficiency in absorbing water and nutrients under water stress conditions and also in order to reduce water loss through the transpiratory process with the reduction of the aerial part in conditions of water deficit.

Figure 7. Allocation of biomass root (A) and Root/ shoot ratio between rates (B) (Crop evapotranspiration: ETC) in the second experiment.



Source: Survey data.

These results are coherent, because with the water limitation the plant seeks to invest its photoassimilates into the root system and in this way the plant survives the water stress conditions so that the formation of flowers and fruits for the perpetuation of the species.

The results of the present study are corroborated by (Poorter et al., 2011) because plants allocate relatively more biomass to the roots if the limiting factor for growth is below the ground (for example, nutrients, water), whereas they allocate relatively more biomass for sprouts if the limiting factor is above the ground (for example, light, CO₂). The "functional" aspect of this response is that it probably increases the growth of the plant, improving the absorption of the most limiting factor.

The ideal partitioning is the one that has functionality and these biomass allocation results together with the osmotic adjustments found under water stress conditions for total soluble sugars, reducing sugars, total proteins and the amino acid Proline found in the cultivar Piel de sapo demonstrates that this genotype is more tolerant to limited conditions of water for having a higher allocation of biomass compared to the other cultivar.

4. Conclusion

The greatest changes in metabolism were observe in the condition of 50% of the melon ETC, a limiting condition for the development of this culture.

The osmotic adjustment of the cultivar Piel de sapo contributed to a greater efficiency in the allocation of photoassimilates for fruit formation, being indicated for limited water conditions.

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