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PHYSIOLOGICAL ASPECTS OF YELLOW PASSION FRUIT WITH USE OF HYDROGEL AND MULCHING[1]

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ABSTRACT - In the Brazilian semi-arid region, water deficit is one of the main factors that compromise the growth and productive yield of crops, including yellow passion fruit, due to the limitation of carbon assimilation by the photosynthetic activity of plants. Therefore, it is necessary to manage the soil with technologies that can reduce the loss of water in the soil and mitigate the effects of water deficit on yellow passion fruit plants cultivated under semi-arid conditions. The objective of this study was to evaluate the application of hydrogel doses and mulching to the soil on the physiological aspects of irrigated yellow passion fruit cultivation. The experiment was carried out in a randomized block design, in a 5 × 2 factorial scheme, referring to five doses of hydrogel (0.0, 0.5, 1.0, 1.5 and 2.0 g dm^{-3} of soil) in soil without and with mulching from signal grass (*Brachiaria decumbens* L.). The variables analyzed were chlorophyll indices, fluorescence (initial, maximum and variable) and gas exchange. The total chlorophyll index was increased with the application of 1.5 g dm^{-3} of hydrogel and the use of mulching; when applying hydrogel doses of 2.0 g dm^{-3} the photosynthetic rate of yellow passion fruit plants increased, whereas their transpiration rate increased with the use of mulching and doses of hydrogel; as a consequence, there was a reduction in water use efficiency.

Keywords: *Passiflora edulis* L.. Gas exchange. Water-retaining polymer. Mulching.

ASPECTOS FISIOLÓGICOS DO MARACUJAZEIRO-AMARELO COM USO DE HIDROGEL E MULCHING

RESUMO - No semiárido brasileiro o déficit hídrico é um dos principais fatores que compromete o crescimento e o rendimento produtivo das culturas, inclusive do maracujazeiro- amarelo, devido à limitação da assimilação de carbono pela atividade fotossintética dos vegetais. Diante disso, faz-se necessário o manejo do solo com tecnologias que possam reduzir a perda de água no solo e que amenize os efeitos do déficit hídrico às plantas de maracujazeiro-amarelo cultivadas em condições de semiaridez. Objetivou-se avaliar a aplicação no solo de doses de hidrogel e mulching sob os aspectos fisiológicos do cultivo de maracujazeiro-amarelo irrigado. O experimento foi desenvolvido em delineamento em blocos casualizados, no esquema fatorial 5 × 2, referente às cinco doses de hidrogel (0,0, 0,5, 1,0, 1,5 e 2,0 g dm^{-3} de solo) no solo sem e com cobertura vegetal oriunda braquiária (*Brachiaria decumbens* L.). As variáveis analisadas foram índices de clorofila, fluorescências (inicial, máxima e variável) e trocas gasosas. O índice de clorofila total foi elevado com a aplicação de 1,5 g dm^{-3} e uso de mulching, ao se aplicar doses de 2,0 g dm^{-3} de hidrogel a taxa fotossintética das plantas de maracujazeiro-amarelo aumentou, já a taxa de transpiração das plantas foi incrementada com o uso de cobertura vegetal e doses de hidrogel, como consequência houve redução na eficiência do uso da água.

Palavras-chave: *Passiflora edulis* L.. Trocas gasosas. Polímero hidrorretentor. Mulch.

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INTRODUCTION

In Brazil, yellow passion fruit (*Passiflora edulis* L.) is one of the most cultivated fruit trees, with a production of 593,429 t in 2019 (IBGE, 2020). The passion fruit crop is important for medium and small farmers, with economic relevance and income generation well distributed throughout the year (FURLANETO et al., 2011; SANTOS et al., 2017). In recent decades, its cultivation has expanded in the semi-arid regions of the Northeast, especially in rural areas of the State of Paraíba (AGUIAR et al., 2017; CAVALCANTE et al., 2018a).

In semi-arid regions, in most years, there is a negative relationship between water evaporation and rainfall, which has caused depletion in photosynthetic efficiency due to atypical changes in gas exchange by plants due to water deficit (GOMES et al., 2012; KALAJI et al., 2016). It should be noted that yellow passion fruit cultivated in the Brazilian semi-arid region under water restriction has low fruit yield as a result of reduced photosynthetic activity (MELO et al., 2014). The initial growth of *Passiflora* spp. is also negatively affected under water deficit, as reported by Souza et al. (2018), who found that reduction in stomatal conductance caused a negative effect on plant growth and biomass accumulation. This makes yellow passion fruit dependent, under these conditions, on irrigation in different phenological stages (CAVALCANTE et al., 2018b).

In this context, increasing water use efficiency through efficient cultural practices and the adoption of new technologies can result in water savings in the agricultural sector (BARAKAT et al., 2015; MONTEIRO NETO et al., 2017). The adoption of a technique, such as the incorporation of water absorbent polymer/hydrogel in the soil, contributes to the increase of water retention in the soil and improves the efficiency of water use by plants, with positive effects on the growth and development of agricultural species (MAZEN; RADWAN; AHMED, 2015; FELIPPE et al., 2016; EL-ASMAR et al., 2017). The hydrogel works to reduce the loss by leaching of nutrients applied via fertilization, mainly nitrogen and potassium (PATTANAAIK et al., 2015), with positive effects on photosynthesis (BEIG et al., 2014; GALES et al., 2016; SANDOVAL et al., 2017), growth (FERNANDES; ARAÚJO; CAMILI, 2015) and productive yield (BARAKAT et al., 2015) of plant species, including fruit trees, using less water in agriculture.

In semi-arid regions, irrigation water can be lost through the evaporation process, especially in cultivated soil without mulching. In this context, the use of mulching close to the root growth area introduces numerous benefits in fruit crops (FREIRE et al., 2014; GOVINDAPPA; PALAVVI; SEENAPPA, 2015), such as water conservation in the soil profile, temperature stability, incorporation of nutrients, suppression of spontaneous plants, reduction of wind and water erosion (BAKSHI et al., 2015), in addition to contributing to the improvement of the efficiency of physiological processes of plants (WANG et al., 2015; ALIABADI et al., 2019).

Therefore, the maintenance of soil moisture with conservation practices, such as the application of hydrogel and mulching, simultaneously, can positively influence the physiological processes of *Passiflora edulis* L. cultivated in the Brazilian semi-arid region. In this context, the objective was to evaluate the application of hydrogel and mulching doses to the soil under the physiological aspects of irrigated yellow passion fruit cultivation.

MATERIAL AND METHODS

The experiment was conducted from September 2016 to June 2018, at Sítio Macaquinhos, located in the municipality of Remígio, Paraíba, Brazil. According to Köppen's classification, the region's climate is of the As' type, which means hot and humid, with rain from March to July (ALVARES et al., 2013). The municipality is georeferenced by the geographic coordinates 7° 00' 1.95" of South latitude, 35° 47' 55" of longitude west of the Greenwich Meridian and altitude of 562 m.

The experimental design used was completely randomized, in a 5 × 2 factorial scheme with three replications, referring to hydrogel doses of 0.0, 0.5, 1.0, 1.5 and 2.0 g dm^{-3} in soil with and with mulching. The yellow passion fruit used in the planting was the cultivar BRS Gigante Amarelo (cv. BRS GA1).

Mulching was carried out with dehydrated signal grass (*Brachiaria decumbens* L.) in a thickness of 8 cm in a circle of 1 m in diameter and 0.78 m^2 in area, considering the plant stem as the center of the hole (FREIRE et al., 2014). Mulching was chemically characterized at the beginning and at the end of the experiment and the results are presented in Table 1.

During the experiment, monthly data of rainfall and evaporation from the Class "A" pan were collected, while the temperature and relative humidity data were obtained from a Datalogger model HT-70 installed in the center of the experiment and are presented in Figure 1. The rainfall values in 2016, 2017 and 2018 were 733, 664 and 698 mm, respectively, concentrated between the months of January and July. The average temperature during the experiment was 25.9 °C, with the highest average of 26.8 °C in 2016; the average relative humidity of the air was 74% with the year 2017 having the highest values (77%), and the average daily evaporation was 5.5 mm.

Table 1. Characterization of chemical attributes of mulching from *Brachiaria decumbens* L., analyzed at the beginning and end of the experiment.

Chemical Attributes	Before	After
N (g kg^{-1})	10.21	16.86
P (g kg^{-1})	2.23	1.22
K (g kg^{-1})	12.72	4.32
Ca (g kg^{-1})	4.11	11.59
Mg (g kg^{-1})	3.02	2.31
S (g kg^{-1})	2.23	1.66
B (mg kg^{-1})	25.46	20.22
Cu (mg kg^{-1})	7.53	9.77
Fe (mg kg^{-1})	138.81	1,212.42
Mn (mg kg^{-1})	46.68	119.34
Zn (mg kg^{-1})	57.02	144.50
Organic carbon (g kg^{-1})	418.54	368.33
C/N	40:1	22:1

N= Nitrogen - N-Kjeldahl by wet digestion; P= Phosphorus – Mehlich 1; K= Potassium - Flame Photometer; Ca= Calcium – Atomic absorption spectrophotometer at a wavelength of 422.7 nm; Mg= Magnesium - Atomic absorption spectrophotometer at a wavelength of 285.2 nm; S= Sulfur - Atomic absorption spectrophotometer at a wavelength of 400.0 nm; B= Boron - UV-VIS spectrophotometer at wavelength of 460 nm; Cu= Copper - Atomic absorption spectrophotometer at a wavelength of 324.7 nm; Fe= Iron - UV-VIS spectrophotometer at wavelength of 508 nm; Mn= Manganese - EAA with air-acetylene flame; Zn= Zinc - EAA with air-acetylene flame; C/N= Carbon/nitrogen ratio.

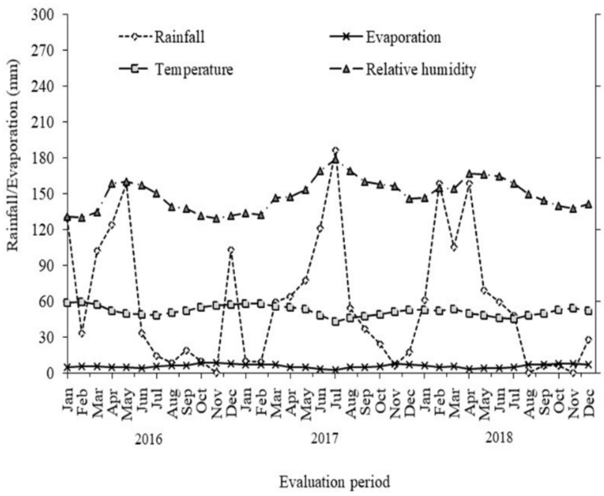

Figure 1. Monthly values of rainfall, evaporation, temperature and air relative humidity in the years the experiment was carried out.

The soil of the experimental area is *Neossolo Regolítico distrófico* (Psamment) (EMBRAPA, 2018) and has, at a depth of 0-0.4 m, the chemical and physical attributes (EMBRAPA, 2017) with the following values: pH in H_2O = 6.20; organic matter = 7.30; P = 13.00 mg dm^{-3}; K^+ = 0.14; Ca^{2+} = 0.78; Mg^{2+} = 0.65; Na^+ = 0.14; Sum of bases = 1.57; H^++Al^{3+} = 1.68; Cation exchange capacity = 3.25 cmolc dm^{-3}; base saturation = 48.31%; Sand = 822; Silt = 81; Clay = 97 g kg^{-1}; Clay dissolved in water = 27 g kg^{-1}; degree of flocculation = 72.16%; Bulk density = 1.40; Particle density = 2.66 g cm^{-3}; Total porosity = 47.76%; Moisture at field capacity = 107.0; moisture at permanent wilting point = 58.0 g kg^{-1}; available water = 49.0 g kg^{-1} and textural class = loamy sand.

The holes were opened with dimensions of 0.40 × 0.40 × 0.40 m, spaced between rows and between plants by 3 m. Of the total volume of soil removed from the holes (64 dm^3), 20 dm^3 from the first 0.2 m were separated to make the mixtures of each dose of water absorbent polymer (Hydroplan®-EB/HyA). It has particle size from 0.3 mm to 1 mm, anionic ionic characteristic, neutral adsorbed water pH, and overall density of 0.8 g cm^{-3}. In addition, it has in its composition copolymer of acrylamide and potassium acrylate, which has an absorption time for 60% equilibrium of 30 min. After homogenization with the soil, the mixture was incorporated into the soil volume of the surface layer, making up 64 dm^3 of each hole.

In the material of the first 0.2 m of soil, 20 dm^3 of cattle manure plus 15 g $hole^{-1}$ of calcitic limestone (CaO = 47%, MgO = 3.4%, RNV = 82%) and 9 g $hole^{-1}$ of agricultural gypsum (CaO = 26%; Moisture = 8%, total P_2O_5 = 0.65%) were incorporated, in order to raise the percentage of saturation by exchangeable bases to 80% (BORGES; SOUZA, 2010). It should be noted that before transplanting, the soil was irrigated for 30 days for the solubilization of the limestone and gypsum mixture. At the end of this period, the phosphorus content of the soil in the holes was increased from 13 to 30 mg dm^{-3} by the incorporation of 27.1 g $hole^{-1}$ of single superphosphate (20% P_2O_5, 20% Ca, 12 % S).

The transplanting of yellow passion fruit seedlings was done on 09/13/2016 when the seedlings had four pairs of fully expanded leaves and height between 23 and 25 cm. The system used to support the plants was a espalier type, with a height of 2.3 m, consisting of a 12 smooth wire installed on top of the stakes (CAVALCANTE et al., 2018b).

From 30 days after transplanting (DAT) the seedlings were fertilized monthly with nitrogen (urea, 45% N) and potassium (potassium chloride, 50% K) in a 1:1 N and K ratio. Fertilization was 5, 10 and 15 g of N and K, respectively, at 60, 90 and 120 DAT and after 120 DAT until the end of harvest in the 2016/2017 season. At 330 DAT, 20 g of N and 20 g of K were applied, totaling, in the period, 170 g of N and K $plant^{-1}$ (equivalent to 380 and 340 g $plant^{-1}$ $year^{-1}$, in the form of urea and potassium chloride).

Top-dressing with phosphorus (12 g $plant^{-1}$ of P_2O_5), every two months, was carried out from 60 DAT, totaling five applications until the end of harvest. Fertilization with NPK in the 2017/2018 season, considering the properly formed root system, followed the doses applied from 120 DAT in the 2016/2017 season.

Drip irrigation was performed with four emitters with a flow rate of 4L h^{-1} and installed at 0.20 and 0.40 m from the plant stem, two on the east side and two on the west side, respectively, providing a volume of water corresponding to 100% of the evapotranspiration requirement (% ETc). The water supply was carried out when the plants showed typical symptoms of water deficit and based on the volumetric soil moisture value obtained in the 0-0.20 m layer with a portable digital soil moisture meter (ECH_2O Check-EC 3212). Irrigation was performed considering the potential crop evapotranspiration (ETc) obtained by the product of ET_0 by the crop coefficient (kc) of 0.64 from initial growth to 58 DAT, 1.13 from crop formation to beginning of flowering (59 at 114 DAT) and 1.25 from flowering to harvest (115 to 150 DAT) (FREIRE et al., 2011).

The evaluations of chlorophyll indexes, chlorophyll fluorescence and gas exchange were carried out between 8:30 am and 11:30 am. The indexes of chlorophyll *a* (Chl*a*), *b* (Chl*b*) and total (Chl*t*) were analyzed before flowering, at 120 DAT, using the electronic chlorophyll meter ClorofiLOG®, CFL 1030 model (FALKER, 2008). The values obtained refer to the product of photodiodes that emit at wavelengths of 635, 660 and 880 nm. In each plant per treatment, three leaves were selected, and readings were taken in the upper, middle and lower parts of each leaf, obtaining an average value (El-HENDAWY; HU; SCHMIDHALTER, 2005).

Using a Modulated Plant Efficiency Analyzer – PEA II® fluorometer (Hansatech Instruments Co., UK) after adaptation of the leaf area to the dark for 30 min (FREIRE et al., 2014), the values of initial fluorescence (F_0), maximum fluorescence (Fm) and variable fluorescence (Fv) were recorded at 120 DAT (MAXWELL; JOHNSON, 2000).

The evaluation of gas exchange occurred during flowering of the plants (120 DAT), with evaluations of stomatal conductance (gs, mol of H_2O m^{-2} s^{-1}), transpiration (E, mmol of H_2O m^{-2} s^{-1}), net photosynthesis (A, μmol m^{-2} s^{-1}) and internal carbon concentration (Ci, μmol m^{-2} s^{-1}). The gas exchange reading was performed using a portable infrared carbon dioxide analyzer (IRGA), LCPro+ Portable Photosynthesis System® model (ADC BioScientific Limited, UK), with temperature adjusted to 25 °C, irradiation of 1,800 μmol photons m^{-2} s^{-1} and air flow 200 mL min^{-1}. The data obtained was used to calculate the water use efficiency (WUE), by relating net photosynthesis to transpiration (A/E) [(μmol m^{-2} s^{-1}) / (mmol H_2O m^{-2} s^{-1})], and the instantaneous efficiency of carboxylation (ECi) [(μmol m^{-2} s^{-1}) / (μmol m^{-2} s^{-1})], by relating the net photosynthesis (A) to the internal carbon concentration (Ci).

The data recorded were subjected to analysis of variance using regression analysis for hydrogel doses and the qualitative factor mulching was compared by the F test (*P*<0.01 and 0.05) using the R software (R CORE TEAM, 2017).

RESULTS AND DISCUSSION

The interaction between hydrogel doses and mulching influenced (*P*<0.05) the chlorophyll b index and leaf fluorescence of yellow passion fruit (Table 2). The hydrogel also interfered with chlorophyll *a*, chlorophyll *b* and total chlorophyll. The influence of the hydrogel × mulching interaction on the physiological parameters of plants is still scarce in scientific reports. However, there is information on the isolated effect of hydrogel and mulching on chlorophyll content and activity in lettuce - *Lactuca sativa* (BEIG et al., 2014), eucalyptus - *Eucalyptus benthamii* (FELIPPE et al., 2016), corn - *Zea mays* and soy - *Glycine max* (GALES et al., 2016); and on the leaf chlorophyll of tomato (*Lycopersicon esculentum* Mill.) in soil with mulching (ALIABADI et al., 2019).

Table 2. Summary of analysis of variance, by mean square, referring to chlorophyll indices and leaf fluorescence in yellow passion fruit plants irrigated in the soil with hydrogel (H) and mulching (M).

SV	DF	Mean square					
		Chl_a	Chl_b	Chl_t	F_0	F_m	F_v
Hydrogel (H)	4	2029**	12.763**	4.759**	34.28*	1.866	1.470**
Mulching (M)	1	60.7^{ns}	115.87^{ns}	344^{ns}	16.88^{ns}	1.062*	811**
H × M	4	159.0^{ns}	205.4**	145^{ns}	82.96**	7.152**	7.440**
Residual	20	204.8	54.2	232	8.48	151	145
Total	29						
CV (%)		3.56	3.88	2.83	2.17	2.01	2.51

SV = Source of variation; DF= Degree of freedom; CV = Coefficient of variation; ^{ns}= not significant; * significant at 5% probability; **= significant at 1% probability.

The chlorophyll *a* index was linearly increased in the leaves of yellow passion fruit with the increment of the hydrogel doses (Figure 2A), reaching the value of 422.6 at the dose of 2.0 g dm^{-3}. While the total chlorophyll index was increased to a value of 559.5 at the 1.48 g dm^{-3} hydrogel dose, higher doses reduced the leaf ChltI value in yellow passion fruit (Figure 2C).

The addition of hydrogel to the soil reduces the loss of water (GALES et al., 2016) and nutrients by leaching, mainly nitrogen, which due to the greater availability of water (PATTANAAIK et al., 2015; MONTEIRO NETO et al., 2017) contributes to mineralization of cattle manure and retention of N from nitrogen fertilization (a structural element of chlorophyll). The water retention promoted by the polymer also contributes to a greater amount of nitrogen in the form of nitrate in the soil solution, which is more easily absorbed by plants (FELIPPE et al., 2016).

Chlorophyll *b* indexes in yellow passion fruit (Figure 2B) were increased up to the estimated maximum doses of 1.23 g dm^{-3} (144.7) in soil without mulching and 1.15 g dm^{-3} (152.4) in soil with mulching. Mulching promoted an increase in chlorophyll *b* due to the benefits to the soil and the plant, especially in the hottest times of the year, reducing water loss through evaporation (FREIRE et al., 2014; ALIABADI et al., 2019) and providing nutrients during decomposition of signal grass (Table 1), such as nitrogen and magnesium.

The leaf chlorophyll indexes observed in yellow passion fruit (Figure 2) corroborate those obtained in the literature. For example, in yellow passion fruit inoculated with different species of mycorrhizae, Oliveira et al. (2019) observed values ranging from 30 to 34 for chlorophyll *a* from 9 to 13 for chlorophyll *b*, and from 40 to 47 for total chlorophyll.

The initial fluorescence responded differently to the application of mulching with increasing doses of polymer (Figure 3A). In soil without mulching, the F_0 of yellow passion fruit plants was increased from 131.1 to 139.5 electrons quantum^{-1} between the lowest and highest dose of hydrogel. On the other hand, in soil with mulching, increasing the dose from 0 to 2.0 g dm^{-3} of hydrogel reduced the F_0 in yellow passion fruit leaves from 140.7 to 130.6 electrons quantum^{-1}.

The maximum and variable fluorescence responded in a similar way to the application of the sources of variation, with higher values in the treatments that had mulching (Figures 3B and 3C). In treatments without mulching, maximum and variable fluorescence decreased up to doses of 1.30 and 1.35 g dm^{-3} of the polymer. In soil with mulching, Fm and Fv were increased up to doses of 1.3 g dm^{-3} of hydrogel, with respective values of 644 and 511 electrons quantum^{-1}. Mulching with crop residues reduces water loss through evaporation, preserving soil water maintenance (BAKSHI et al., 2015). In this context, with adequate soil water content, there was an increase in the cellular capacity to transport electrons and dissipate excess energy by chlorophyll, verified by the fluorescence values. It is noteworthy that this recorded fact is important because it is a protection mechanism of the photosystem II of plants against extreme environmental conditions (GOMES et al., 2012; WANG et al., 2015; KALAJI et al., 2016).

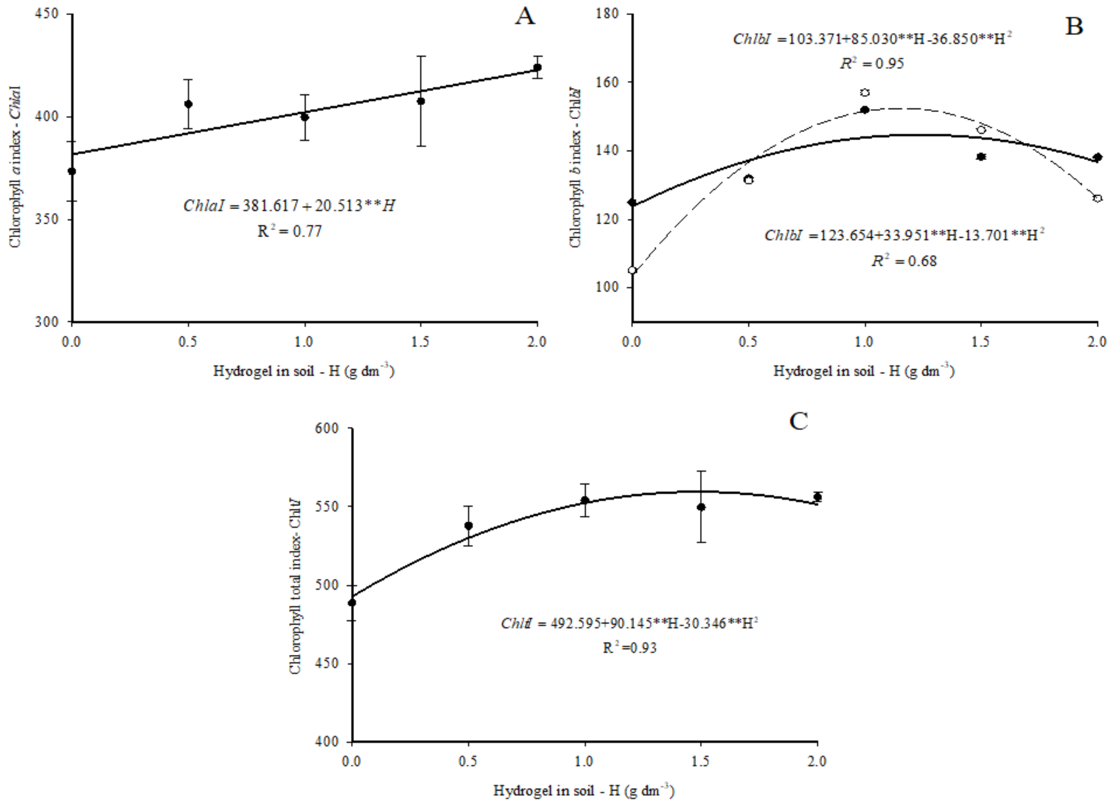

Figure 2. Leaf indices in yellow passion fruit of chlorophyll *a* in soil with doses of hydrogel (A), chlorophyll *b* in soil without (—) and with (- - -) mulching and doses of hydrogel (B) and total chlorophyll (C) in soil.

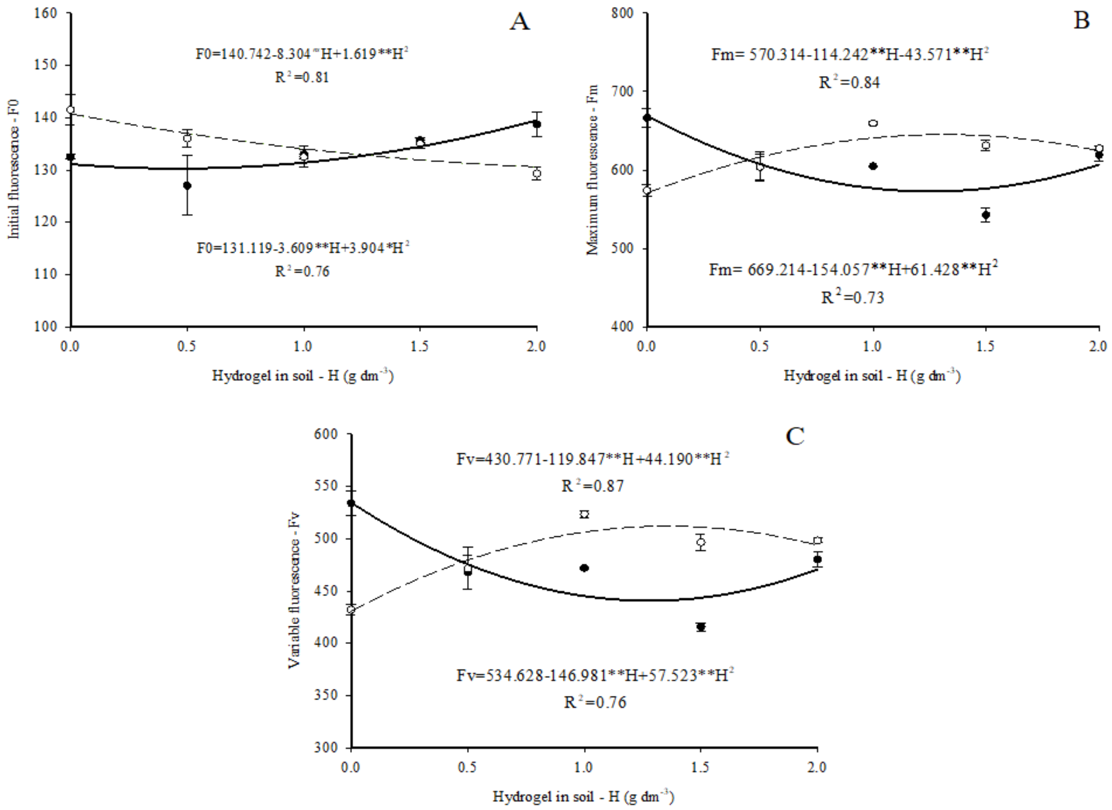

Figure 3. Initial fluorescence (A), maximum fluorescence (B) and variable fluorescence (C) of chlorophyll *a* in leaves of yellow passion fruit cultivated in soil without (—) and with (- - -) mulching and hydrogel.

As seen in Table 3, the interaction between the hydrogel and mulching influenced the gas exchange in yellow passion fruit. There are reports in the literature on the response to polymer or mulching applied alone in other agricultural crops under irrigation or water deficit (BARAKAT et al., 2015; GOVINDAPPA; PALAVVI; SEENAPPA, 2015; MAZEN; RADWAN; AHMED, 2015). Mulching increases the photosynthetic efficiency of yellow passion fruit irrigated with non-saline water under organic fertilization (FREIRE et al., 2014). Under conditions of low water availability, Aliabadi et al. (2019) observed that mulching contributed positively to the physiological aspects of tomato (*Lycopersicon esculentum* Mill.). Similar behavior was verified for the hydrogel (FELIPPE et al., 2016), which caused beneficial effects on the gas exchange of *Eucalyptus benthamii* seedlings.

Despite the reductions in the stomatal conductance of yellow passion fruit with application of the polymer up to a dose of 0.89 g dm^{-3} in soil without mulching and 0.96 g dm^{-3} in soil with mulching, the highest values of gs were found in plants cultivated in the soil with 2.0 g dm^{-3} of the water-retaining polymer (Figure 4A). When comparing the values of yellow passion fruit cultivated in the soil with the lowest and highest dose of hydrogel, the gs increased from 0.11 to 0.12 mmol m^2 s^{-1} in the treatment without mulching and from 0.12 to 0.13 mmol m^2 s^{-1} in the treatment with mulching. The simultaneous use of these techniques allowed less water loss by evaporation, through the use of mulching (BAKSHI et al., 2015), and greater water retention, through the application of the polymer, which slowly makes it available to plants under water deficit conditions in the soil (FELIPPE et al., al., 2016; MONTEIRO NETO et al., 2017), with no stomatal limitation in yellow passion fruit.

Table 3. Summary of analysis of variance, by mean square, of gas exchange in yellow passion fruit plants cultivated in soil with hydrogel (H) and mulching (M).

SV	DF	Mean square				
		A	Ci	E	g_s	A/E
Hydrogel (H)	4	2.0698**	478.1**	3.344**	0.0019583**	0.8059**
Mulching (M)	1	1.6287*	81.9^{ns}	0.654*	0.0000300^{ns}	0.0375^{ns}
H × M	4	1.7613**	461.3**	2.622**	0.0008050**	1.4451**
Residual	20	0.3215	54.2	0.127	0.0001033	0.0146
Total	29	-	-	-	-	-
CV(%)		6.02	3.31	9.50	8.84	7.22

SV = Source of variation; DF= Degree of freedom; CV = Coefficient of variation; ns= not significant; * significant at 5% probability; **= significant at 1% probability.

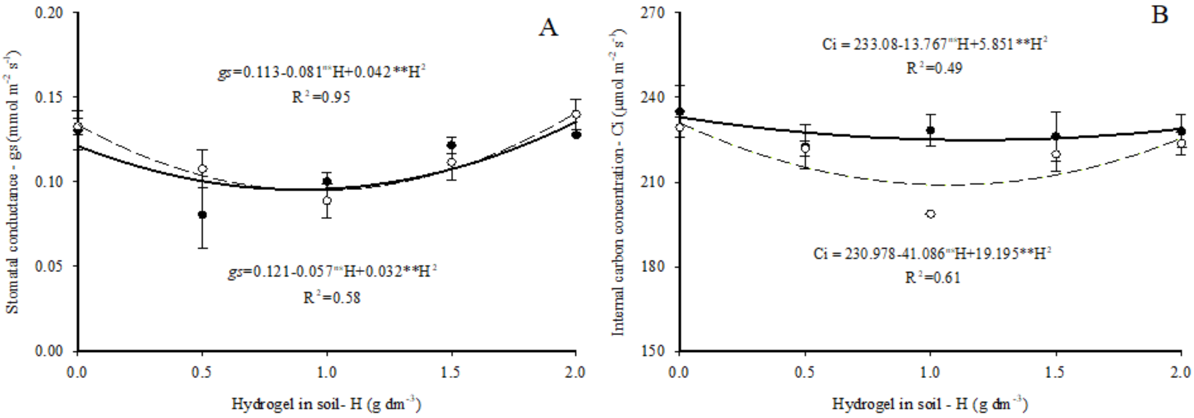

Figure 4. Stomatal conductance (A) and internal carbon concentration (B) in leaves of yellow passion fruit cultivated in soil without (─) and with (---) mulching and doses of hydrogel.

The internal carbon concentration in the leaves of yellow passion fruit cultivated in soil without mulching varied little with increasing doses of the water-retaining polymer (Figure 4B) and showed, among the doses of hydrogel applied, the mean value of 228.03 µmol m^2 s^{-1}. In soil with mulching, the Ci of leaf carbon dioxide in yellow passion fruit reached the highest value of 230.1 µmol m^2 s^{-1} in the absence of polymer and decreased up to a dose of 1.07 g. When comparing the mean values in the soil without mulching (228.03 µmol m^2 s^{-1}) and with mulching (218.68 µmol m^2 s^{-1}), it was verified that the mulching reduced by 4.1% the internal carbon concentration in the leaves of yellow passion fruit. These results corroborate those of Freire et al. (2014), who concluded that the application of mulching reduces by 4.4% the internal concentration of CO_2 in irrigated yellow passion fruit in the State of Paraíba, Brazil.

The greater internal concentration of CO_2 is linked to the greater or lesser degree of stomatal opening in the plants and the efficiency of carbon utilization by them. Although there was no difference in the gs of plants in the soil without and with mulching (Figure 4A), those that grew in the soil without this practice were more effective in influencing carbon dioxide. Plants under adverse conditions (water stress) tend to acclimate, combining more efficient stomatal control with high levels of internal carbon concentrations (SAUSEN; ROSA, 2010; SOUZA et al., 2018), as occurred in yellow passion fruit (Figure 4A and 4B).

The net photosynthesis of yellow passion fruit was linearly increased with increasing doses of hydrogel, mainly in the soil with mulching (Figure 5A). Increasing the dose of hydrogel from 0.0 to 2.0 g dm^{-3} increased photosynthesis in soil without and with mulching from 7.99 and 8.38 to 10.38 CO_2 m^2 s^{-1}, respectively. The hydrogel contributes to maintaining soil moisture after irrigation, which increases the amount of water absorbed by the plants, which will be used during the photosynthetic process (SANDOVAL et al., 2017). A similar trend was verified by Felippe et al. (2016), with increases in net photosynthesis in *Eucalyptus benthamii* seedlings after irrigation on the substrate with hydrogel.

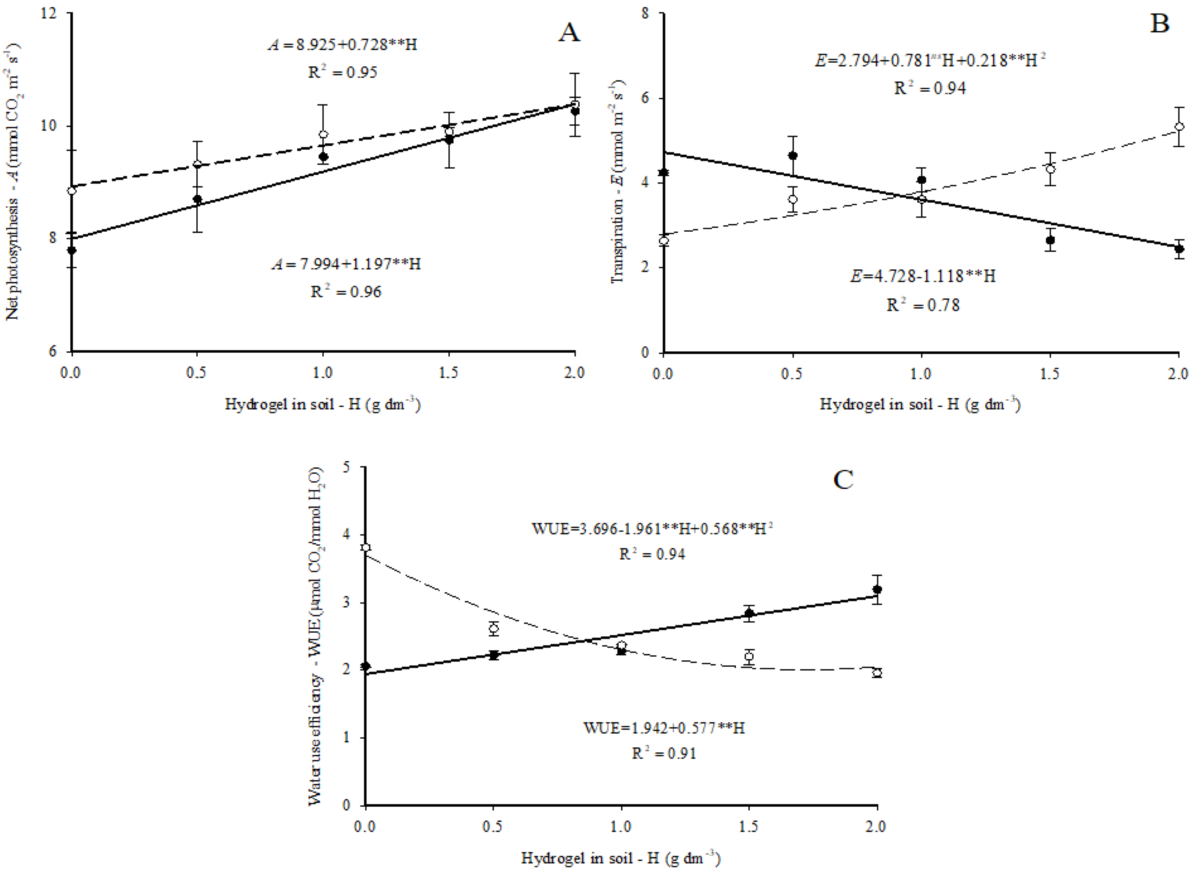

Figure 5. Net photosynthesis (A), transpiration (B) and water use efficiency (C) in leaves of yellow passion fruit cultivated in soil without (─) and with (- - -) mulching and doses of hydrogel.

When comparing the data of soil without the water-retaining polymer, there was a positive effect of mulching, since its application on the soil surface where the roots grow promotes a 5% increase in the photosynthetic rate of yellow passion fruit. The effect of mulching in maintaining soil moisture, making the soil (BAKSHI et al., 2015; GOVINDAPPA; PALAVVI; SEENAPPA, 2015), improves the photosynthetic efficiency of plants, as found by Wang et al. (2015) in the improvement of photosynthesis of peach tree (*Prunus persica* L.) within the range of 10.7 to 16.5% using this technique.

The transpiration of yellow passion fruit plants responded differently as the doses of the hydrogel polymer were increased under conditions of soil without and with mulching (Figure 5B). In soil without mulching, the transpiration rate decreases linearly in the proportion of 1.118 mmol m^2 s^{-1} per unit increment of the hydrogel. In turn, the transpiration of plants grown in soil with mulching was increased from 2.794 to 5.228 mmol m^2 s^{-1} when comparing the doses of 0.0 with 2.0 g of hydrogel dm^{-3} of soil. Similar behavior was observed by Freire et al. (2014) in yellow passion fruit fertilized with bovine biofertilizer, where mulching in the soil increased the transpiration rate by 51.7%.

The behavior of the photosynthetic rate (Figure 5A) and transpiration rate (Figure 5B) also interfered in an antagonistic way in the water use efficiency (Figure 5C) of yellow passion fruit in soil without and with mulching, due to the increase of the doses of hydrogel. In the soil without mulching, the WUE was increased from 1.942 to 3.096 μmol CO_2/ mmol H_2O, with an increase of 59.4% between the doses of 0.0 and 2.0 g dm^{-3} of hydrogel. On the other hand, in soil with mulching, the water use efficiency was reduced by 44.6% between the lowest and highest doses of the water-retaining polymer.

The increase in transpiration (Figure 5B) and reduction in water use efficiency (Figure 5C) in yellow passion fruit cultivated in soil with mulching are not in agreement with those presented by Aliabadi et al. (2019). The authors observed that tomato plants irrigated and cultivated in the soil under mulching had a low transpiration rate, which resulted in greater water use efficiency, with increments of 97.9% with mulching from wheat (*Triticum* spp.) straw. Probably, the adequate soil moisture content promoted by the use of hydrogel and mulching did not limit the physiological processes of yellow passion fruit, with no restrictions on photosynthesis and transpiration. Under conditions of low soil moisture, plants tend to combine an increase in the photosynthetic rate with low water losses by transpiration (acclimatization), which results in an improvement in water use efficiency (FELIPPE et al., 2016).

CONCLUSIONS

Application of 1.5 g dm^{-3} of hydrogel and mulching in the soil increase the chlorophyll index and activity of irrigated yellow passion fruit.

Increasing the doses of the water-retaining polymer up to 2.0 g dm^{-3} of soil increases the photosynthetic rate of yellow passion fruit cv. BRS GA1 in soil with mulching; however, due to the benefits of the cultural practice in keeping the soil wetter and less warm, the plants did not restrict transpiration, which reduced their water use efficiency.

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