DISTRIBUTION OF WATER IN SANDY SOIL APPLIED BY DRIP

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ABSTRACT: The search for the use of water with high levels of efficiency has motivated the use of drip irrigation in several agricultural systems. However, for the efficiency be ensured, it is necessary that the water distribution in the soil profile must to be known in more details. As it is a highly variable process, function of the local characteristics, is essential the study of each case. The objective of this research was evaluating the water distribution in the soil profile, from drippers installed in surface and 0.15 m below the soil surface. The experiment was realized in the Technical Center of Irrigation (TCI) of the State University of Maringá – PR. The water monitoring in the soil profile was done with TDR probes installed in a box containing sandy soil, at the depths from 0.05 to 0.80 m; and 0.05 to 0.35 m of lateral spacing, at intervals of 0.05 m, totalizing 30 probes. The treatments were differentiated in relation of the installation depth of the emitters (0.0 and 0.15 m) and flow (1, 2, 4, 6, and 8 L h^{-1}). The irrigation time was 8 hours continuous with reading of the TDR probes each 30 minutes. The results allowed concluding that the wet area with the emitter positioned on the soil surface was directly proportional to the flow increase. For the underground dripper, this area was substantially smaller and the water losses by percolation were higher, mainly to the flows higher than 4 L h^{-1}, which provided to unacceptable water losses that should be avoided.

KEYWORDS: time Domain Reflectometry, TDR probes, irrigation.

DISTRIBUIÇÃO DA ÁGUA EM SOLO ARENOSO APLICADA VIA GOTEJAMENTO

RESUMO: A busca pela utilização de água com elevados níveis de eficiência tem motivado o emprego da irrigação por gotejamento em diversos sistemas agrícolas. No entanto, para que esta eficiência seja assegurada, faz-se necessário que a distribuição de água no perfil do solo seja conhecida de forma detalhada. Como se trata de um processo muito variável, em função das características locais, é essencial seu estudo, para cada condição operacional. O objetivo do presente trabalho foi avaliar a distribuição da água aplicada no perfil do solo, a partir de gotejadores instalados na superfície e a 0,15 m abaixo dela. O experimento foi realizado no Centro Técnico de Irrigação (CTI) da Universidade Estadual de Maringá – PR. O monitoramento da água no perfil do solo foi feito com sondas de TDR instaladas em uma caixa contendo solo arenoso, nas profundidades de 0,05 a 0,80 m, com 0,05 a 0,35 m de espaçamento lateral, em intervalos de 0,05 m, totalizando 30 sondas. Os tratamentos foram diferenciados em relação à profundidade de instalação do emissor (0,0 e 0,15 m) e vazão aplicada (1; 2; 4; 6 e 8 L h^{-1}). O tempo de irrigação foi de 8 horas contínuas, com leituras das sondas do TDR a cada 30 minutos. Os resultados permitiram concluir que a área molhada com o emissor posicionado na superfície do solo foi diretamente proporcional ao aumento da vazão. Para gotejador enterrado, a esta área foi substancialmente menor, e as perdas de água por percolação foram mais elevadas, sobretudo para vazões acima de 4 L h^{-1}, as quais proporcionaram perdas inaceitáveis da água, devendo ser evitadas.

PALAVRAS-CHAVE: reflectometria no Domínio do Tempo, sondas de TDR, irrigação.

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INTRODUCTION

The drip irrigation system is recognized for high efficiency in the implementation of water and fertilizer. However, this application must be associated with a well sized irrigation project, which considers, among several factors, the movement of water in the soil (BERNARDO et al., 2008). In relation to the placement of water source it can be located on the surface, what is more common, or can be buried, that is in subsurface.

The buried drip system, compared to the surface has as its main advantages applying water and fertilizer directly into the root zone of plants, providing greater growth, reducing potential losses due to evaporation, favoring the mechanical cultivation procedures, reducing the moisture on the surface of the soil, disease incidence and the attack of rodents to the pipes (MELO et al., 2010; LIU et. al., 2011).

The use of drip irrigation with emitter buried has been adopted more frequently, demonstrating the importance and efficiency in the use of this technique to the Brazilian conditions, with emphasis on melon crops (MONTEIRO, 2007), papaya (COELHO FILHO et al., 2007), sugarcane (DARLI & CRUZ, 2008; GAVA et al., 2011), eucalyptus (MELO et al., 2010), coffee (MARTINS et al., 2007). Nevertheless, the surface drip has also been recommended by some researchers to carrot (Lima et al., 2012), onion (VILAS BOAS et al., 2012), tomato fields (PIRES et al., 2009) among others.

The water movement in the soil, from a point source, is complex and depends on a large number of variables, sometimes of difficult measurement and in most cases based only on soil texture (LAMM et al., 2007). The distribution of water in the soil profile, from a point source of water application promotes the formation of a wet bulb that corresponds to the volume of soil moistened. The knowledge of its dimensions is an indispensable tool in determining how and when to irrigate. The dimensions of the wet bulb can be measured directly in the field, with open trenches, or by indirect methods, using tables or pre-established models (KELLER & BLIESNER, 1990). However, differences in chemical and physical compositions of Brazilian soils allow indirect methods, adjusted for all soils, are not always adequate, making indispensable specific studies (BARROS et al., 2009).

The horizontal and vertical dimensions of the wet bulb allow adequacy in the water application in the culture characteristics in order to get efficiency of irrigation and fertigation (ZANINI et al., 2007). To do so, it must have a combination of the flow emitter and spacing in the system, so that it can be applied the water volume compatible with the culture water demand, in a region of soil profile in which this water is effectively used (SOUZA et al., 2004; LOPES et al., 2009; MAIA, 2010).

For an environment suitable to the development of plants is fundamental the choice of emitters and proper values of their flow; this is the basic step for the design of drip irrigation projects. Thus, the objective of this study was to evaluate the movement of water in sandy soil, using different flows emitters positioned on the surface and subsurface of the soil to provide basic subsidies to the design of drip irrigation.

MATERIAL AND METHODS

The experiment was installed in the laboratory at the Irrigation Technical Center (CTI) of the Universidade Estadual de Maringá-PR, located in the Northwest of the State of Paraná. Plastic boxes were used with volume of 0.70 m^3 filled with representative soil of "Sandstone Caiuá" classified as Psamític Dystrophic Red Latosol, (EMBRAPA, 2006); with average density of 1530 kg m^{-3} and values of field capacity and permanent wilting point of 0.30 and 0.16 m^3 m^{-3} respectively. The values of granulometric fractions and textural ranking are presented on Table 1 and the dimensions of the used plastic box are shown in Figure 1.

TABLE 1. Particle size analysis of the soil to depths of 0 to 0.20 m, 0.20 to 0.40 m, 0.40 to 0.60 m.

Depth	Sand	Silt (%)	Clay	Textual Class
0.00 – 0.20	85.80	3.20	11.00	SANDY
0.20 – 0.40	84.70	3.30	12.00	SANDY
0.40 – 0.60	80.20	5.60	14.20	SANDY
Total porosity (%)				43

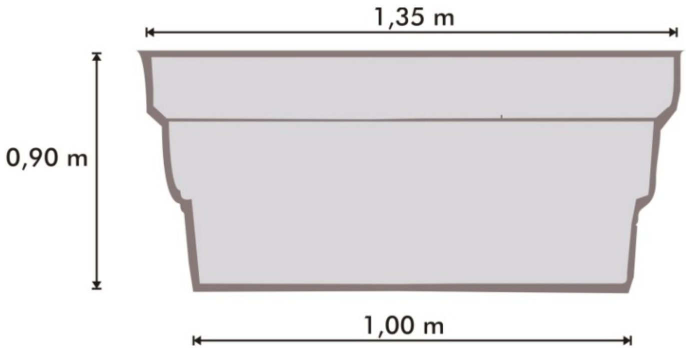

FIGURE 1. Dimensions of the box used for experimentation.

After the placement of the boxes in a suitable place, the first step was to promote an opening at their bases, to serve as drainage system. After internally, it was placed a layer of crushed stone, approximately 0.10 m covered by a Bidim fabric mat. Further, the box was filled with soil without clod, sieved on a mesh of 0.005 x 0.005 m and dried in the air. The accommodation / restructuring of the soil particles inside the box was conducted with watering over 30 days based on the method proposed by POLANIA et al. (2009).After this step undisturbed soil samples were collected for determination of average density.

The experimental design used was the fully randomized trial based on different flow rates (1, 2, 4, 6, and 8 L h^{-1}) and two depths of emitters (0.0 and 0.15 m) totaling 10 treatments with three repetitions irrigated by drip system.

Initially, for assembly the emitter, it was made a small hole in a PVC pipe of 0.5 inch in diameter required for inserting a micro tube of 1.5 m in length and 1 mm in diameter. This micro tube was wrapped on PVC pipe and then fixed with duct tape, leaving only the last 0.15 m to the end for water application. At one end of the head tube was set a drawer gate, enabling flow adjustment during each irrigation event. On the opposite end it was attached a small drain, which was kept closed during water applications. The system pressure was monitored by a pressure gauge installed near the emitter and maintained at 98 kPa . Figure 2 outlines the parts of the emitter and their main dimensions.

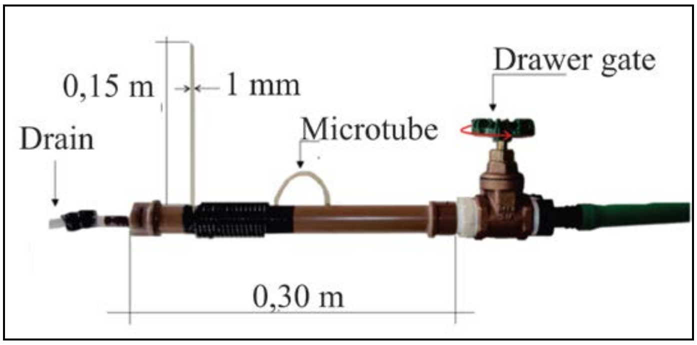

FIGURE 2. Dimensions of emitter built for experimentation.

Irrigations were continuous, for each treatment, lasting 8 hours. Measurements of wet area on the surface of the soil, were performed with a millimeter scale ruler at intervals of 0.5 hours. This determination is based on the relationship between the wet and dry area, the latter estimated by the maximum radius which the probes were present radially, that is, 0.35 m. The measurement of the diameter for the calculation of the wet area was held in two directions, horizontally and vertically as shown in Figure 3.

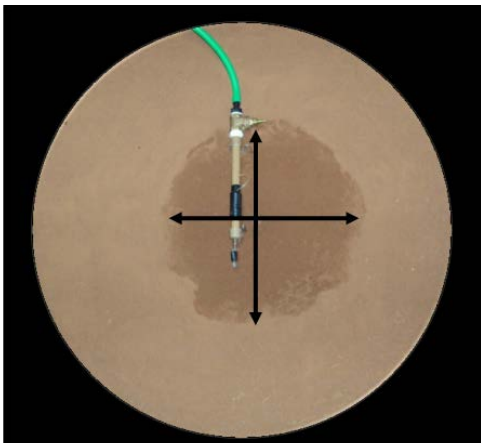

FIGURE 3. Direction representation of the measures, horizontal and vertical determination of the wetted area.

The measurement of soil moisture and its monitoring over time as a function of the applied flow were performed with the use of an equipment TDR TRASE (soil moisture equipment Corp., Santa Barbara, CA) connected in the probes inserted in the soil in the depths from 0.05 to 0.80 and 0.05 to 0.35 away from the emitter, promoting simultaneously specific measures with the movement of the water in the soil . The probes were constructed according to the methodology proposed by SOUZA et al. (2006) and the arrangement in the soil profile for monitoring the humidity based on NOGUEIRA et al. (2000). The distribution of water in the soil profile was monitored by 30 probes installed during the filling of the boxes with the soil dried in the air, which were connected to a multiplexer connected to the TDR equipment, automating the process of readings (Figure 4).

The conversion of the Apparent Dielectric Constant (k_a) measured by TDR for soil moisture in $m^3\ m^{-3}$ was made by means of the calibration model presented in [eq. (1)], obtained specifically for the studied soil, following the procedures established in the manufacturer's standards. The adjustment obtained between the pairs of values of the soil moisture (θ) versus (k_a) was significant. The model explained 72% of the variation in water content on maximum and minimum interval of 0.28 to 0.16 $m^3\ m^{-3}$, respectively.

$$\theta = 0.013*k_a + 0.091 \quad (R^2 = 0.72*) \qquad (1)$$

where,

θ - Soil moisture $m^3\ m^{-3}$,

k_a -Apparent Dielectric Constant (dimensionless).

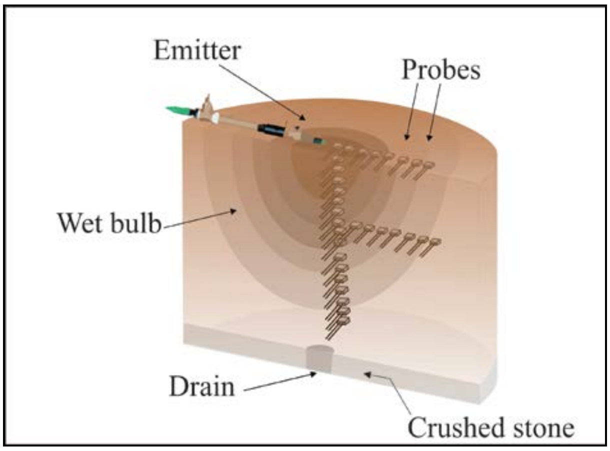

FIGURE 4. Scheme of distribution of TDR probes for determining the movement of the water.

Initially, the experimental data were submitted to the Shapiro-Wilk tests (P > 0.01) and Levene (P > 0.01), for verification of normality and residual homoscedasticity, respectively. Subsequently, it was submitted to variance analysis with quantitative effects on orthogonal polynomials, according to its significance by the test F. As for variance analysis as for the estimation of coefficients of the regression models, it was used the statistical program R, version 2.2.1 (R. DEVELOPMENT CORE TEAM, 2013). Then were drawn the maps of water distribution in the soil, by means of interpolation using the method of the inverse square of the distance, considering the different flows and depth of the emitters using the features available in the software Surfer® 8.0 (GOLDEN SOFTWARE, 2002).

RESULTS AND DISCUSSION

Figure 5 lists the wet superficial area and the advancement of vertical water as a function of irrigation time and different flows studied with the emitter on soil surface. According to Figure 5 (A) and (B) the increasing on wetted area is proportional to the increase in flow emitters positioned on the ground surface.

In the initial phase of the infiltration process, until 1 hour, emitters of 1, 2, and 4 L h^{-1} presented similar conformation, differentiating shortly thereafter. This fact shows that for horizontal advance of water in the soil occurs under the evaluated conditions it is necessary that the area just below the point of water emission has enough moisture to override gravitational potential forces leaving to act the matric potential in the system. The largest flows assessed, 6 and 8 L h^{-1} prove this assertion, since, due to the greater supply of water, there has been greater advancement of water in the soil, horizontally. These results corroborate with those presented by BRESLER et al. (1971), BRESLER (1978), SCHWARTZMAN & ZUR (1986), and KELLER & BLIESNER (1990), who concluded that the increase in emitter flow results in an increase in horizontal movement and a lower expansion on vertical movement of water in the wet bulb.

In the two evaluated systems, drip on surface and buried, the stabilization of the wet area occurred when the water applied to the soil has reached the limit of 0.80 m, simultaneously with the drainage process . This result corroborates with study by SOUZA et al. (2007), which is found that occurred leaching of the solution and stabilization of the wet surface area on sandy soil when applied frequent irrigation depth, after a period of 6 hours and a flow rate of 1 L h^{-1}. Different results were observed by BARROS et al. (2009), who concluded that the high frequency irrigation, in Red Nitosols did not promote stabilization of the wetted area being the emitter positioned on surface or 0.10 m depth. These results show evident changes in the process of water distribution in the soil, as function of physical variations on intrinsic properties on the soil, explaining the need for specific studies to the planning of irrigation by drip, in a proper manner.

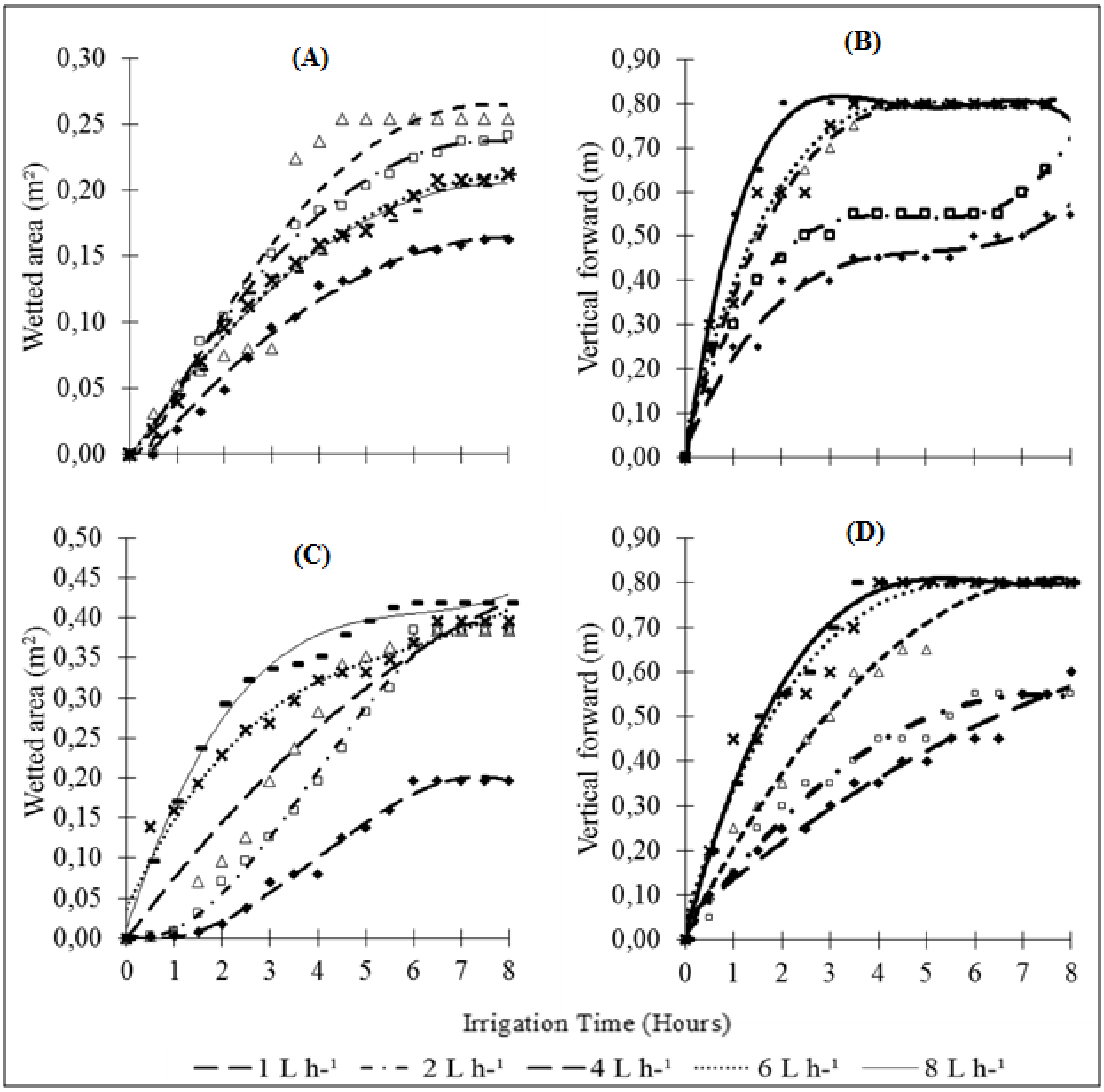

FIGURE 5. Wet area and vertical forward of the front wetting as function of time for irrigation for the emitters at surface (A) and (B) and subsurface (C) and (D), respectively.

As for the formation of the wetted area, the vertical forward of the soil water as a function of time is proportional to the increase on flow rate of the emitters. Thus, this process is faster for higher flow rates, 6, and 8 L h^{-1}, reaching half the depth of the study (0.40 m) in approximately 1 hour after the beginning of irrigation. The use of these emitters to soils of this nature should adopt an elaborate irrigation management in order to avoid excessive loss of water to limits not explored by the root system of the crop and possibly fertilizer applied through irrigation.

The other flows 1; 2 and 4 L h^{-1} presented vertical advance less pronounced, as shown on Figure 5 (B) and (D). To 1 L h^{-1}, half depth (0.40 m) was reached approximately 4.5 hours after the beginning of irrigation. Similarly and with faster vertical advance, water applied by emitters of 2 L h^{-1} reached the depth of 0.40 m in 3.5 hours while, with the flow of 4 L h^{-1} the time was less than 2.5 hours.

The values shown on Figure 5 (B) and (D) expressed the wetting front reached the depth limit data acquisition (0.80 m) while the flow of 1 and 2 L h^{-1} the irrigation for 8 consecutive hours was not enough to the vertical forward reached the same depth.

As described on table 1, the soil in question presents very high sand content, which is associated with a pore size distribution concentrated in the range of macro pores, which constitutes the largest part of its total porosity. This fact makes possible high infiltration rates, i.e. the vertical movement of water in the soil occurs without major restrictions, especially from a punctual source of water application, with low flows.

SOUZA et al. (2004) reported that the two main forces that govern the advancement of wetting front are the gravitational and matrix potential, and depending on the applied flow, occurs initially the acting on the gravitational potential at the expense of the matrix potential, forcing the water flow in the vertical direction. Figure 5 (C) and (D) represent the relationship between the wetted area on the soil surface as a function of irrigation time and flow used with the emitter positioned to 0.15 m.

The wet surface area with buried emitters is lower compared to emitter placed on the soil surface, moreover, it has not been possible to observe a direct proportionality between the flow rates used and the wetted area, as featured previously on emitters positioned on the soil surface.

The biggest trend in the formation of the wetted area is represented by the flow of 4 L h^{-1} followed by 2 L h^{-1}. This relationship is enough to clarify that there was a better balance between the total potential that govern the flow of water to these two treatments. Thus, on the occasion that is crucial the use of subsurface emitter and formation of a wetted area on the soil surface where can be chosen the flow of 2 and 4 L h^{-1}. According to MAROUELLI et al. (2002) the biggest problem, when using buried drip irrigation is the high rate of losses of the seedlings in the early stages of growing. In this case, some producers adopt a second irrigation, usually sprinkling until the planting is established; depending on the culture value this investment is not feasible for the subsurface system.

The smallest proportion of wetted area was obtained with the emitter on the flow of 1 L h^{-1}. Under the study conditions it was possible to identify the low capacity for capillary rise of water in this soil. Factors inherent to the physical characteristics of the soil, high total porosity, and sandy texture, as described in Table 1 are associated to this fact. Unlike the flow of 2 and 4 L h^{-1}, this emitter, with this small flow, can fit better to irrigation projects that do not require surface moisture in proportion presented for the surface emitter.

In the case of flow of 6 and 8 L h^{-1} there was a resemblance in the proportion of formation on superficial wetted area. However, similarly to treatments with emitter positioned on the surface, this trial was characterized by the rapid advance of the vertically wetting front, as shown on Figure 6. Under the conditions of the water assessment applied to the soil has reached the depth of 0.40 m at approximately 1 hour with flow of 8 L h^{-1} and a little more than one hour, considering the flow of 6 L h^{-1}. This time was 3 hours when used the flow of 4 L h^{-1}.

The smaller flows, 1, and 2 L h^{-1} did not promote the range of depth data acquisition limit of 0.80 m depth, in 8 hours irrigation. In order to complement this information, as Figures 6 and 7 aimed to show the horizontal and vertical advance of the soil wetting front comparing to the different moisture profiles (m^{3} m^{-3}), flow of emitters (L h^{-1}) and irrigation time, in hours. Due to the high number of generated graphics, it was chosen wet bulbs formed up to a depth of 0.40 m, which corresponds to the depth of the active root system of the majority cultivated plants.

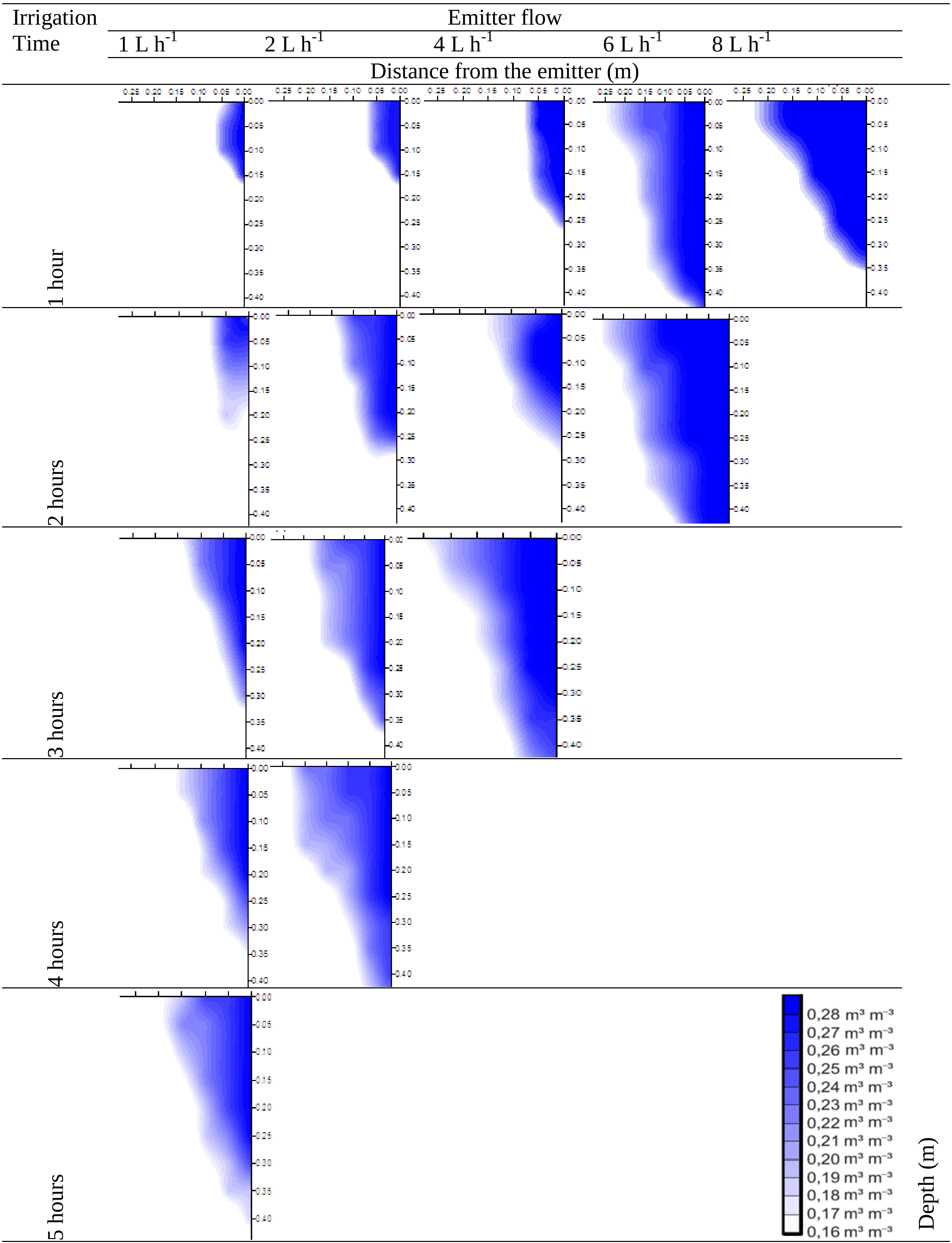

FIGURE 6. Distribution of water for different flow rates up to 0.40 m depth, and emitter placed in the surface.

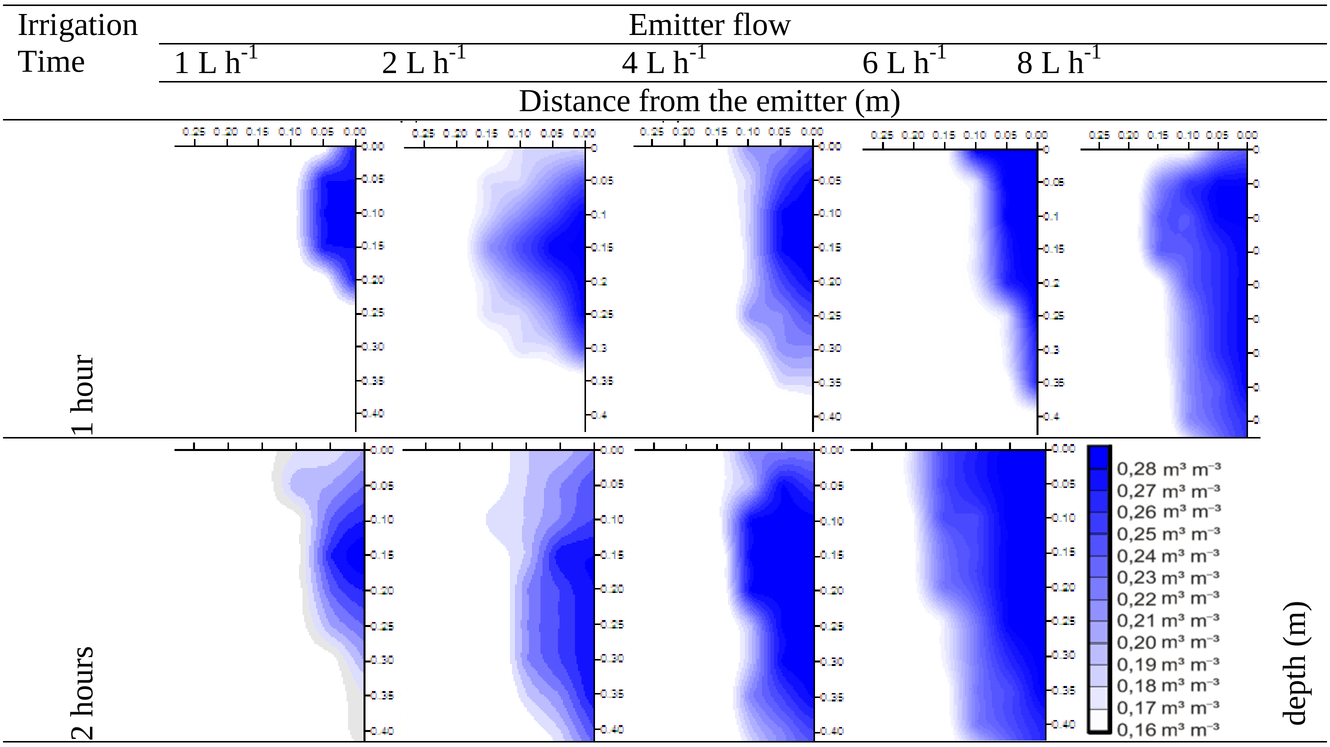

FIGURE 7. Distribution of water for different flow rates up to 0.40 m depth, and emitter placed in the subsurface.

CONCLUSIONS

The obtained results showed that the process of wet bulb formation in dripping presents itself with high variability due to the characteristics of each site and the pattern of water application. It is imperative that local evaluation must be conducted.

Buried emitter can be used for wet bulb formation of smaller width and lower wet surface, providing water at a shorter distance from the emission point. Consequently, the advance in depth is greater under these conditions. For this standard installation, flow over 4 h^{-1} should be avoided due to the large advance in depth which promotes high water losses.

Emitter positioned on the surface promotes greater lateral advancement of water, allowing the use of higher flow rates, with proportionally smaller water losses in depth.

The appropriate combination of the parameters, from the values obtained in this study, can support drip irrigation projects in areas with this soil, ensuring high levels of searched efficiency.

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