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EFFECT OF WATER REGIME AND PALM MASS ON CULTIVATION OF GREEN PEPPER

REGIMES HÍDRICOS E DOSES DE MASSAS DE PALMA NO CULTIVO DO PIMENTÃO VERDE

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ABSTRACT: In this study, we aimed to evaluate the agronomic behavior of green peppers subjected to different water regimes and masses of forage cactus incorporated into sandy soil in a tropical climate. The treatments were organized in a 4 × 4 factorial scheme, with water regimes and forage cactus masses incorporated into the soil in a randomized block design. The results allowed us to observe an isolated significant difference for each factor studied. The water regime RH=100% of the vessel capacity (VC) and mass density of 100 g dm^{-3} of forage cactus incorporated into the soil positively affected the plant height variables, stem diameter, total chlorophyll, and water potential; specifically, these treatments were superior to soil with water restriction and without the addition of forage palm by 63%, 15%, 61%, and 71%, and 87%, 85%, 81%, and 63%, respectively. The doses of soil conditioner masses containing 0 g dm^{-3} and 100 g dm^{-3} of palm in the soil showed the best results for the number of fruits (3.25 and 2.00 fruits), number of commercial fruits (2.0 and 1.5 fruits), and fruit length (88.87 mm and 95.92 mm). Forage cactus mass of 100 g dm^{-1} of Quartzarenic Neosol and 100% VC irrigation water regime is the most recommended treatment for the protected cultivation of green pepper, as it positively influences productivity and the morphophysiological characteristics of the crop.

Keywords: *Capsicum annum* L., irrigation management, forage palm, morphophysiological behavior.

RESUMO: O objetivo desse trabalho foi avaliar o comportamento agronômico do pimentão verde submetido a regimes hídricos e massas de palma forrageira incorporada ao solo de textura arenosa em clima tropical. Os tratamentos foram organizados no esquema fatorial 4 x 4, com regimes hídricos e doses de massas de palma forrageira incorporadas ao solo, no delineamento em blocos casualizados. Os resultados obtidos permitem observar diferença significativa isolada para cada fator estudado, sendo que os tratamentos RH=100% da capacidade de água no vaso e os com 100 g dm^{-3} de palma forrageira incorporada ao solo apresentaram resultados positivos para as variáveis altura de plantas, diâmetro do caule, clorofila total e potencial hídrico denotando superioridade de 63%, 15%, 61%, 71% e 87%, 85%, 81%, 63%, respectivamente, quando comparados ao solo com restrição hídrica e sem adição de massa de palma forrageira ao solo. As doses de massas de condicionador de solo contendo 0 g dm^{-3} e 100 g dm^{-3} de palma no solo apresentaram os melhores resultados para as variáveis número de frutos (3,25 e 2,00 frutos), número de frutos comerciais (2,0 e 1,5 frutos) e comprimento de frutos (88,87 e 95,92 mm). A dose de massa de palma forrageira de 100 g dm^{-1} de neossolo quartzarênico e regime hídrico de irrigação 100% VC configura-se como sendo os mais recomendados para o cultivo desta cultura em cultivo protegido, por influenciar positivamente a produtividade e as características morfofisiológicas do pimentão verde.

Palavras-chave: *Capsicum annuum L.*, manejo da irrigação, palma forrageira, comportamento morfofisiológico.

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INTRODUCTION

Pepper (Capsicum annuum L.) belongs to the Solanaceae family and is one of the most cultivated vegetables in Brazil, with an annual production of approximately 290,000 tons (SOUZA et al., 2019). Pepper has a significant social and economic importance in the country, and the main producing states are Minas Gerais, São Paulo, Rio de Janeiro, Espírito Santo, Ceará, and Pernambuco, which account for 87% of the national production (PALMIERI et al., 2017).

Pepper is widely exploited, mainly by small- and medium-sized horticultures, because the beginning of production is fast and results in a rapid return on investments (LOPES et al., 2018). In particular, pepper supports family farming and promotes better integration between smallholders and agroindustry, resulting in 2000 ha−1 in the states of São Paulo, Minas Gerais, Goiás, Ceará, and Rio Grande do Sul (DELGADO; BERGAMASCO, 2017).

In Brazil, edaphoclimatic conditions are conducive to the cultivation of peppers; the production is concentrated in São Paulo and Minas Gerais, which output up to 5,000 ha and 120,000 tons per year, respectively (COSTA et al., 2019). However, water deficiency is limiting high yields, especially in the cultivation of vegetables in a protected environment or the field (ANTHONY; SHINGANDHUPE, 2004; KIRDA et al., 2004; GUANG-CHENG et al., 2008; PATANÈ, COSENTINO, 2010). The importance of sustainable agricultural production has increased in recent years because of the negative impacts of synthetic chemical pesticides and fertilizers used in conventional agricultural production on the soil, water resources, and environment (CRISTACHE et al., 2018). Studies have indicated that the water content in sandy soils restricts the increase in agricultural production, leading producers to seek strategies for the greater use of water by chili crops. Water management in chili crops is extremely important at all stages of plant development because it influences stand establishment, disease incidence and severity, and fruit quality. Therefore, adequate water supply should be guaranteed during the crop cycle (SEZEN et al., 2006).

Carvalho et al. (2011) studied the economic viability of pepper irrigated under five water regimes (50%, 75%, 100%, 125%, and 150%) in protected cultivation and concluded that the number of fruits per plant, the average weight of fruits and, consequently, the production per plant, were optimized under soil water replacement levels of 100%, 125%, and 150%, with 35.30 t ha−1 of fruits when they received 443.90 mm of water in the cycle. Aragon et al. (2012) reported an increase in productivity under 125% of the water slide estimated with the Class A tank, totaling 927.25 mm during the crop cycle in a protected environment.

To rationalize the use of water by chili crops, it is necessary to reduce losses in irrigation and adopt strategies that increase soil water retention, storage capacity, infiltration, etc. In this context, the use of conditioners, which are added to the soil, structurally modify it, and increase the water retention capacity, are being studied, although the results are inconclusive. By increasing the water retention capacity of the soil, it is possible to reduce the irrigation depth and the economic and environmental costs of production.

Forage palm is an agroecological alternative that can be used to reduce irrigation depth in agricultural production. It is a plant material that is approximately 90% water and contains minerals such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}), and vitamins A, B, and C (MORAIS et al., 2010); these characteristics promote vigor and growth of plants owing to the ability of the polymer to condition the soil and by improving their physical-chemical conditions (CARVALHO, 2016).

Because of its high water content, palm can be used as a soil conditioner, reducing the water slides during the production of green pepper. However, little is known about the use of this plant in soil water retention and storage, making it necessary to study soils of different textures to favor soil aggregation and water availability for crops of agronomic interest.

Thus, studies on protected environments associated with the adequacy of technologies that assist in the rational management of irrigation are fundamental to achieving higher yields. The objective of this study was to evaluate the productivity and morphophysiological characteristics of chili cultures under different water regimes and forage palm masses incorporated into sandy soil in tropical climates.

MATERIAL AND METHODS

Experimental area

The experiment was carried out from November 2019 to February 2021 at the Faculty of Agrarian and Veterinary Sciences, State University of São Paulo (UNESP), Jaboticabal Campus, in the Plasticulture Sector, which belongs to the Department of Engineering and Exact Sciences (21°15'22' 'S, 48°18'58 '' O, 595 m). During this period, an average air temperature of 32.9 °C and relative humidity of 52.7% were recorded.

The experimental design was in randomized blocks, factorial 4 × 4, consisting of four water regimes: RH1 = 55%, RH2= 70%, RH3= 85%, and RH4= 100% of vessel capacity (VC); four masses of fractional forage palm were incorporated into the soil: PF1= 0, PF2 = 50, PF3 = 75, and PF4 = 100 g dm^{-3} soil, totaling 16 treatments with four replications. Pots of 7 dm^{-3} containing Quartzarenic Neosol soil (EMBRAPA, 2018) were collected from a company based in Monte Alto, SP. The chemical characterization of the soil revealed the following characteristics: organic matter = 9 g dm^{-3}; pH ($CaCl_2$) = 4.3; P_2O_5 = 48 mmolc dm^{-3}; K_2O = 0.3 mmolc dm^{-3}; Mg = 1 mmolc dm^{-3}; Ca = 40 mmolc dm^{-3}, and V = 21%. The physical characterization of the soil revealed the following: clay (5 g kg^{-1}), silt (1 g kg^{-1}), total sand (94 g kg^{-1}), coarse sand (33 g kg^{-1}), and fine sand (61 g kg^{-1}).

The soil acidity was corrected by applying MgO (PRNT 70%) and raising the percentage of saturation per base, at the calculated dose of 5.13 g per vase.

Planting fertilization followed the recommendations of Bulletin 100 IAC (VAN RAIJ et al., 1997); the amounts of fertilizers supplied per pot plant were 5.33 g of Simple Superphosphate, 0.9 g of potassium chloride, and 0.27 g of urea. Cover fertilization was also performed four times during crop development, providing 0.43 g urea and 0.25 g potassium chloride.

Transplanting and irrigation management

The seedlings were acquired from a suitable agricultural company, and transplantation was performed when the seedlings presented four or five definitive leaves. The irrigation level of 100% of the VC was obtained through soil saturation in the pot and subsequent drainage after seven days, thus defining the "vessel capacity", which corresponds to the maximum amount of water that can be retained in the soil volume (CASAROLI; JONG VAN LIER, 2008). The irrigation was carried out through the adoption of a one-day irrigation shift, in the morning between 7:30 a.m. and 8:30 a.m. The daily blade applied was determined from the evapotranspiration of the culture, which weighed five vessels per treatment.Until ten days after transplantation, all treatments were irrigated with total water replacement, determined in RH1 (100% VC), to ensure the establishment of seedlings. After this period, the application of water regimes was initiated. Figure 1 shows the slides used for the treatments.

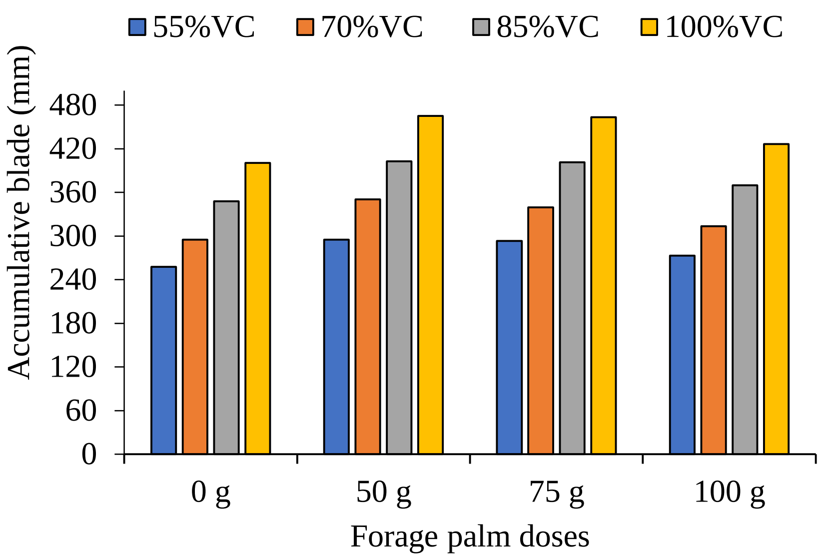

Figure 1. Cumulative irrigation depth during cultivation of green pepper in a protected environment. UNESP, Jaboticabal, 2021.

Evaluated characteristics

The evaluations were performed in each experimental unit, corresponding to one plant per pot, measuring the following parameters: plant height (AP, cm) measured at the beginning of flowering using a graduated ruler, stem diameter (DC, mm) determined 5 cm from the soil using a digital caliper, and total chlorophyll (adimensional) determined using a chlorophyll meter (ChlorofiLOG, model CFL 1030) on the first fully expanded sheet most exposed to solar radiation.

To determine the leaf water potential (kPa), we used a soil-moisture pressure chamber (model 3005) in the middle third of the leaf blade of the first fully developed leaf; the number of fruits (NF, fruits per plant) was calculated as fruit count per plant plot, fruit length (mm) was determined from the insertion of the peduncle to the end of the fruit, total productivity (Prod, t ha−1) was estimated based on the mass of the total fruit per plot and by the area covered by the plant (0.5 m2), performing two harvests and extrapolating to hectares.

The efficiency of water use was obtained based on the total productivity of peppers per unit of water consumed.

Statistical analysis

The data were subjected to variance and regression analyses. Means were compared by the Tukey test at 5% probability

RESULTS AND DISCUSSION

According to the results obtained for plant height and stem diameter for green pepper plants, no significant effect was found for the interaction between the factors water regime (RH) and forage palm mass (PF); however, there was a significant difference in the isolated effect of HR and PF ($p<0.05$).

Plant height (Figure 2 B) was positively influenced by the established water regimes, with a higher mean value for RH 100% VC (44.49 cm), and by the forage palm mass when 100 g dm−3 soil (42.58 cm) was used.

As a vegetable, chili requires a large amount of water during the cycle. Higher height under the highest water regime (100% VC) and higher palm mass (100 g dm−3 of soil) favored higher emissions of branches by the crop, which directly impacted the increase in biomass of the chili crop.

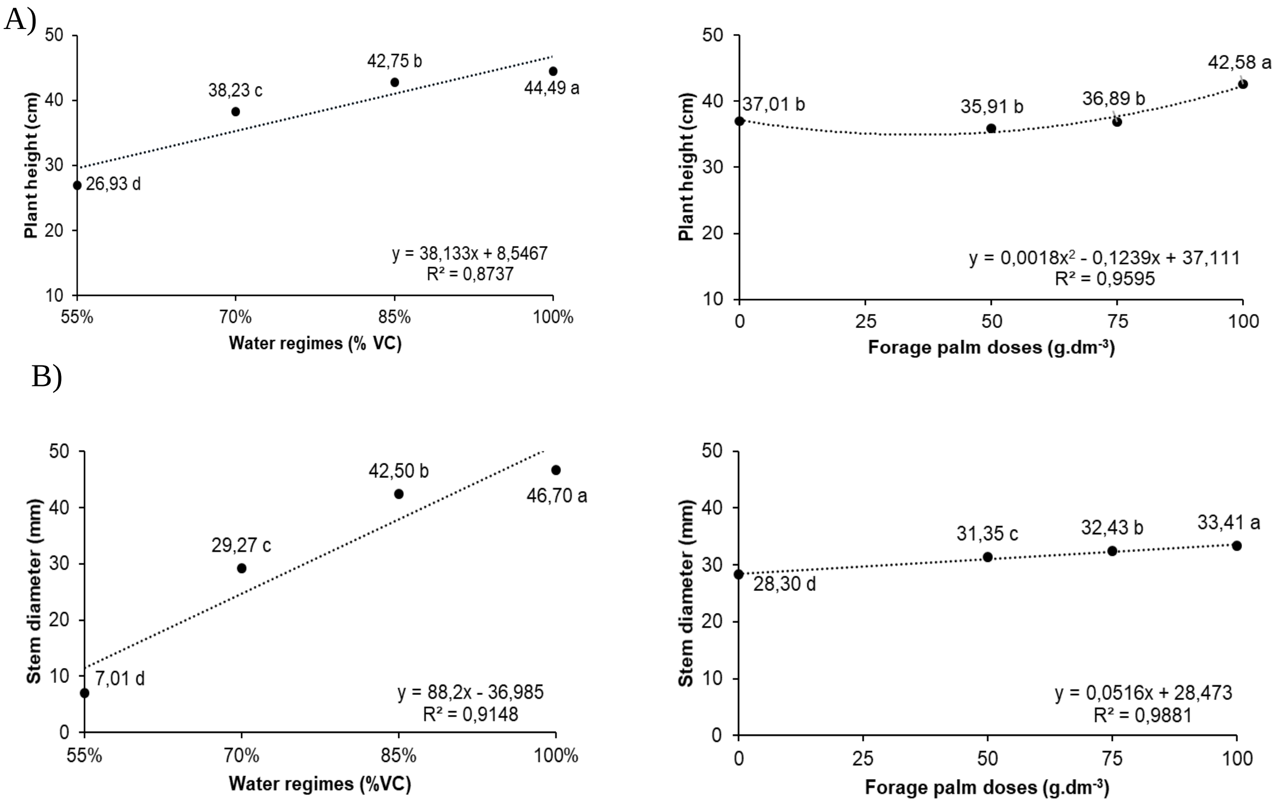

Figure 2. Plant height (A) and stem diameter (B) of green pepper plant under different water regimes and forage palm masses. UNESP, Jaboticabal, 2020.

Plant height increased during the growing period under the water regimes, and palm mass was incorporated into the soil. This result is expected because growth is undetermined, and chili plants grow continuously (ROCHA et al., 2018). Anthony and Singhandupe (2004) studied peppers (Capsicum var California Wonder) irrigated by drip and grooves and verified that the height of the plant increased with an increase in the applied blade, influencing the final productivity of the crop.

The stem diameter showed consistent behavior; 100% VC and palm mass of 100 g dm−3 favored an increase in crop gain, with mean values of 46.70 mm and 33.41 mm, respectively (Figure 2 B). The larger the stem diameter in peppers, the greater the accumulation of photoassimilates, which directly influences the final productivity, besides ensuring better support for the crop. These results corroborate those obtained by Santana et al. (2004), who reported a significant effect of irrigation on stem diameter.

Total chlorophyll and leaf water potential were positively influenced by the increase in water regimes and forage palm mass (Figure 3 A and B). Higher total chlorophyll content was observed in the highest water regime (44.49) and forage palm mass (42.58).

Chlorophyll is strongly influenced by environmental factors, such as the availability of light, water, and mineral nutrients, and when plants are subjected to stress (KAYA et al., 2013). Thus, in this study, these indices were lower for plants under the 55% VC water regime (26.96) and forage palm mass of 0 g dm−3 (37.01).

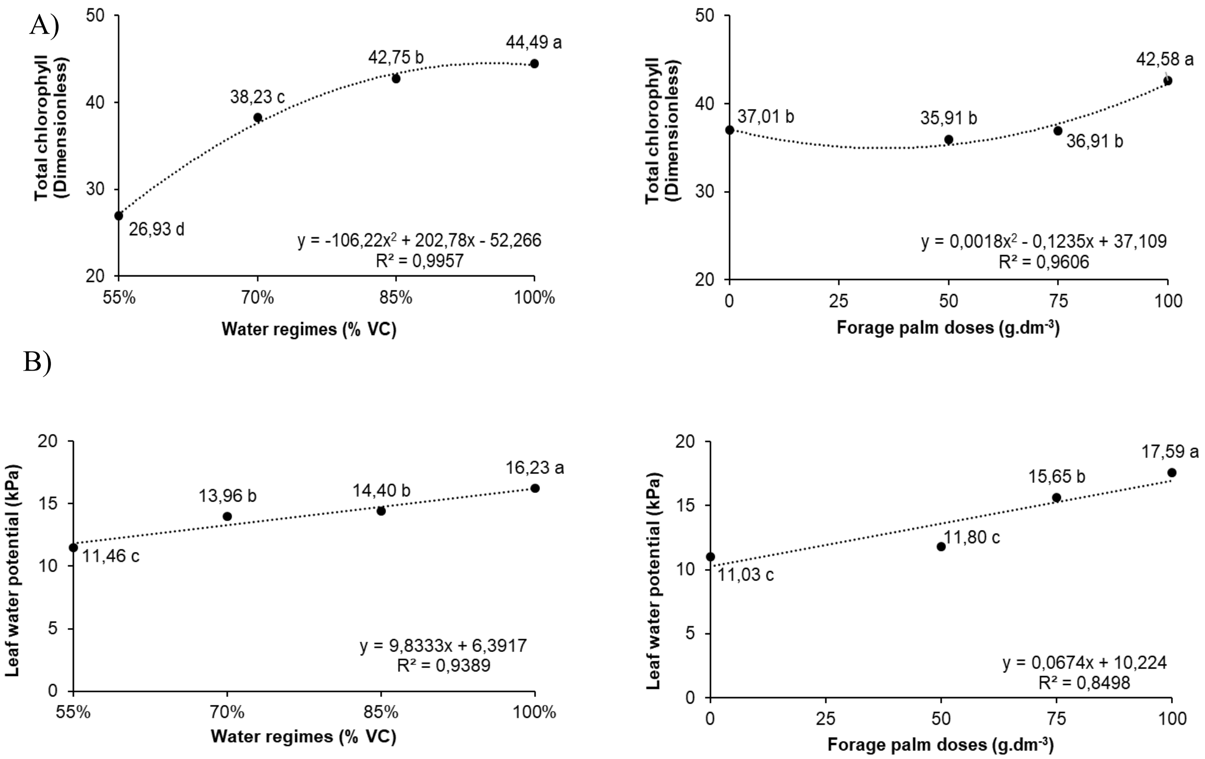

Figure 3. Total chlorophyll (A) and leaf water potential (B) of the green pepper plant under different water regimes and forage palm masses. UNESP, Jaboticabal, 2020**.**

The physiological characteristics of chili leaves are presented in Figure 3 B. There was no interaction between the water regimes and the masses of forage palm incorporated into the soil. For the 100% VC water regime, a higher leaf water potential (16.23 kPa) was observed at noon, which was 70.6% higher than that under the 55% VC water regime. For palm masses, higher water potential (17.59 kPa) was observed for the mass of 100 g dm−3 soil, which was 62.7% higher than that in the treatment with 0 g dm−3 soil (11.03). In the case of protected cultivation, Farias et al. (1992) showed that inside greenhouses, diffuse solar radiation is, on average, 65° higher than that externally. These results suggest that such variations occur as a function of transpiration, without the corresponding refund of water lost by the leaf. The effects of the number of fruits, fruit length, total productivity, and water use efficiency were significant when isolated (Table 1). No difference was observed in the number of fruits harvested in the first harvest between water regimes.

Table 1. Average number of fruits (NF), fruit length (Lfruit), total productivity (TP), and water use efficiency (USA) for green pepper in the first and second harvest under the effect of water regimes and forage palm masses in sandy soil. UNESP, Jaboticabal - SP, 2020.

Treatments	1ª harvest				2ª harvest			
	NF	Lfruit	TP	USA	NF	Lfruit	TP	USA
	-	mm^{-1}	$t\ ha^{-1}$	$kg\ m^{-3}$	-	mm^{-1}	$t\ ha^{-1}$	$kg\ m^{-3}$
Water regimes								
55% VC	1,68 a	96,96 a	3,09 ab	1,13 a	1,18 b	81,79 a	2,34 b	0,53 b
70% VC	1,87 a	96,68 a	3,52 ab	1,13 a	1,43 ab	92,03 a	2,30 ab	0,85 ab
85% VC	2,18 a	99,96 a	2,71 b	0,91ab	2,12 a	96,06 a	3,81 a	1,02 a
100% VC	2,43 a	107,14 a	3,98 a	0,73 b	1,25 b	102,70 a	2,35 ab	0,82 ab
Palm doses	NF	Lfruit	TP	USA	NF	Lfruit	TP	USA
0 $g\ dm^{-3}$ soil	3,25 a	91,01 a	5,08 a	1,63 a	2,00 a	88,87 ab	1,90 a	1,16 a
50 $g\ dm^{-3}$ soil	1,25 b	100,38 a	2,26 b	0,99 b	1,25 b	84,60 b	2,66 a	0,85 a
75 $g\ dm^{-3}$ soil	1,68 b	101,80 a	2,59 b	0,67 c	1,25 b	103,19 a	2,94 a	0,71 ab
100 $g\ dm^{-3}$ soil	2,00 ab	107,80 a	3,37 b	0,60 c	1,50 ab	95,92 ab	3,60 a	0,50 b
Interação RH x PF	ns	ns	ns	ns	ns	ns	ns	ns
cv (%)	8,20	8,98	10,23	15,77	15,14	29,47	15,25	14,17

VC: Water capacity in the vessel; (*) significant by F test to 5%; (**) significant by F test to 1%; ns: not significant; cv (%): coefficient of variation.

For the treatment with the palm mass dose of 0 g dm^{-3} of sandy soil, the average value was 3.25 fruits per plant. One possible explanation is that the forage palm has allelochemical components that prevent the absorption of nutrients by the plant, thus preventing the formation of fruits and their catch after fertilization of the flower. This behavior was different for the number of fruits in the second harvest, in which, for the 70% and 85% VC water regimes, better mean values were obtained for 1.43 and 2.12 fruits, respectively. Regarding the absence of forage palm mass (0 g dm^{-3}) and higher palm concentration of 100 g dm^{-3} of soil, the highest mean values were 2 and 1.5 fruits per plant.

Fruit length was influenced only by forage palm mass in the second harvest. The highest mean values obtained were 88.87 mm (0 g dm^{-3}), 103.19 mm (75 g dm^{-3}), and 95.92 mm (100 g dm^{-3}). This analysis of fruit quality per harvest is important, as it determines the characteristics for the classification and commercialization of chili, provided that the Brazilian market values large fruits (SANTOS et al., 2017). With this, the producer can manage the supply of pepper available on the market and thus obtain better prices considering the characteristics of the harvested fruits.

The effects of water regimes and palm mass on the total productivity of chili fruits were significant when isolated (Table 1). Productivity ranged from 2.26 t ha^{-1} to 5.08 t ha^{-1} in the first harvest and from 1.90 t ha^{-1} to 3.81 t ha^{-1} in the second harvest. The average productivity was inconsistent with the national average value of 22.3 t ha^{-1} (GOTO et al., 2016). This can be explained by temperature fluctuations during the crop cycle in a protected environment.

Owing to the increase in temperature and water loss by evapotranspiration during the day, flower abortion occurred, which negatively influenced the productivity of the chili plant.

Improved water use efficiency (USA) was found under the lowest water regimes and smallest masses of forage palms (Table 1).

The increase in water use efficiency was obtained by maintaining productivity and low water use (SANTOS et al., 2016), which explains the results of this study since treatments with 55%, 75%, and 85% VC are among the most productive treatments with the lowest amount of water during the chili crop cycle (Table 1).

CONCLUSIONS

The use of forage palm masses incorporated into sandy soil in a protected crop under tropical conditions has become fundamental in view of the water supply and reductions in irrigation depth during the green pepper crop cycle.

The most recommended treatment for the protected cultivation of this crop is a forage palm mass of 100 g dm^{-1} of Quartzarenic Neosol and the 100% VC irrigation water regime because it positively influences the productivity and morphophysiological characteristics of green pepper.

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