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DETERMINAÇÃO DO BULBO MOLHADO EM GOTEJAMENTO SUPERFICIAL E SUBSUPERFICIAL PARA CACHOEIRA DO SUL-RS

HENRIQUE SLAIFFER[1] E EZEQUIEL SARETTA[2]

[1]Graduando em Engenharia Agrícola da Universidade Federal de Santa Maria, Campus Cachoeira do Sul (Rodovia Taufik Germano, 3013, 96503-205, Cachoeira do Sul, Rio Grande do Sul, Brasil). E-mail:henriqueslaiffer@hotmail.com.
[2]Professor da Universidade Federal de Santa Maria, Campus Cachoeira do Sul (Rodovia Taufik Germano, 3013, 96503-205, Cachoeira do Sul, Rio Grande do Sul, Brasil). E-mail: ezequiel.saretta@ufsm.br.

1 RESUMO

O entendimento da dinâmica do bulbo formado por emissores de gotejamento em uma aplicação pontual é importante para o dimensionamento de projetos. Com o aumento da instalação de sistemas de gotejamento subsuperficial, a quantificação do bulbo nessa condição também é fundamental para o sucesso do empreendimento. Por isso, este trabalho buscou avaliar as dimensões do bulbo e da área molhada em função da vazão, tanto para a aplicação em superfície quanto em subsuperfície, em Argissolo no município de Cachoeira do Sul, RS. O delineamento experimental utilizado foi inteiramente aleatorizado, em esquema fatorial duplo, composto por cinco vazões (1 a 5 L/h) para duas posições de emissão (superfície e 0,1 m de profundidade), medindo-se o bulbo em profundidade, além da área horizontal e profundidade alcançada. Não houve interação entre os fatores de teste, logo, o projetista necessita apenas uma condição (superficial e subsuperficial) para o dimensionamento do sistema de irrigação. O diâmetro superficial do bulbo molhado, diâmetro máximo e profundidade se relacionaram com a vazão por meio de uma equação potencial, enquanto a área se ajustou ao modelo linear. O diâmetro máximo do bulbo molhado tende a ser obtido em superfície, sendo esse suficiente para a caracterização da área molhada, mesmo para a aplicação em sistema de irrigação subsuperficial.

Palavras – Chave: dinâmica do bulbo, projeto de irrigação, irrigação localizada, Argissolo.

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WET BULB DETERMINATION FROM SURFACE AND SUBSURFACE DRIP IRRIGATION IN CACHOEIRA DO SUL-RS

2 ABSTRACT

The dynamics of the bulb formed by emitters in a source-point application are important for the sizing of projects. Because of the increasing of the installation of subsurface drip irrigation, quantification of the bulb at this condition is fundamental for the success of the irrigation enterprises. Therefore, this work aimed to evaluate bulb dimensions and wetted area as a function of flow, both on the surface and in subsurface application, at Argisoil in the municipality of Cachoeira do Sul, RS. Experimental design was completely randomized in double factorial, composed of five emitter flows (1 to 5 L/h) and two emitter positions (surface and 0.1 m of depth), measuring the bulb at various depths, besides the

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horizontal area and the depth reached. There was no interaction between factors, hence the designers need one condition (surface or subsurface) for sizing the irrigation system. The surface wet bulb diameter, maximum diameter, and depth related to flow by a potential equation, while the area adjusted to the linear model. The maximum wet bulb diameter tends to be obtained on the surface, and it is sufficient for the characterization of the wetted area, even for a subsurface irrigation application.

Keywords: bulb dynamics, project of irrigation, localized irrigation, Argisoil.

3 INTRODUCTION

microirrigation projects. Currently, for humid regions, it is recommended that at least 20% of the area available for the plant be irrigated, 33% for arid regions, and 40% for semiarid regions (BARROS et al., 2019). In the early days of microirrigation systems, the wet fraction was greater than 50%, sometimes reaching 90%. However, with technological developments and other needs, the trend is toward a reduction. On the other hand, it has long been known that lower wet fraction values tend to restrict root development, which tends to concentrate near emission points, thus increasing the susceptibility of plants to water stress and reducing their productivity (BUCKS; DAVIS, 1986).

It is also common to install drip lines subsurface to avoid damage to piping in agricultural operations (THORBURN; COOK; BRISTOW, 2003), in addition to achieving greater application efficiency. This strategy potentially leads to different wetted areas of the dripper, with different bulb dimensions. In clayey soils, for example, owing to their lower infiltration rate, the bulb diameter tends to be larger. In sandy soils, where water tends to percolate more easily, greater bulb depth is expected (MAIA; LEVIEN, 2010).

Analytical and numerical models (KILIC, 2020), nonlinear regressions, and neural networks (KARIMI et al., 2020) are options that have been evaluated for wet bulb prediction under different soil conditions and emitter positions. However, these adjustments have been conducted in the laboratory via reduced-scale models, with possible limitations in reproducing the undisturbed soil structure. Over time, such methodologies will be widely used in all stages of an irrigation project, but they will hardly dispense with *in situ experiments* that generate data sources for project sizing (THORBURN; COOK; BRISTOW, 2003).

In this sense, knowledge of the irrigated soil percentage is relevant, and the dimensioning of the wetted area must be linked to efficient water use. Therefore, experiments for this purpose are necessary, especially for long-lived crops such as orchards, where the irrigation system will be permanently installed. For this to occur, the wetted bulb of the drip irrigation system must be dimensioned, which can be expressed by a mathematical relationship with the emitter flow rate and the application time (MAIA; LEVIEN; MEDEIROS, 2010; BEZERRA, 2015). From this, it is assumed that the horizontal wetted area approximates a circle, which is estimated from diameter measurements. Even so, area measurements should not be dispensed to obtain accurate estimates of the fraction of roots developing in dry/wet regions (KARIMI et al., 2020).

Assuming that the dimensions and wetted area of the bulb increase with the emission flow rate, the objective of this work was to evaluate these variables for dripping conditions on the soil surface and subsurface in Cachoeira do Sul to provide basic sizing information to designers.

4 MATERIALS AND METHODS

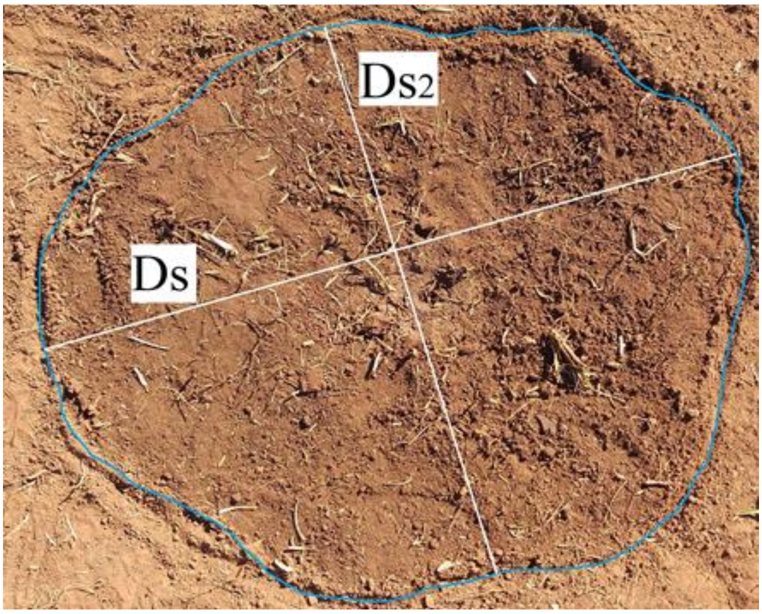
The study was conducted in an experimental area of the Federal University of Santa Maria, Cachoeira do Sul Campus, Rio Grande do Sul. The site is characterized by hilly (rainfed) areas, with an average elevation of 60 m, where the predominant soil is a Red–Yellow Argisol, a native fallow field. The region has expanded cultivation in these areas, with both annual and perennial crops, requiring information on irrigation conditions. The average annual precipitation is approximately 1,500 mm, according to climatological standards from the National Institute of Meteorology (INMET) and data from the campus weather station (as of 2019).

A completely randomized experimental design was used in a double factorial scheme: five flow rates (1, 2, 3, 4 and 5 L/h) and two emission positions (surface and 0.1 m depth), totaling 10 treatments, with two replicates. For all the treatments, the application time was 2 h, since under the same flow rate, the horizontal movement of the bulb did not significantly increase (COOK et al., 2006; OULD MOHAMED EL-HAFEDH; DAGHARI; MAALEJ, 2001; WARRICK, 1986).

A float mechanism was used to maintain a constant load, to which 4 mm diameter microtubes were connected. Individual valves on the microtubes allowed for adjustment of the flow rates, which were measured both at the beginning and end of the tests to ensure stability. A one-hour wait was allowed after the end of the test before the measurements could begin, allowing water movement in the soil profile to cease.

The variables analyzed were surface diameter (Ds), maximum bulb diameter (Dm) along the entire depth profile, maximum depth (Pm) reached by the bulb throughout the profile, and the bulb area on the soil surface, which was obtained through imaging (Figure 1).

Figure 1. Area of the bulb sheltered on the surface, considering a circle with diameter Ds or an ellipse with diameters Ds and Ds2.



Ds: Diameter at the surface (largest diameter of the ellipse)
Ds2: Smallest diameter of the ellipse

Using a metric tape measure with 1 mm intervals, the Ds and horizontal diameters were measured every 5 cm in depth until the Dm was reached, similar to the methods used by Bezerra (2015) and Maia, Levien and Medeiros (2010). Trenches were dug at each application point, levelling the profile for measurements. Subsequently, vertical excavation was carried out until the Pm of the bulb was reached.

To measure the area, photographs of the bulbs on the soil surface were taken, along with a reference length measurement (tape measure). Each image was imported into the image processing software ImageJ (owned by the National Institutes of Health), and its scale was adjusted on the basis of a reference. The surface areas were also estimated from the measurement of Ds, assuming a circular geometry, and from the measurement of the smallest (Ds_2) and largest diameter (Ds), assuming an elliptical geometry (Figure 1).

All measured variables were subjected to the Shapiro–Wilk normality test at the 5% probability level. Subsequently, analysis of variance was performed at the same significance level, revealing the degrees of freedom of the interaction when it was significant. When there were significant effects for the dripper position factor, the treatment with the highest mean value was identified. The t test was also applied to assess the tendency for Dm and Ds to converge.

Because flow rate is a quantitative factor, when it presented a significant difference in the analysis of variance, regression analysis was used to evaluate the models that presented significant coefficients. All measured variables were analyzed for linear, quadratic, and potential models (Equation 1), with the latter being preferred when there was significance due to its extensive use in the literature. Remove from table

$$y = aq^b \quad (1)$$

where:
y is the measured variable;
q is the dripper flow rate, L/h; and
a, b are the adjustment coefficients.

5 RESULTS AND DISCUSSION

The analysis of variance revealed no significant interaction effect between flow rate and dripper position for any of the variables analyzed (Table 1). The dripper position did not significantly affect surface or subsurface irrigation in the analyses. This finding indicates that future evaluation or design procedures do not need to control (separate) the effects of dripper position, simplifying test execution and analysis of results in subsurface irrigation projects with installation depths up to 10 cm.

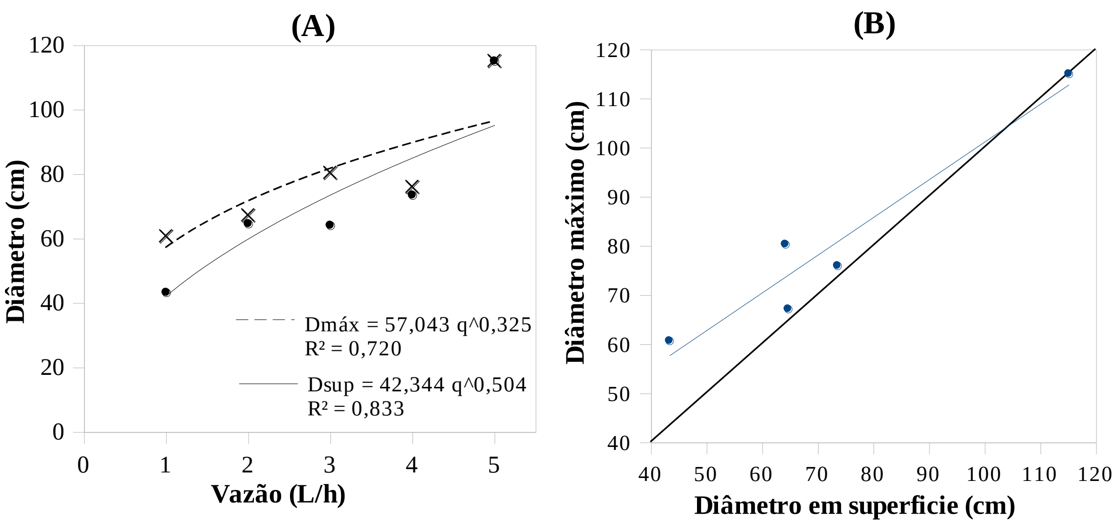
Table 1. Summary of the results of the analysis of variance for the surface diameter (Ds), maximum diameter (Dm) and maximum depth of the bulb (PPm).

Variation factor	Ds	Dm	PM	Image area	Ellipse area	Circle area
	Pr Value > Fc					
Flow rate	0.001	0.001	0.002	0.002	0.009	0.001
Position	0.113	0.966	0.895	0.925	0.583	0.253
Flow * Position	0.121	0.856	0.616	0.375	0.451	0.830

Pr = probability, Fc = calculated value of F – Fisher-Snedecor.

On the other hand, the flow rate significantly affected all the variables analyzed (Table 1). Figure 2A represents the relationship between the flow rate and surface bulb size, with the potential model being the one that presented a statistical fit through regression analysis. For a flow rate of 1 L/h, the estimated surface diameter was 42 cm, reaching 95 cm as the flow rate increased to 5 L/h. Since the exponent was approximately 0.5, the increase in flow rate does not correspond to the same increase in surface bulb size.

Figure 2. Dimensions obtained as a function of flow rate and bulb diameter (A). Convergence analysis for bulb dimensions (B).



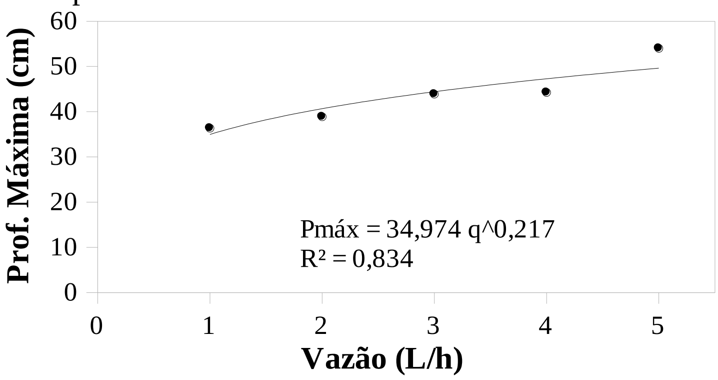
Subsurface water application was able to wet the soil surface in the same proportion as surface application. In a soil with similar characteristics to the one evaluated, Cook et al. (2006) obtained results similar to those of this study for surface and subsurface emitters for both 1 h and 4 h of water application, with a flow rate of 1.65 L/h. According to Thorburn, Cook, and Bristow (2003), who evaluated 29 different soils, the diameter and depth are expected to be greater for surface emitters than for subsurface emitters since part of the water from buried emitters moves upward, reducing the volume moved in the horizontal and vertical directions.

On the other hand, in specific tests carried out in Red Nitosol, different results from those of the present work were verified by Barros et al. (2009), which is in agreement with the findings of Marques, Frizzone and Teixeira (2006) that subsurface dripping does not provide satisfactory wetting of the soil surface.

It was expected that subsurface water application would result in a horizontal increase in the bulb at depth, thus resulting in a maximum bulb diameter and a surface diameter. However, within the fit limits, the equations converged between the maximum and surface diameters (Figure 2A). Thus, the maximum diameter tended toward the surface diameter, with no significant difference between them (t test). Figure 2B shows the convergence of bulb diameters in wet bulb assessments for this soil, highlighting that surface measurements are sufficient for analysis.

The bulb's reach depth also potentially adjusted in relation to the flow rate (Figure 3), similar to that reported by Bezerra (2015). Even for the lowest flow rate, the bulb reached the estimated depth of 35 cm, increasing to 50 cm when the flow rate was 5 L/h. The designer must pay attention to this increase in depth, limiting the flow rate according to the effective depth of the crop's root system to avoid water percolation (SOUZA; MATSURA, 2004).

Figure 3. Bulb reach depth as a function of flow rate.

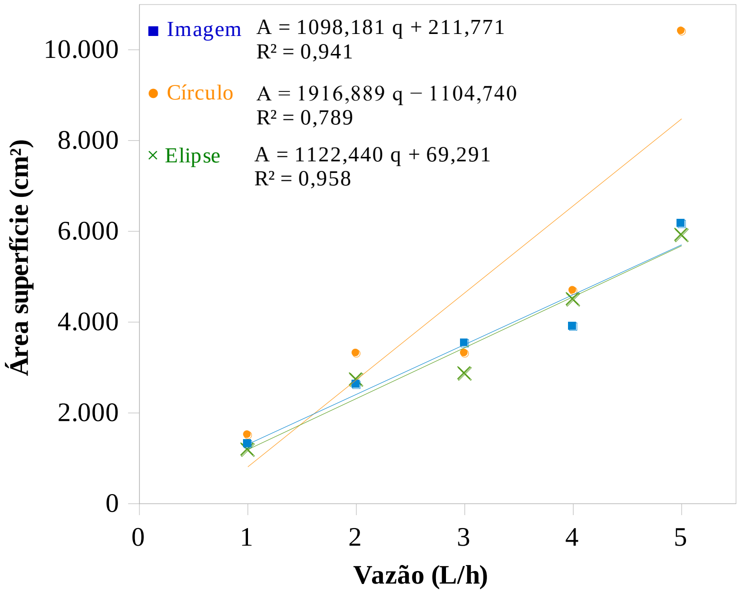


The effective absorption depth of most crops is 40 cm, which is a value commonly reported by Pires et al. (2001) reported that flow rates above 2 L/h were excessive for drip systems in the evaluated soil, similar to the results obtained for tomatoes grown in clay soil by Ould Mohamed El- Hafedh, Daghari and Maalej (2001). For pipes with integrated tablet-type drippers, the flow rates commonly found commercially in the study region vary between 0.5 and 1.5 L/h, which is adequate for the results obtained in this study.

The increase in the horizontal size of the bulb (Figure 2 A) was more sensitive to the increase in flow rate in relation to the depth of the bulb (Figure 3). For the initial flow rate of 1 L/h, the maximum diameter was 60.7 cm, increasing to 115.1 cm when the flow rate increased to 5 L/h, and the depth increased from 36.4 cm to 54 cm. This greater evolution of water movement in the horizontal direction due to the increase in flow rate with depth was also observed in the evaluations of Souza and Matsura (2004).

As the dimensions of the bulb increased (Figure 2), the area measured per image also increased, as shown in Figure 4. However, unlike the previous variables, only the linear model was significant.

Figure 4. Horizontal area of the bulb on the surface, obtained via image observation and geometry (area calculation).



The surface area values obtained in the tests (Figure 4) were approximately 1.5 times greater than those reported by Ould Mohamed El- Hafedh, Daghari and Maalej (2001) for silty clay loam soil; this difference occurred because of natural differences between the soils studied. The same authors also observed linear behavior between the flow rate and the wetted area, obtaining wetted areas of 1.60, 2.70 and 4.80 cm² for flow rates of 2, 4 and 8 L/h, respectively.

Typically, the horizontal size of the bulb at the surface is considered the diameter, assuming that the water application has a circular shape. However, this must be evaluated for each soil condition studied, as an example is the situation observed by Rosa et al. (2004) for an Oxisol in the northwestern region of Paraná, where the authors observed an asymmetric horizontal advance in the movement of water along the soil profile, which possibly varied over time.

In addition to the imaged area ratio, Figure 4 shows the estimated area results, which assume circular and elliptical shapes. For the circular geometry, the diameter of the bulb in the figure was considered. For ellipses, the bulb measurement was considered the largest diameter, and an additional perpendicular measurement was considered the smallest diameter.

When assumed to be elliptical, the surface area presented results similar to those of the image and the ellipse for all flow rates. The circular shape behaved similarly to the previous shape up to a flow rate of 4 L/h but overestimated the area when the flow rate was 5 L/h. Therefore, for flow rates up to 4 L/h, there is no need to consider the bulb as elliptical; it is sufficient to simply take a measurement as the diameter, assuming that the wet bulb is symmetrical for this region, unlike what was proposed by Rosa et al. (2004) in the northwest region of Paraná. There is also no need to image the horizontal surface to obtain the area, which simplifies the process of estimating the same area.

On the basis of the results obtained regarding both bulb dimensions and area, future investigations in other soils in the region can explore other parameters, such as the ideal wet fraction for crops, dripping under *mulching conditions*, and surface slope. Model adjustments via neural networks have proven effective in estimating bulbs, with potential applications in subsurface irrigation studies, as explored by Karimi. et al. (2020). However, such investigations are still carried out in the laboratory, with the soil placed in transparent boxes, thus aiming to facilitate measurements. However, the soil structure significantly impacts the wetting pattern (THORBURN; COOK; BRISTOW, 2003). Therefore, future research may include new characteristics that expand the applicability of the results, facilitating the sizing of irrigation systems.

6 CONCLUSIONS

The surface diameter of the wet bulb, maximum diameter and depth increased with increasing dripper (emitter) flow rate, indicating a potential relationship.

Under the same conditions as those used in the present study, the maximum diameter of the wet bulb in a subsurface drip irrigation system tends to be the same as that at the surface, with the latter being sufficient to characterize wetting.

Flow rates greater than 2 L/h in a subsurface and surface drip irrigation system in the region of the present study may cause water loss through percolation, and the designer responsible for dimensioning must be careful when selecting this value.

The surface area of the wet bulb increased linearly with the flow rate, presenting the same behavior as the results obtained by imaging and through circular and elliptical geometric shapes, and it was possible to choose between these options during the characterization of this variable in projects developed in the region of the present study.

The installation of a drip irrigation system with emitters located both on the surface and subsurface presented, under the conditions of the present study, the same results, allowing measurements regarding the wet bulb to be made in only one of these locations (surface or subsurface).

7 ACKNOWLEDGMENTS

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