



Growth and productivity of bell pepper grown in vases in a protected environment with different irrigation managements

Crescimento e produtividade do pimentão cultivado em vasos em um ambiente protegido com diferentes manejos de irrigação

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The main objective of this study was to assess the feasibility of different irrigation management methods for growing bell pepper in vases under protected conditions in Ibiapaba, Ceará. The experiment was conducted in a protected environment, in the experimental area of the Instituto Agropolos do Ceará, in São Benedito-CE. To this end, four irrigation methodologies were evaluated to quantify the volume of water to be replenished in the pots: M1: based on drainage micro-lysimeters (reference methodology); M2: based on the area of the vase; M3: based on the plant stand per hectare; and M4: based on the volume of the vase, under a randomized block design, with four replications. In addition to the total volume of water applied by each method, the following variables were assessed: plant height, stem diameter, leaf size, aerial and root biomass, and yields. The use of methodologies M3 and M1 resulted in greater plant heights, stem diameters, accumulations of aerial part biomass, and yields of bell pepper. The M2 and M4 methodologies underestimated the volume demanded from the micro-lysimeter, while the M3 methodology overestimated it. The adjustment coefficients of the other methods about the volume demanded from the micro-lysimeter were 5.43, 0.49, and 9.18, for methods M2, M3, and M4, respectively.

Keywords: *Capsicum annuum*, lysimetry, water management.

O principal objetivo deste estudo foi avaliar a viabilidade de diferentes métodos de manejo de irrigação para o cultivo de pimentão em vasos sob condições protegidas na Ibiapaba, Ceará. O experimento foi conduzido em ambiente protegido, na área experimental do Instituto Agropolos do Ceará, em São Benedito-CE. Para isso, foram avaliadas quatro metodologias de irrigação para quantificar o volume de água a ser repostos nos vasos: M1: com base em microlisímetros de drenagem (metodologia de referência); M2: com base na área do vaso; M3: com base no estande de plantas por hectare; e M4: com base no volume do vaso, em um delineamento em blocos casualizados, com quatro repetições. Além do volume total de água aplicado por cada método, foram avaliadas as seguintes variáveis: altura da planta, diâmetro do caule, tamanho das folhas, biomassa aérea e radicular e produtividade. O uso das metodologias M3 e M1 resultou em maiores alturas de plantas, diâmetros de caule, acúmulos de biomassa da parte aérea e produtividade do pimentão. As metodologias M2 e M4 subestimaram o volume demandado pelo microlisímetro, enquanto a metodologia M3 o superestimou. Os coeficientes de ajuste dos outros métodos sobre o volume demandado pelo microlisímetro foram de 5,43, 0,49 e 9,18, para os métodos M2, M3 e M4, respectivamente.

Palavras-chaves: *Capsicum annuum*, lisimetria, manejo de água.

1. INTRODUCTION

Bell pepper (*Capsicum annuum* L.) is a vegetable consumed worldwide thanks to their organoleptic characteristics. The fruit is rich in antioxidants and essential vitamins [1] for the body. Bell pepper originated in the Americas and Brazil occupies a total area of 11,188 hectares with a production of 554,904 tons, resulting in a national productivity of 49.6 t ha⁻¹ [2] in open field conditions.

The plant is a shrub-like vegetable of the Solanaceae order, with a pivoting root system that can reach a depth of 1.2 m [3]. It requires soils with good aeration, depth, and good drainage for its cultivation, as the plant is sensitive to root asphyxiation [4]. It is a tropical plant that needs temperatures between 20 and 30 °C for its full development, with a temperature of 25 °C ideal for germination. Adult chili plants are intolerant to frost temperatures above 35 °C cause fruit abortion and flower drop [5].

Both excess and lack of water are detrimental to the development of the bell pepper crop, especially in the reproductive phase, so irrigation management is of paramount importance for production gains [6]. Water deficit reduces nutrient absorption and, low water absorption by the plant results in damage that can range from changes in fruit and plant anatomy to physiological and biochemical changes, which vary according to the levels of water stress. These changes can damage the entire plant cycle [7].

The lysimeter is a reference device consisting of an impermeable tank equipped with a basal drainage system that isolates a soil profile. This instrument makes it possible to obtain detailed data on the water balance of the volume sampled. This equipment was created to study deep drainage and the concentration of nutrients extracted from the soil located inside the box and, later began to be used as a reference method for studying evapotranspiration [8].

Traditional equations for quantifying the volume of water to be applied to the plant under soil cultivation conditions have often been used incorrectly when managing irrigation in vases [9]. As a result, most of the time this leads to a condition of water deficiency, due to the densification of the roots in the pots, which leads to greater water consumption per volume of soil. Therefore, there is a need to quantify coefficients that can adjust the volumes estimated by usual methodologies to be equivalent to the volumes measured in micro lysimeters.

Given the above, the main objective of this study was to assess the viability of different irrigation management methodologies for growing peppers in pots in a protected environment in the Ibiapaba region of Ceará. And, as a secondary objective, to estimate adjustment coefficients for the other methodologies in order to obtain the volume required from micro lysimetry.

2. MATERIAL AND METHODS

2.1 Experiment area

The research was conducted in the experimental area of the Escola de Floricultura do Ceará-Tecflores, located in the city of São Benedito-CE (04°02'55" S; 40°51'54" W), and 901 m elevation above sea level, belonging to the Instituto Agropolos do Ceará. The municipality's climate was classified as BSh (warm semi-arid mild tropical), according to Alvares et al. (2014) [10], with average monthly temperatures ranging from 22 to 29 °C and average annual rainfall of 944.2 mm. The soil used in the experiment was classified as Neossolo Quartzarênico [11].

2.2 Vases preparation and experimental design

The experimental design adopted was a randomized complete block design with four treatments and four blocks, with three replications per block (totaling twelve replications per treatment), resulting in a total of 48 vase cultivated with bell pepper. The treatments consisted of four irrigation management methods used to quantify the water volume to be replenished to the plants (V): M1, based on micro-drainage lysimeters (considered the reference method); M2, based on reference evapotranspiration (ET_o), crop coefficient (K_c), and vase surface area; M3, based on ET_o, K_c, and the number of plants per hectare; and M4, based on ET_o, K_c, and vase volume, as shown in Table 1. The surface area of the vase was 0.049 m² the plant density was set at 20,000 plants ha⁻¹ (equivalent to a spacing of 0.5 x 1.0 m); and the vase volume and height were 0.0147 m³ and approximately 0.30 m, respectively.

Table 1: Description of the methodologies used as irrigation treatments for bell pepper in a protected environment. São Benedito-CE, Brazil.

Methodology	Description
M1	Volume (L day ⁻¹) = quantified by micro lysimetry
M2	Volume (L day ⁻¹) = ETo (L m ⁻² day ⁻¹) x Kc x area of the vase (m ²)
M3	$Volume (L day^{-1}) = \frac{ETo (L day^{-1}) \times Kc}{number\ of\ plants\ (ha^{-1})}$
M4	$Volume (L day^{-1}) = \frac{ETo (L day^{-1}) \times Kc \times vol.\ vase\ (L)}{volume\ of\ soil\ exploited\ (L) *}$

* The soil volume was exploited for one hectare, considering an effective root depth of 0.30 m.

The vases were then filled with soil from the site so that they all had a similar mass and volume to reduce the risk of unevenness. The soil was sandy loam with known physical analyses. The physical results were: 741.3 g kg⁻¹ sand; 142.5 g kg⁻¹ silt; 116.2 g kg⁻¹ clay; soil density of 1.25 g cm⁻³; particle density of 2.55 g cm⁻³; and 51% total soil porosity, according to Menezes et al. (2024) [12]. The vases were then placed on top of two bricks at a height of 9.0 cm to allow excess water to drain away, should it occur.

Twelve of the vases, according to the design (methodology 1), were adapted to the condition of a micro lysimeter, in which the drained volume was fed into a container graduated in milliliters. After quantifying the average volume drained from these micro lysimeter vases, the volume used per plant was calculated, in milliliters per day, corresponding to the crop's evapotranspiration, in volume per vase, using equation 01:

$$V_u = V_c - V_d \quad (01)$$

In which:

V_u is the volume of water used by the plant per vase (in milliliters vase⁻¹ day⁻¹);

V_c is the volume placed the previous day (in milliliters vase⁻¹ day⁻¹);

V_d is the average volume drained (in milliliters vase⁻¹ day⁻¹).

2.3 Irrigation and bell pepper plant management

To estimate the volume of the water to be applied daily in the other methodologies (2 to 4), the reference evapotranspiration (ETo) was initially estimated using the Class 'A' tank method, which was installed in situ, taking into account the conditions of the protected environment and using K_p = 1.0, this value was used due to the controlled conditions of the protected environment, such as constant relative humidity, no wind, and a class tank without a border. The water level data in the tank was collected daily at nine o'clock in the morning and then entered into spreadsheets.

To quantify crop evapotranspiration (ET_c), ETo was multiplied by the bell pepper crop coefficient values (K_c) proposed by Doorenbos and Kassan (1994) [13], which were 0.4, 0.7, 1.05 and 0.85 for phases I, II, III and IV, respectively. The volumes to be applied in each of these methodologies were then quantified according to the equations in Table 1.

The crop used was green bell pepper and hybrid Tiberius, and the seedlings were purchased in partnership with local nurseries. The seedlings were transplanted 32 days after sowing, one plant per pot, and distributed at a spacing of 0.5 x 1.0 m. The plants were grown under a single trellis system.

Irrigation management began three days before transplanting when all the vases were brought to vase capacity. For 10 days after transplanting (DAT), volumes of water

corresponding to the crop's evapotranspiration quantified using micro-lysimeters were placed in all the vases every day, to establish the crop. After 10 DAT, the treatments began, with different volumes of water, as described in Table 1.

From transplanting to harvesting, various cultural treatments were carried out in order to provide the best conditions for plant development and minimize the occurrence of phytosanitary and/or physiological problems. Fertilization was managed on the basis of soil analysis and recommendations for the crop. It was applied manually every fortnight, according to the crop's absorption curve by phase and by nutrient. Weed control in the pots was carried out throughout the crop cycle, using manual extractions.

2.4 Analyzed variables

At 60 and 75 days after transplanting (DAT), the following variables were assessed: plant height (PH), stem diameter (SD), and leaf area (LA). Plant height was measured from the plant collar to the apical meristem using a graduated ruler (100 cm). Stem diameter was determined at 1 cm above the plant collar using a digital caliper (0.05 mm precision). Leaf area (LA) was estimated using a non-destructive method by multiplying the leaf length, maximum width, and the total number of leaves per plant, adjusted by a shape correction factor using a graduated ruler.

At the end of the experimental cycle, the crop yield and biomass variables were evaluated: root dry matter (RDM), shoot dry matter (SDM), total dry matter (TDM), and fruit yield per plant (kg plant^{-1}). Harvesting of bell peppers began at 65 DAT and was performed periodically. Fruit mass was determined using a precision scale (1.0 g). Total yield per plant (kg plant^{-1}) was calculated by summing the mass of all harvested fruits per plant throughout the cycle. Total crop productivity (kg ha^{-1}) was subsequently estimated by extrapolating the individual plant yield based on the established population of 20,000 plants ha^{-1} . The cumulative water volume applied by each treatment was recorded daily in a spreadsheet from 10 DAT until the end of the experiment.

Adjustment coefficients were then estimated using the ratio between the total volume applied by a given irrigation methodology and the total volume applied by the micro-drainage lysimeters, which served as the reference method.

2.5 Data analysis

The data for each variable was subjected to the Shapiro-Wilk test to check for normality, the F test for analysis of variance (ANOVA), and the Tukey test, all at 5% probability, using the SISVAR software [14].

3. RESULTS AND DISCUSSION

3.1 Summary of analysis of variance

Table 2 shows the summary of the analysis of variance for the growth variables analyzed at 60 and 75 DAT and the production variables at the end of the experiment. According to the analysis, significant effects can be seen between the methodologies at the two growth assessment times and the end of the experiment. With the single exception of leaf area, all the variables showed significant responses at the $p < 0.05$ level.

Table 2: ANOVA summary for plant height (PH), and stem diameter (SD) at 60 and 75 days after transplanting (DAT) and for root dry mass (RDM), aerial part dry mass (APDM), total dry mass (TDM), production per plant (PRODP) and productivity (PROD), at the end of the crop cycle, as a function of the different methodologies for quantifying the volume of water to be replenished daily.

Sources of variation	GL	Mean Squares									
		60 DAT			75 DAT		RDM (g)	APDM (g)	TDM (g)	PRODP (kg pl ⁻¹)	PROD (t ha ⁻¹)
		PH (cm)	SD (mm)	LA (cm ⁻²)	PH (cm)	SD (mm)					
M	3	263.81*	11.11*	446.96*	426.12**	18.91**	214.54**	1226.87**	2439.36**	1.51**	608.21**
Blok	3	36.33 ^{ns}	2.16 ^{ns}	1288.39 ^{ns}	64.96 ^{ns}	1.96 ^{ns}	23.02 ^{ns}	4.80 ^{ns}	21.71 ^{ns}	0.06 ^{ns}	25.30 ^{ns}
Error	9	68.35	2.41	125.09	51.68	1.66	10.12	50.16	61.76	0.08	35.44
Mean		49.02	8.77	52.68	54.31	7.47	10.43	38.43	48.87	0.57	11.51
CV (%)		16.87	17.72	21.23	13.24	17.23	30.48	18.43	16.08	51.71	51.68

ns – Not significant up to 5%; *, ** - Significant at 5 and 1%, respectively, by the F-test; M – Methodologies; GL– Degree of freedom; CV – Coefficient of variation.

3.2 Growth Variable

Figure 1A shows the average values for the height and diameter of bell pepper plants as a function of the four methodologies at 60 and 75 DAT. Plant growth followed distinct trends for plant height and stem diameter. While plant height increased from 60 to 75 DAT across all methodologies (Figure 1A), a reduction in stem diameter was observed for the same period (Figure 1B). This decrease in stem diameter at 75 DAT can be targets to the intense redirection of photo assimilates to fruit development (which act as preferential sinks during this stage) and the high transpiratory demand of the increased leaf area, which temporarily reduces tissue turgidity in the stem. Although there were no significant differences between the M1 plants (irrigated from the micro-lysimeters; they received 65 L over the entire cycle) and the M3 plants, which received the largest volumes over the entire cycle (132.84 liters), the M3 plants obtained the greatest heights, 57.8 cm, and 64.5 cm, at 60 and 75 DAT, respectively.

Plant height increased between measurements at 60 and 75 DAT in all methodologies. Working with a lysimeter in a hydroponic system with substrate, Carvalho et al. (2020) [15] found that the greatest heights were observed at 90 days, and at 60 DAT the plants already had an average height of 66.67 cm, corresponding to half the height observed at the end of cultivation.

When compared in percentage terms, methodologies M1 and M3 obtained the greatest increases in height between the two growth assessments, with 17.5% and 9.8%, respectively. For the other methodologies, the increases were 8.6% (M2) and 5.7% (M4). According to Taiz and Zeiger (2013) [16], a reduction in plant growth is, among other factors, one of the secondary effects that occur when plants are subjected to a reduction in water availability, which was the case with M2 and M4.

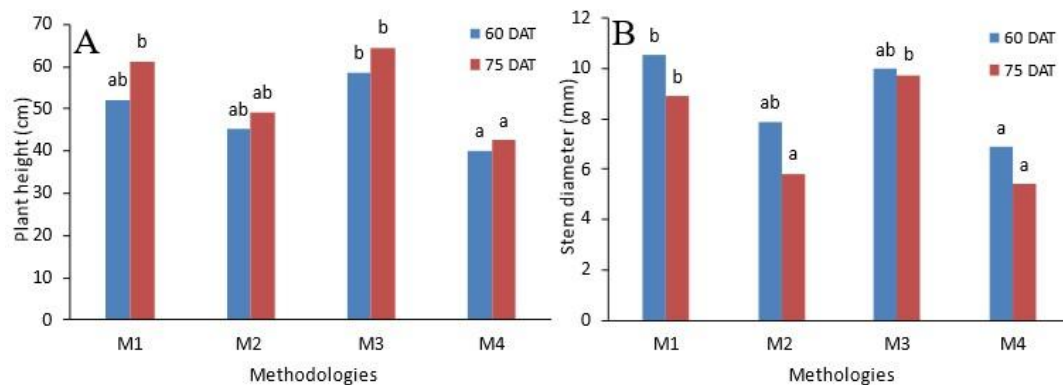


Figure 1: Average height and diameter of bell pepper plants in a protected environment under different irrigation management methodologies. The letters indicate the statistical difference between the methodologies using the Tukey test at 5% probability.

For the stem diameter (SD) variable, the highest values were observed in the first 60 days in all methodologies. The M3 methodology had the best results, but the diameter values in the M1 methodology were also very significant in both measurement periods.

The stem diameter variable showed the highest values in the first evaluation at 60 DAT for the four methodologies tested here. Unlike the results observed in this research, Padrón et al. (2015) [17], evaluating the effect of different irrigation rates on bell pepper, found that stem diameter was not significantly influenced throughout the crop cycle.

Leaf area was reduced at 75 DAT, with greater intensities in the M2 and M4 methodologies, which can be explained by the lower volumes of water replenished. Reductions in the plant's water supply inhibit leaf expansion and stem growth but, on the other hand, stimulate root elongation [16]. It can also be assumed that this decrease is to expected as a result of the reduction in the proportion of leaves in the total dry matter due to the formation of branches and, subsequently, flowers and fruit [18].

3.3 Production Variable

The accumulated biomass at 60 DAT was 70.5, 32.0, 69.6, and 23.4 g plant⁻¹, respectively, for M1, M2, M3, and M4, with M1 and M3 being in surplus (Figure 2). It can also be seen that the biomass accumulated by the root system amounts to around 20% of the total accumulated by the plant. It can, therefore, be inferred that the plants prioritized accumulating more biomass in the aerial part than in the root system.

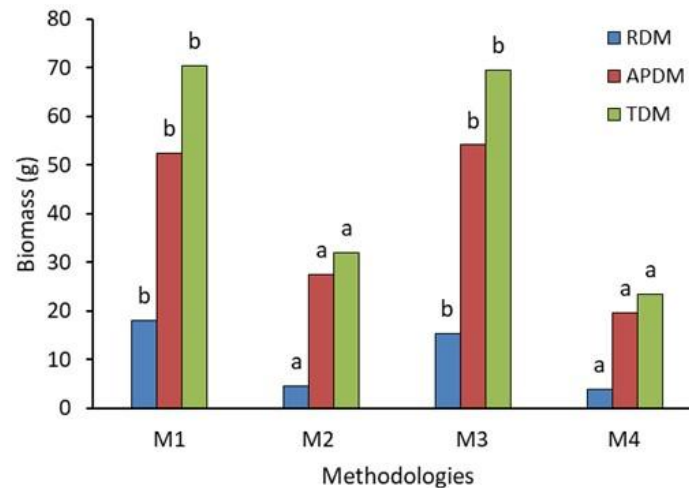


Figure 2: Average accumulated biomass of chili plants in a protected environment under different irrigation management methodologies. RDM – Root Dry Mass; APDM – Aerial Part Dry Mass; TDM – Total Dry Mass. The letters indicate the statistical difference between the methodologies using the Tukey test at 5% probability.

Plant biomass production was higher in the methodologies that received higher volumes of water (M3 and M1) compared to the other two methodologies tested. Figure 2 shows that the biomass accumulated by the root system amounted to 25.5%, 14.1%, 22.2%, and 16.4% of the total accumulated by the plant for M1, M2, M3, and M4, respectively. Padrón et al. (2015) [17], studying the growth of bell pepper in two cultivation systems, found that the biomass accumulated by the root system reached 7% and 8% of the total accumulated by the plant in conventional and no-till systems, respectively, at 58 DAT. According to the same authors, it was possible to see that the plant prioritizes the accumulation of biomass in the aerial part to the detriment of the root system, which is an important aspect for farmers to consider when managing irrigation, considering the small volume of soil explored by bell pepper roots.

For this study, the greater relative weight of the roots compared to those reported in the aforementioned study is due to the greater limitation of soil to be explored imposed by the volume of the vase, implying the need to intensify the absorption of water and nutrients per volume made available, hence the relative enlargement of the root systems.

When analyzing the volume of water applied with the M3 methodology, which is much higher than that required from the micro lysimeters, it can be said that it is not justified, especially in semi-arid regions as an example the biomass production for these two methodologies was statistically the same. It can be inferred that excessive volumes of water applied under vase growing conditions do not contribute significantly to the plant's dry matter production.

The M3 methodology became excessive due to the small volume of the vase compared to the volume exploited by the plant in the soil. In other words, there are few pores in the vase (51%) for water retention, which results in exaggerated drainage when using a traditional methodology to quantify the water demand of crops with larger volumes of soil to exploit.

The highest average yield of bell pepper per plant was obtained with the M3 methodology (1.28 kg plant⁻¹; Figure 3). However, with the M1 methodology, the average yield was close to

1.0 kg plant⁻¹, which did not differ statistically from the M3 yield. The yields of the M2 and M4 methodologies did not differ from each other, however, they were below 0.1 kg plant⁻¹, statistically lower than those of M1 and M3.

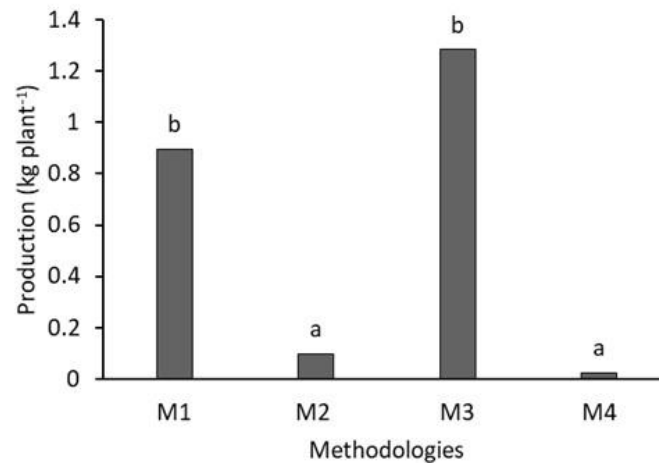


Figure 3: Average yield per bell pepper plant in a protected environment under different irrigation management methodologies. The letters indicate the statistical difference between the methodologies using the Tukey test at 5% probability.

Evaluating the yield of bell pepper per plant (Figure 3) it can be inferred that due to the different hybrids and, consequently, different growing cycles, the definition of an average yield per bell pepper plant as cited in the literature is very variable. According to Miranda et al. (2015) [19], yields of 3.0 to 4.0 kg plant⁻¹ are expected for crops grown in protected environments. In this study, a total of two harvests were performed between 45 and 60 DAT. Taking the literature data as a reference, the yield obtained in this research was well below what is expected to be produced per bell pepper plant in a protected environment, especially in M2 and M4. This lower performance is attributed not only to a shorter harvesting window compared to commercial cycles, but also to the fact that the crop was grown in pots and subjected to water deficiencies in these specific methodologies. Conversely, Carvalho et al. (2020) [15] evaluated bell pepper evapotranspiration in lysimeters under a hydroponic system with substrate and obtained a production of 4.0 kg plant⁻¹ under non-limiting water conditions and extended harvesting.

However, producers' lack of knowledge about the water needs of cultivated plants, as well as proper irrigation management, leads them to use quantities of water that exceed the plant water demand [20], a fact confirmed by the M3 methodology, which simulated an excessive replacement of water. On the other hand, water deficit in the crops development phase can cause a reduction in productivity, which is more pronounced when the water deficit continues from the flowering phase until harvest [6], a fact recorded in the M2 and M4 methodologies.

When it comes to using irrigation as a technique, especially in high-value commercial crops such as protected crops, the correct sizing of the irrigation system and its irrigation management are fundamental, especially in terms of information on various basic variables such as reference evapotranspiration (ET_o), crop evapotranspiration (ET_c) and crop coefficient (K_c), adjusted to local conditions.

3.4 Total water consumption by plants

Figure 4 shows the accumulated volume of water (L vase⁻¹) during the bell pepper crop cycle, starting at 10 DAT, using the different methodologies (M1, M2, M3, and M4), with the differences between the treatments indicated by letters, according to the Tukey test at 5%

probability. It can be seen that the water application methodologies for growing bell pepper are statistically different from each other.

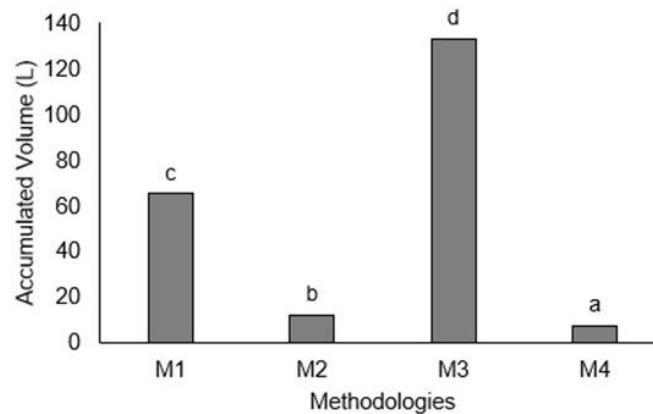


Figure 4: Volume of water applied to peppers grown in pots in a protected environment, from 10 DAT onwards, under different irrigation management methodologies. The letters indicate the statistical difference between the methodologies using the Tukey test at 5% probability.

It can be seen that methodology M3 (daily volume quantified based on planting density per hectare) had the highest accumulated volume of water in the crop cycle, reaching 132.84 L, indicating that the volume applied was significantly higher than all the other methodologies. Methodology M1 (micro-lysimetry) provided the second highest accumulated volume, which was 65.18 L of water, significantly lower than M3 but higher than M2 (water replenishment quantified from the area of the vase) and M4 (quantification from the volume of the vase). Methodology M2 provided an accumulated value of 12.0 L of water, which was statistically lower than M1 and M3 but higher than M4. Finally, the M4 methodology had the lowest accumulated volume of water, at around 7.10 L, which was statistically inferior to the other water application methodologies for growing bell pepper.

Therefore, taking methodology M1 (micro-lysimetry) as a reference, it can be seen that in methodology M2 (volume applied daily calculated from the area of the vase) only 18.41% of the plants' water demand was applied, thus underestimating it. With the M3 methodology, the volume applied (calculated from the number of plants per hectare) was more than 100% higher than that measured in the micro-lysimeters. With the M4 methodology (volume calculated from the volume of the vase), only 10.9% of the volume demanded from the micro lysimeters was applied, showing the greatest difference.

Consequently, the adjustment coefficients of the other methodologies in relation to the total volume demanded from the micro lysimeters were 5.43, 0.49, and 9.18 for methodologies M2, M3, and M4, respectively.

The results shown in Figure 4 indicate significant differences in the accumulated volumes of water between the different water management methodologies used to grow bell pepper. Methodology M3, which is based on planting density per hectare, had the highest accumulated volume, using a density of 20,000 plants ha⁻¹. Planting density influences crop water demand since areas with a greater number of plants require greater volumes of water to maintain an adequate water balance and optimize productivity [21-23]. And higher densities reduce the volume to be applied per plant. In this case, if a density of 40,000 plants ha⁻¹ had been used in this research, the volume applied with it would have been close to the values required using micro-lysimetry.

Adjusting the density can directly affect the efficiency of water use and crop yield, highlighting that the type of irrigation methodology chosen must be compatible with the planting spacing to maximize water use [24, 25] in the soil and the open field. However, when growing in vase in a protected environment, sizing the volume to be applied according to

planting density proved to be efficient in terms of productivity but wasteful in terms of water resources.

Notably, plant biomass development strongly responded to the applied water volume, which explains the distinct behaviors observed among the treatments. It should be noted that the M3 methodology did not differ statistically from the M1 methodology regarding most vegetative variables such as plant height and stem diameter (Figures 1A and 1B) despite applying more than double the water volume (132.84 L e 65.18 L). This lack of significant difference indicates a plateau in crop response, characterizing a luxurious water consumption in M3, where the excess water did not translate into incremental growth. The use of micro lysimeters (M1) to measure the actual evapotranspiration of plants allows for more precise control of the water applied and, consequently, optimizes the use of water compared to more generalized methods [26, 27].

Conversely, the results conclusively demonstrate that methodologies M2 and M4 severely underestimate the water needs and, consequently, the production potential of bell pepper. Irrigation based on the area of the vase (M2) or its limited volume (M4) induces severe water deficit. This restriction directly suppressed plant development, as evidenced by the significantly lower values of height and stem diameter in these treatments (Figures 1A and 1B). Studies already suggest that more precise methodologies, which take into account the specific needs of the plant and its growing environment, tend to result in better responses in terms of plant development and water efficiency [28]. Previous studies have shown that irrigation methods based on container volume can underestimate the plants water needs [29].

4. CONCLUSION

The use of methodologies M3 and M1 resulted in greater plant heights, stem diameters, accumulations of aerial biomass, and yield of bell pepper.

The M2 and M4 methodologies underestimated the volume demanded from micro-lysimetry, while the M3 methodology overestimated it.

The adjustment coefficients of the other methodologies in relation to the volume demanded from micro-lysimetry were 5.43, 0.49, and 9.18 for methodologies M2, M3, and M4, respectively.

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