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DIFFERENT SUBSTRATES AND IRRIGATION DEPTHS ON PRODUCTION COMPONENTS OF THE 'BIQUINHO' PEPPER*

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1 ABSTRACT

This work had as a primary objective to evaluate the production response and water use efficiency by 'biquinho' pepper cultivated with different substrates and irrigation depths. The experiment was conducted in a greenhouse located at the Alegrete campus of the Federal University of Pampa. We performed an entirely randomized 2 x 5 two-factor experimental design (two substrate compositions and five irrigation depths). The substrate composition treatments used were a commercial substrate and a mixture of commercial substrate + carbonized rice husk. The treatments for the water replacement depths were 25, 50, 75, 100, and 125% of the water-holding capacity for each substrate. We assessed the following components at the end of the cycle: production, water use efficiency, and fruit diameter, length, average weight, and number. The yield and water use efficiency components were more when using the commercial substrate + carbonized rice husk composition. The maximum technical production efficiency was obtained for an irrigation depth of 101.7% of the water-holding capacity. However, water use efficiency was higher when using an irrigation depth of 69.17%.

Keywords: *Capsicum chinense*; carbonized rice husk; water use efficiency.

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DIFERENTES SUBSTRATOS E LÂMINAS DE IRRIGAÇÃO SOBRE OS COMPONENTES DE PRODUÇÃO DA PIMENTA BIQUINHO

2 RESUMO

O presente trabalho teve como objetivo principal avaliar a resposta de produção e eficiência do uso da água pela pimenta biquinho cultivada com diferentes substratos e lâminas de irrigação. O experimento foi conduzido em casa de vegetação localizada na Universidade Federal do Pampa – *Campus* Alegrete. O delineamento experimental foi inteiramente casualizado composto de um bifatorial 2 x 5 (duas composições de substratos e cinco lâminas de irrigação).

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Os tratamentos de composição dos substratos utilizados foram um substrato comercial e uma mistura de substrato comercial + casca de arroz carbonizada. Os tratamentos para as lâminas de reposição hídrica foram: 25, 50, 75, 100 e 125% da capacidade de retenção de água para cada substrato. Ao final do ciclo, avaliaram-se os componentes: produção, eficiência do uso da água e diâmetro, comprimento, peso médio e número de frutos. Os componentes de rendimento e a eficiência do uso da água foram maiores quando utilizada a composição de substrato comercial + casca de arroz carbonizada. A máxima eficiência técnica de produção foi obtida para uma lâmina de irrigação de 101,7% da capacidade de retenção de água. Por outro lado, a eficiência do uso da água foi maior quando utilizada uma lâmina de irrigação de 69,17%.

Palavras-chave: *Capsicum chinense*; casca de arroz carbonizada; eficiência do uso da água.

3 INTRODUCTION

Rio Grande do Sul is one of the major peppers (*Capsicum spp.*) producing states of Brazil (PINHEIRO; AMARO; PEREIRA, 2011). Several varieties are produced in the Southern of Brazil with the highest production in the state, the main varieties produced in Rio Grande do Sul state are 'dedo-de-moça' pepper (*C. baccatum*), chili pepper (*C. frutescens*), 'biquinho' pepper (*C. chinense*), 'cumari' pepper (*C. chinense*), cayenne (*C. annuum)* and jalapeño (*C. annuum*) (NEITZKE, 2012).

The 'biquinho' pepper (*Capsicum chinense*) stands out for aggregating high commercial value depending on the commercialization region, is a profitable alternative for small properties, and much appreciated both pickled and fresh due to its main characteristic: the absence of pungency, which makes its fruit sweet (HEINRICH et al., 2015).

The climate conditions, mainly the temperature, nutrient input, and adequate irrigation management are factors that directly influence the production of 'biquinho' pepper. The crop output from crops cultivated in greenhouses may be more substantial compared to those cultivated in the field, and may present superior quality (PURQUERIO; TIVELLI, 2006; RODRIGUES et al., 2007; ROUPHAEL et al., 2018). Substrate cultivation offers advantages for better crop development compared to soil cultivation, such as reduced root salinization, decrease in the occurrence of phytosanitary issues, and a more proper nutrition and irrigation management (ANDRIOLO, 1999; GIRARDI et al., 2012; ASADUZZAMAN et al., 2015).

The substrate must present ideal conditions for crop growth which primarily depend on physical characteristics, such as proper aeration and water retention. The heavy use of commercial substrates that employ mixtures of materials aiming to obtain these features is common, materials stemming from industrial waste is an example of waste reuse in substrate mixtures (BELLÉ; KÄMPF, 1994; SIMÕES et al., 2015). This is the case of the carbonized rice husk, which is used as raw material to generate energy, and as a substrate, is easy to acquire, has a low cost for the producer, and is already established as a great conditioner of soils and substrates.

Simões et al. (2015) reported that the use of carbonized rice husk as a substrate conditioner is a feasible alternative for producing organic lettuce seedlings. However, some authors have found satisfactory production results of gypsophila and strawberry cultivars when using only carbonized rice husk as a pure substrate (GIRARDI et al., 2012; COSTA et al., 2016).

In this context, irrigation is also one of the most limiting factors for plant growth and development since both water deficiency and excess may affect such processes. Water stress may hamper the final pepper fruit production during the flowering process, causing flowers and new fruits to fall, and prevent flowers from being fertilized (MARINHO et al., 2016).

When studying the yield of the habanero pepper cultivar for different irrigation depths (60, 50, 40, 30, and 20% of the substrate capacity) cultivated in a greenhouse, Quintal-Ortiz et al. (2012) found that the crop productivity decreased with the reduction of the irrigation depth. Assessing two pepper plants of the *Capsicum* genus (chili pepper and red pepper), Barroca et al. (2015) concluded that the water deficit altered the production and average mass of fruits for both cultivars.

When the water supply and irrigation equipment are suitable, producers tend to irrigate above the crop water needs, believing that applying more water will increase crop yield (AKINBILE; YUSOFF, 2011). This occurs due to a lack of technical knowledge and often because of difficult access to information regarding proper irrigation management.

Recent studies with ‘biquinho’ pepper (VALERA, 2017; DIEL et al., 2020) were developed in the South region of Brazil, but there is still a lack of research involving the use of substrates and adequate irrigation management in this crop production. The use of carbonized rice husk as a substrate becomes an alternative since it is the main residue generated by the large rice production in the Rio Grande do Sul state. Thus, this work evaluated the influence of substrates and irrigation depths on production components, maximum technical production efficiency and water use efficiency for ‘biquinho’ pepper production in the Rio Grande do Sul.

4 MATERIAL AND METHODS

The experiment was conducted in a greenhouse located at the experimental area of the Agricultural Engineering course of the Federal University of Pampa, Alegrete campus, Rio Grande do Sul state, Brazil (29°47'24.1"S, 55°46'06.7"W), in the period from October 25th, 2016 to April 2nd, 2017.

The crop used was the ‘biquinho’ pepper (BRS Moema), seeded in styrofoam trays with 128 cells and transplanted to vases 2.6 liters when they presented at least six definitive leaves.

The experiment was an entirely randomized 2 x 5 two-factor design, with three replications. The first factor was two substrate treatments (S1 - commercial substrate by Mecplant®; and S2 - commercial substrate by Mecplant® + carbonized rice husk, at a proportion of 1:1). An analysis of the physical characteristics of the substrate was performed at the Biotechnology Laboratory - Analysis of Horticultural Substrates, belonging to the Department of Horticulture and Forestry of the Federal University of Rio Grande do Sul (Table 1).

Table 1. Chemical and physical analysis of substrates S1 (commercial substrate) and S2 (commercial substrate + carbonized rice husk)

Sample	S1	S2
pH (H_2O)	5.61	5.81
EC (mS cm^{-1})	0.73	0.60
MD (kg m^{-3})	627.67	403.7
DD (kg m^{-3})	271.23	232.75
CM (%)	56.79	42.35
TP (%)	88.81	81.69
AS (%)	39.59	45.72
EAW (%)	11.38	11.95
BW (%)	0.95	0.23
RW (%)	36.88	23.79
WHC 10 (%)	49.22	35.97
WHC 50 (%)	37.84	24.02
WHC 100 (%)	36.88	23.79

MD = moist density; DD = dry density; CM = current moisture; pH = determined in water, 1:5 dilution (v/v); EC = electrical conductivity obtained for a 1:5 solution (v/v); TP = total porosity; AS = aeration space; EAW = easily available water; BW = buffering water; AW = available water; RW = remaining water. WHC10 = water holding capacity under the suction of a 10 cm water column; WHC50 = water holding capacity under the suction of a 50 cm water column; WHC100 = water holding capacity under the suction of a 100 cm water column.

The second factor corresponded to five water replacement depths based on the water-holding capacity (WHC), according to the methodology applied by Kämpf (2006), with the substrate plus water being retained after 24 hours being 1750 and 1510 g for S1 and S2, respectively. Irrigation depths were then calculated from these data for each treatment (D1 - 25%, D2 - 50%, D3 - 75%, D4 - 100%, and D5 - 125% of the WHC).

The water-holding capacity variation was determined by weighing all vases in two-day intervals. We used the water balance equation (Equation 1) to calculate the water consumption of the crop:

$$Etc = M_i - Mf + I - D \quad (1)$$

Where: Etc is the evapotranspiration of the in the vase plant, at one interval of two days; M_i is the mass of the substrate and water in the vase at the beginning of the time interval considered; M_f is the mass of the substrate and water remaining at the end of the considered time interval; I is irrigation applied to the vase in the time interval; and D is the percolation (or draining) that may occur. The values of rain precipitation and surface runoff were zeroed in the greenhouse environment.

At the end of the crop cycle, we evaluated the number of fruits per plant, the diameter, length, average mass, and production (g $plant^{-1}$) of fruits, and the water use efficiency (WUE). Fruit diameters and lengths were measured using a digital caliper, while the average fruit mass was obtained through the ratio between the total mass and number of fruits, and WUE was calculated as per Equation 2:

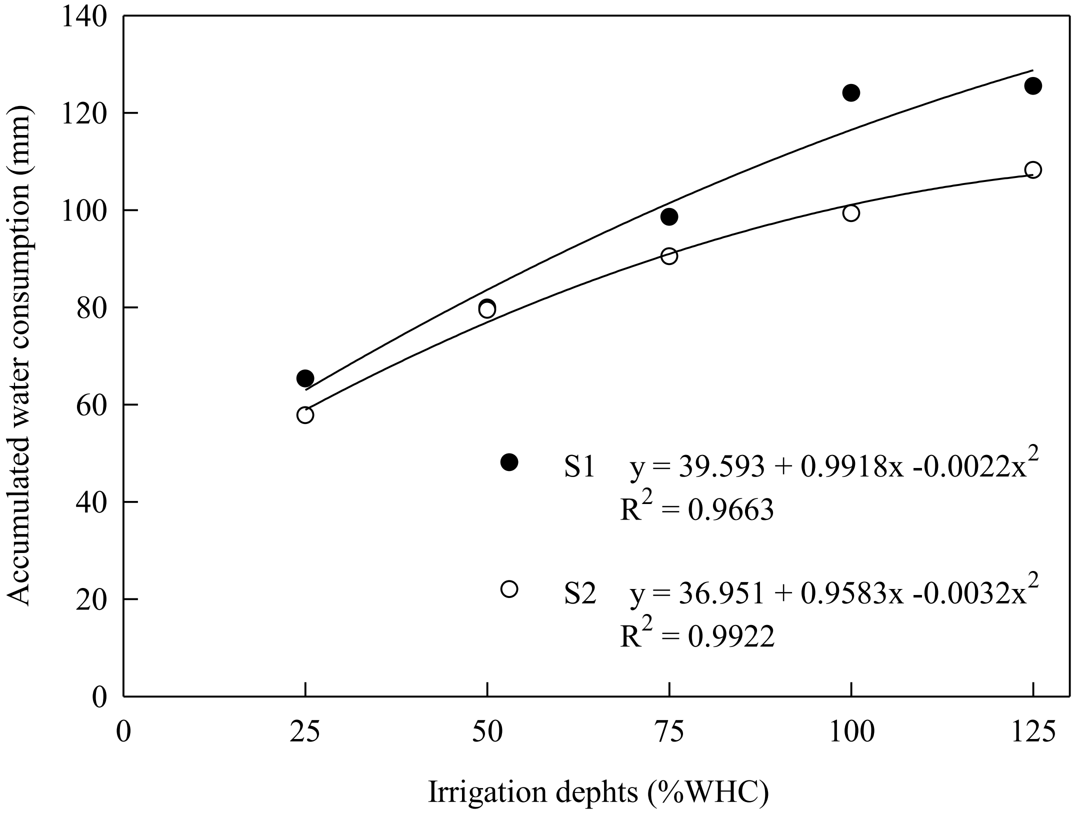
$$WUE = \frac{fruit\ production\ (kg)}{total\ water\ consumption\ (m^3)} \quad (2)$$

Statistical analysis was performed using analysis of variance at a 5% probability of error. As the factors (S x D) were quanti-qualitative, regression analysis was performed when there was interaction, while regression was performed for the quantitative data and comparison of means for qualitative data in the case of no interaction.

5 RESULTS AND DISCUSSION

The accumulated water consumption data (mm) are provided in Figure 1, where it can be observed that there was an interaction between the irrigation depths and the substrates. When splitting the substrates for each irrigation level, a significant difference has observed between the two substrates, except for the 50% irrigation depth of the WHC. S1 presented a higher accumulated water consumption than S2, and this consumption difference between the factors may be explained by the physical characteristics of the substrates (Table 1). In practice, this fact may be proven since S2 presented more drainage during the irrigation at depths of 100% and 125% WHC. This characteristic demonstrates that the commercial substrate has a higher micropore percentage, thus being able to hold more water.

Figure 1. Accumulated water consumption (mm) according to the water holding capacity (% WHC) for treatments S1 and S2

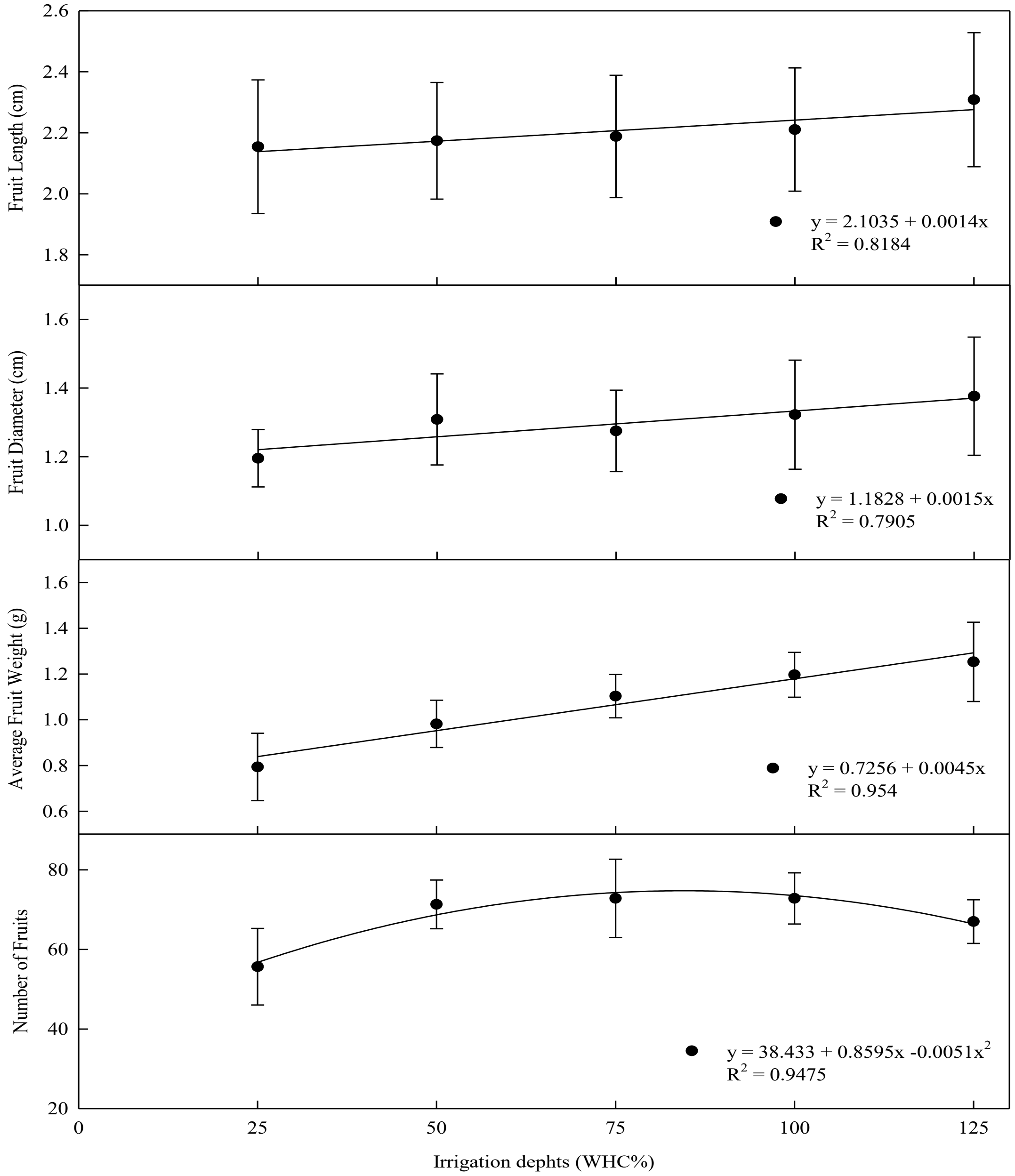


When studying the water consumption of the kalanchoe crop cultivated in containers adopting the same irrigation management of this work and assessing different substrate compositions, Souza et al. (2010) observed that the composition with carbonized rice husk + organic matter presented the smallest water consumption among the treatments, differing statistically from others, and thus agreeing with the present results, which showed a lower water consumption for the substrate combined with carbonized rice husk.

Similar results were observed by Soares et al. (2012) when evaluating the water consumption of vase Asian lily for different substrate compositions by weighing the containers daily. The authors observed a more significant water consumption for the mixture of coconut fiber + rice husk ash, and lower consumption for carbonized rice husk and carbonized rice husk + 'Terra does Paraíso'; however, the carbonized rice husk presented more irrigation frequency.

There was no interaction between the substrate and irrigation depth factors for the yield components of fruit length (cm), diameter (cm), average weight (g), and the number of fruits per plant. The average data for these parameters according to the irrigation depths may be observed in Figure 2.

Figure 2. Influence of the water replacement depths according to the yield parameters of the 'biquinho' pepper



The data for the fruit length and diameter variables presented a statistically significant difference among the irrigation depths and showed a linear behavior, with treatment D5 (125% WHC) having the highest values for both evaluations: 2.3 and 1.37 cm, respectively. S1 and S2 showed a significant difference only for fruit diameter, with values of 1.28 and 1.32 cm, respectively.

The values are considered as standard according to Carvalho et al. (2014) for the ‘biquinho’ pepper are of approximately 1.5 to 2.0 cm of fruit length and 1.5 cm of diameter. However, according to Ribeiro and Reifschneider (2008), the fruit length varies between 2.5 and 2.8 cm. All data observed for the average fruit diameter values were below 1.5 cm (Figure 2).

Only irrigation depths differed statistically for the average weight values observed. This parameter presented a linear behavior with the highest value for D5 (1.25 g) (i.e. the higher the water increment in the substrate, the more significant the fruit mass). All treatments presented average data below 1.5 grams, which is the average fruit weight considered for the cultivar (CARVALHO et al., 2014).

We only observed a statistically significant difference for the irrigation depths for the number of fruits per plant variable. The highest value found was for depths D5 and D4, which obtained the same average value (72.83).

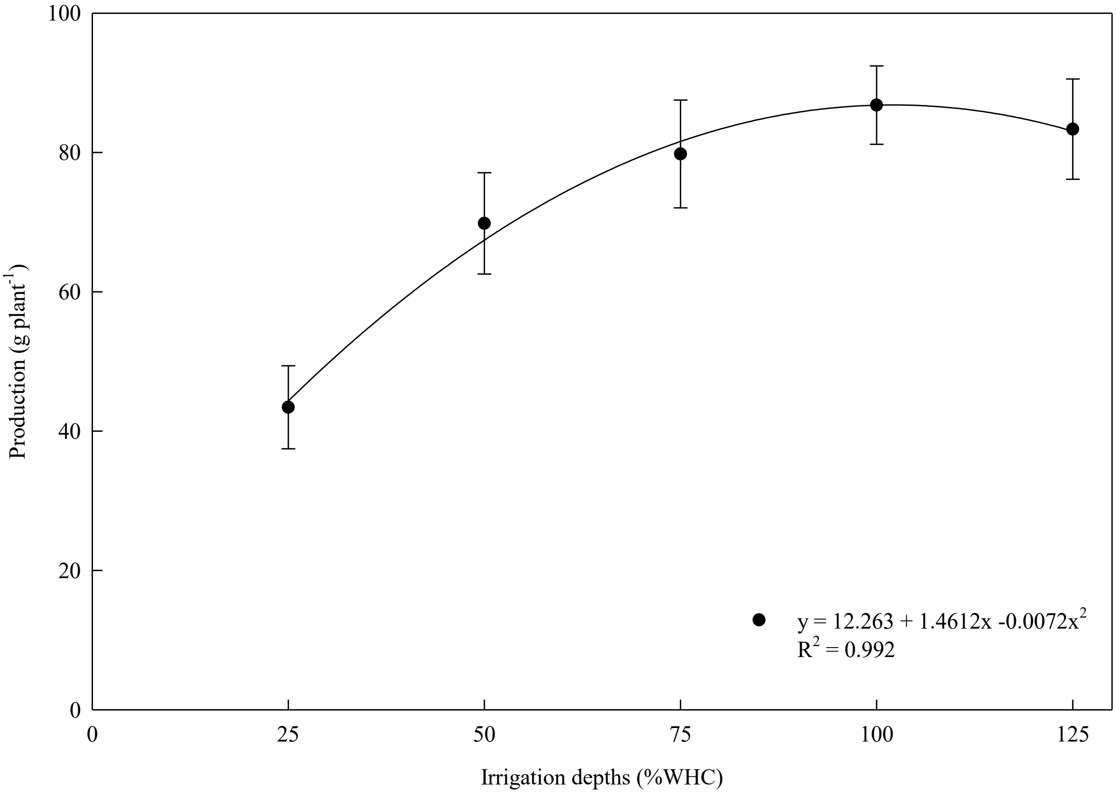
Evaluating the bell pepper crop (*Capsicum annuum*) under different irrigation depths (Class A evaporation pan method, CAE) and nitrogen doses, Aragão et al. (2012) observed that the most considerable fruit length and diameter were found in the treatment that did not receive nitrogen doses in which was applied the lowest depths (50 and 75% of the CAE), unlike this work, which obtained higher values for the largest depth.

On the other hand, Barroca *et al*. (2015) evaluated red pepper and chili pepper under different irrigation depths (40, 70, 100, 130, and 160% of the reference evapotranspiration) in an experiment conducted in the field, and found that the highest values for the length, diameter, and average weight of the fruits were observed in the depth of 130% of the reference evapotranspiration, regardless of the variety. According to these authors, the water deficiency reduced the length, diameter, and average weight of the fruits, which confirms the results of the present study, given that the values of such variables raised along the increase of the water replacement depths.

When working with *Capsicum annuum* pepper plants with irrigation depths of 50, 75, and 100% CAE, Sezen et al. (2011) observed that the most significant fruit lengths and diameters were also found for the largest irrigation depth (100%).

Figure 3 presents the production results of the ‘biquinho’ pepper (g plant^{-1}) for different water replacement depths, in which there was no interaction between the factors: substrate and irrigation depths. However, there was a significant difference between the irrigation depths and substrates, separately.

Figure 3. Influence of the different irrigation depths on production (g plant^{-1}) of the 'biquinho' pepper



The maximum technical efficiency for factor D (irrigation depths) was estimated for the irrigation depth of 101.47% WHC, with a production of 86.39 g plant^{-1}. The S1 treatment showed an average value of 68.18 g plant^{-1}, while S2 presented 77.16 g plant^{-1}, constituting the highest result for production.

The productivity of pepper plants from the *Capsicum* genus varies from 10 to 30 t ha^{-1} (RIBEIRO; REIFSCHNEIDER, 2008). By transforming the production data into productivity data based on the spacing in which the vases were exposed in the greenhouse (25 plants m^{-2}), we obtained a maximum productivity of 21.6 t ha^{-1}, while the average productivity value for S2 was of 19.3 t ha^{-1}. Then by extrapolating the average production data in g plant^{-1} to productivity in t ha^{-1}, all treatments would be within the range of 10 to 30 t ha^{-1}.

The production of the mixture of commercial substrate + carbonized rice husk demonstrates that despite the treatment had suffered from foliar abscission at the beginning of crop fructification likely due to water stress, S2 managed to obtained higher results for the yield and water use efficiency components.

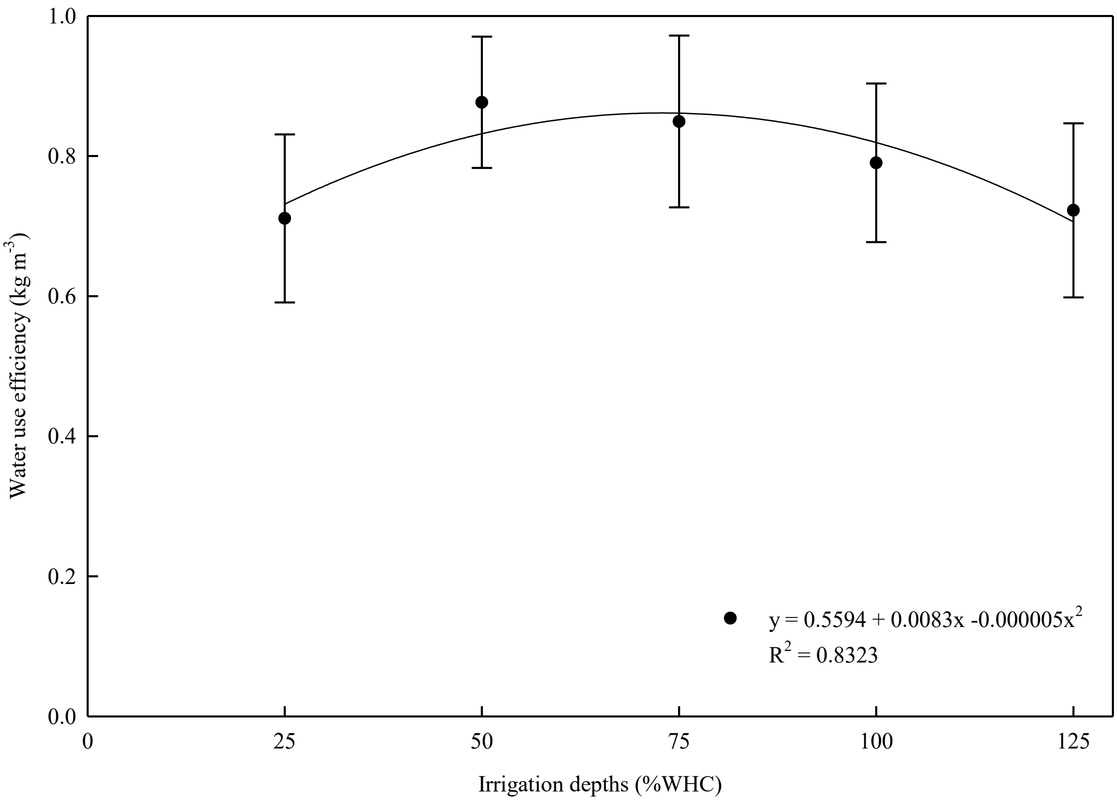
Marinho et al. (2016) observed that water deficit in tabasco pepper at different development phases provided smaller productivity to the plant at the vegetative stage compared to the water deficit at the reproductive phase. However, the irrigation depth that provided the most significant production at both times was 100% of the evapotranspiration of the crop, thus corroborating with this study. In the same sense, Barroca et al. (2015) found greater productivity for two cultivars of the *Capsicum* genus in the irrigation depths of 100% and 130% of evaporation for chili pepper and red pepper crops, respectively.

Regarding the use of substrate compositions, the 'biquinho' pepper production best responded to the S2 treatment, which contained a composition of 50% commercial substrate and 50% carbonized rice husk. Corroborating this study, Bellé and Kämpf (1994) showed that the best indication for using carbonized rice husk as a soil conditioner is at a proportion of up to 50%. On the other hand, Girardi et al. (2012) obtained positive responses in the production of gypsophila cultivated with 100% carbonized rice husk.

The mixture of different components for forming a substrate may improve physical and water parameters of the cultivation medium, providing the plant with better conditions for its productivity (AULER et al., 2015). In agreement with the above, Sezen et al. (2010) evaluated the production of tomatoes in different substrates and irrigation depths and frequencies, and they could observe that the highest output was obtained with treatment with 150% of the evaporation of a Class A pan, twice a day, and with the mixture of turf + volcanic ash.

The water use efficiency (WUE) values can be seen in Figure 4, and just as it was observed for the production parameters, there was no interaction between factors substrates and irrigation depths, although presenting statistically significant difference for both factors separately.

Figure 4. Influence of the different irrigation depths on the water use efficiency (WUE) of the 'biquinho' pepper



The maximum technical efficiency for the water replacement depths was for an irrigation depth of 69.17% WHC with a WUE of 0.85 kg m^{-3}. Although the highest fruit production having been observed for an irrigation depth of 101.47% WHC, the best relationship between production and water applied was obtained for an irrigation depth of 69.17% WHC. Just as for production, the treatment with substrate S2 presented the best result for water use efficiency, with an output of 77.16 g $plant^{-1}$ for a total irrigation depth of 87.04 mm.

The decrease in water availability for plants, without there being reduction in their productivity, it is what characterizes water use efficiency, possibly bringing lower production costs to cultivation with water savings, without hampering the cultivar's management. For this study, the best WUE was found for an intermediary water replacement depth, in agreement with what was reported by Valnir Júnior *et al*. (2015) and Marinho et al. (2016) when assessing water use efficiency for the tabasco pepper (*Capsicum frutescens*), they observed that the irrigation depth of 40% crop evapotranspiration, presented the best result for WUE. In contrast, when evaluating WUE in a sweet pepper crop (*Capsicum annuum* L.), Ćosić et al. (2015) observed that the treatment that received irrigation depth of 100% crop evapotranspiration presented the highest WUE, as well as higher production.

When working with substrate compositions and different irrigation depths, some authors also found better WUE for irrigation depths with lower water availability and in mixtures of two compounds, as done in a study by Sezen et al. (2010), in which the best WUE was obtained in the treatment of irrigation depth of 75% of the evaporation of the Class A pan.

The information found in this work demonstrates that the use of carbonized rice husk as a substrate conditioner may generate higher water savings without hampering the crop productivity compared to the pure commercial substrate, despite the possible occurrence of water stress during growth.

6 CONCLUSIONS

The use of the commercial substrate + carbonized rice husk enhances the results of yield and the fruit length, diameter, average weight, and number for the crop. The average number of fruits per plant presents the highest results for irrigation depths of 75 and 100% of the water-holding capacity. The length, diameter, and the average weight of the fruits are more considerable when there is a higher water availability.

The composition of commercial substrate + carbonized rice husk increases the production of the 'biquinho' pepper. The production of the 'biquinho' pepper presents better results for an irrigation depth of 101.7% of the water-holding capacity; however, the water use efficiency suggests that one obtain lower water consumption with irrigation depth of 69.17% of the water-holding capacity for maximum technical efficiency, without expressive production loss for the cultivation conditions under which we carried out this work.

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