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WET BULB FORMATION IN SANDY AND CLAY TEXTURES UNDER DRIP IRRIGATION SYSTEM

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1 ABSTRACT

This study aimed to evaluate the formation of wet bulbs in sandy and clayey cultivated soil. The evaluations were made in two Coffea Canephora cultivated areas, the soil texture being sandy to loam (area 01) or sandy clay (area 02) typical of coastal zones. For the wet bulb characterization, to measure soil moisture, several cylindrical access-tubes were mounted for use in time-domain reflectometry. The tubes were arranged at six points in relation to the plant, being one point on the planting line between two plants and five points on the planting line (0.10; 0.40; 0.70; 1.10 e 1.50 m of the plant), the measurements conducted in four depths ranges (0.00-0.20; 0.20-0.40; 0.40-0.60 e 0.60-0.80 m) with three replicates. The wet bulb presented vertical formation in the area with sandy to loam texture and reached a depth between 0.40 and 0.50 m, with a range of up to 0.10 m between coffee lines. The wet bulb formation occurred in the horizontal direction in the area with sandy clay texture, reaching depth values of 0.20 to 0.30 m, with a range of 0.10 to 0.15 m between lines.

Keywords: drip irrigation, irrigation management, water movement in the soil

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2 RESUMO

Objetivou-se avaliar a formação do bulbo molhado em solo arenoso e argiloso cultivado, sob irrigação localizada. As avaliações ocorreram em duas áreas cultivadas com cafeeiro Conilon, sendo o solo de textura de arenosa a média (área 01) e textura argilo arenosa (área 02), típico de tabuleiros. Para a caracterização do bulbo molhado foi realizada instalação de tubos de acesso para medição da umidade do solo por meio da reflectometria no domínio do tempo. Os tubos foram dispostos em seis pontos em relação à planta, sendo um ponto na linha de plantio do cafeeiro entre duas plantas, e em cinco pontos na entre linha (0,10; 0,40; 0,70; 1,10 e 1,50 m da planta), sendo as medições realizadas em quatro faixas de profundidades (0,00-0,20; 0,20-0,40; 0,40-0,60 e 0,60-0,80 m) com três repetições. O bulbo molhado apresentou formação para a área com textura arenosa a média na direção vertical, atingido profundidade entre 0,40 a 0,50 m, com alcance de até 0,10 m na entrelinha do cafeeiro. A área com textura

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argilo arenosa a formação do bulbo se deu na direção horizontal, atingido profundidade entre 0,20 a 0,30 m, com alcance de 0,10 a 0,15 m na entrelinha do cafeeiro.

Palavras-chave: gotejamento, manejo da irrigação, movimento de água no solo

3 INTRODUCTION

The bulb or wet volume of the soil is the water distribution in the wet volume by dripping; is formed from a point source of water in the soil, which propagates three-dimensionally through the wetting front, as well as an indispensable tool for determining how much and when to irrigate (BARROS et al., 2009; ELAIUY et al., 2015).

According to Subbaiah (2013), the flow of water through drip irrigation is more complex, given that water is distributed from emitters, and through each emitter it spreads in all directions. Such water distribution is in sharp contrast to the dynamics and geometry of the wet soil volume when sprinkler irrigation is performed, in which the total area of the soil surface is wet and the vertical distribution of water content in the soil is essentially constant (ZUR, 1996).

Reliable information on the dimensions of the bulb under drip irrigation helps to determinate the ideal emitters flow rate and spacing proposing a reduction in the system cost and provide better soil water conditions for a better use of water and fertilizers, as well to help in the adequate estimation of drippers per plant and its location in relation to plants or plant lines and directly influence crop productivity and water slide calculations and the number of nutrients in the wet soil volume, being of great importance for the fertigation program (MAIA, 2010; KEYYAN; PETERS, 2011; ELAIUY et al., 2015).

This volume can be measured directly in the field, through opening trenches or using indirect measurements, such as tables or mathematical models (BIZARI; GRECCO; SOUZA, 2016).

Alternatively, the form of a wet soil volume can be measured and controlled using water content detection equipment such as time-domain reflectometry (TDR), which measures the water content and electrical conductivity using a single probe within the soil volume. The TDR method provides nondestructive and repetitive measurements with relatively high accuracy (± 1-2% volumetric), (TOPP; DAVIS; ANNAN, 1980; COELHO; OR, 1996; SOUZA; MATSURA, 2003), being a promising technique in the study of wet soil volume (SOUZA; FOLEGATTI; OR, 2009).

Unfortunately, such measurements are often underestimated, and the current practice in Brazil and worldwide is often based on empirical information or data collected indiscriminately from professional literature (ELAIUY et al., 2015).

There is a need for a robust, yet easily approach to calculate and visualize the moistening pattern from drip irrigation systems to aid in management (SUBBAIAH, 2013). Due to the specificity of the soils, the adjusted tables for this purpose are not always adequate for the Brazilian conditions, being necessary studies that adequately indicate this volume. (BIZARI; GRECCO; SOUZA, 2016)

The shape and size of the wet bulb depend on the flow rate applied, the type of emitter, the duration of irrigation and the soil type (PIZARRO, 1996). Other factors influencing the dimensions of the wet bulb are: soil structure and texture, irrigation system, emitter height in relation to the soil, initial soil moisture and presence of concretions and gravel (BELL et al., 1990; FOLCH; FÁBREGA, 1999; ELAIUY et al., 2015).

This study aimed to evaluate the formation of the wet bulb in sandy and clayey soil under local irrigation.

4 MATERIALS AND METHODS

The experiment was conducted in two areas cultivated with coffee Conilon (*Coffea canephora* Pierre ex Froehner), using drip irrigation, located in the city of São Mateus, ES, with an altitude of 39 meters. The soils of study areas 01 and 02 were classified as Red-Yellow Latosol, sandy to loam texture (area 01) and sandy clay texture (area 02), typical of coastal trays, according to Embrapa methodology (2013), predominating in all areas with flat topography with a declivity lower than 1%.

For the characterization of the soils and granulometry, deformed samples were taken at two positions in the planting line and between planting line of the coffee tree at four depths (0.00-0.20; 0.20-0.40; 0.40-0.60 e 0.60-0.80 m), and four replicates, the analyzes were performed according to Embrapa methodology (2011). The Table 1 and 2 shows the results of the granulometric and physical-hydrical soil analyzes.

Table 1. Soil granulometric at four depths and two positions in the two areas under study, in São Mateus-ES.**Error! Not a valid link.**Definition: Sd – soil density

Table 2. Physical-hydrical attributes at four depths and two positions in the two areas under study, in São Mateus-ES.

Area	Position	Depth (m)	Macro (%)	Micro	FC	WP
1	Planting line	0,00-0,20	26,31	18,45	19,8	8,5
		0,20-0,40	26,07	18,89	19,5	8,6
		0,40-0,60	18,65	21,56	18,8	8,1
		0,60-0,80	17,44	22,68	18,9	8,7
	Between ines	0,00-0,20	19,45	21,89	19,5	8,6
		0,20-0,40	18,78	21,78	19,3	8,7
		0,40-0,60	18,9	22,04	18,4	8,9
		0,60-0,80	19,02	22,1	18,2	8,9
2	Planting line	0,00-0,20	23,56	18,98	22,6	8,5
		0,20-0,40	23,8	18,64	22,3	8
		0,40-0,60	17,76	21,78	21,6	8
		0,60-0,80	17,56	22,89	21,6	7,9
	Between ines	0,00-0,20	20,8	16,5	22,2	8,4
		0,20-0,40	19,57	18,89	22,1	8,1
		0,40-0,60	17,89	21,32	21,4	7,9
		0,60-0,80	17,67	22,59	21,2	7,9

Definition: Macro – Macroporosity; Micro – Microporosity; FC – Field capacity (%vol); WP – Permanent wilting point (%vol).

The irrigation system used in the experimental areas was the drip irrigation system, with emitter flow of 2.5 L h^{-1}, spaced 0.50 m apart, using self-compensating dippers and a filter system to avoid drip clogging. Irrigation management in area 01 was conducted by applying two hours of irrigation water every day, with Christiansen uniformity and water distribution equal to 90 and 89%, respectively. The management in area 02 was performed irrigating 2.5 h twice a week, totaling 5 h per week, with Christiansen uniformity and water distribution equal to 91 and 90%, respectively.

For wet bulb characterization, Tecanat access pipes were instaled in two experimental areas, with 4.4-cm diameter and a depth of 1 meter, to measure soil moisture using the time-domain reflectometry (TDR). In the tube installation, it was necessary to use specific equipment that was consistent with an iron soil probe, Dutch soil probe, rubber hammer and a tripod to facilitate tube insertion in the ground level.

The tubes were plumbed at 0.20 m intervals using a rubber hammer and a probe, after each increment in depth the Dutch soil probe was used to excavate and remove the soil inside the tube. At the end of the installation, the tubes were cleaned internally with the aid of a sponge attached to the soil probe. At the lower end of the tube, a rubber ring was placed to seal the tube and at the upper end a cap was placed.

The tubes were arranged at six points in relation to the plant, being one point in the planting line between two plants and five points between the planting lines (0.10; 0.40; 0.70; 1.10 e 1.50 m of the plant), being the measurements taken in four depths (0.00-0.20; 0.20-0.40; 0.40-0.60 e 0.60-0.80 m) with three replicates in each area studied.

The reading of soil moisture was performed through a TDR probe model TRIME-PICO IPH T3/44, connected to a Bluetooth module, in which part of the sensor had 0.20 m long and capacity for measuring 3.0 liters of soil volume. The probe was inserted within the Tecanat tubes every 0.20 m, where Bluetooth module was activated, emitting an electromagnetic pulse, which performed reading of soil moisture and sending to a Palm Talk reading in volume percentage. The readings were done before and after irrigation.

Soil moisture obtained from TDR technique was adjusted through regression with dry oven technique for all of the areas and depth studied. For this adjust, 50 undeformed samples were used, removing the samples by an Uhland sampler with a diameter of 0.05 m and a height of 0.03 m, the same distance of the Tecanat tubes on adjacent plant.

Samples were taken to the oven to 105ºC for 24 hours for determination of dry soil weight, making it possible to obtain the soil moisture on gravity bases corresponding to each depth, thus, tracing regression curves for soil moisture adjusts.

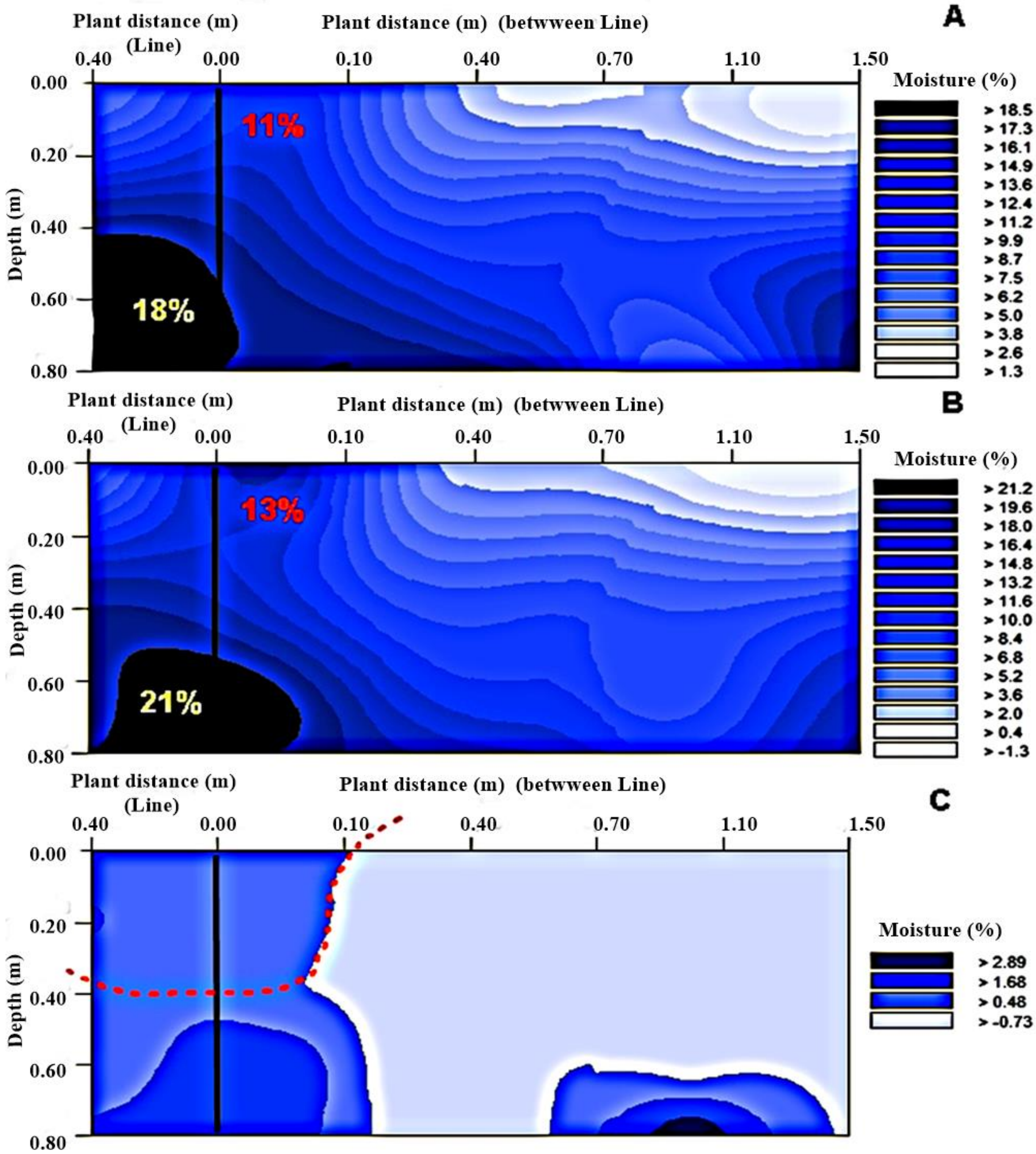
Isoline graphics were made for the characterization of the wet bulb in the soil profile in two dimensions and different plant and depth distances, using GS+ program version 10 (ROBERTSON, 2008).

5 RESULTS AND DISCUSSION

Soil moisture contents below field capacity were observed before irrigation in both areas studied, until the depth of 0,30 m in the coffee row, decreasing expressively from 0,10 m distant of the plant between rows, reaching values below permanent wilting point (Figure 1A).

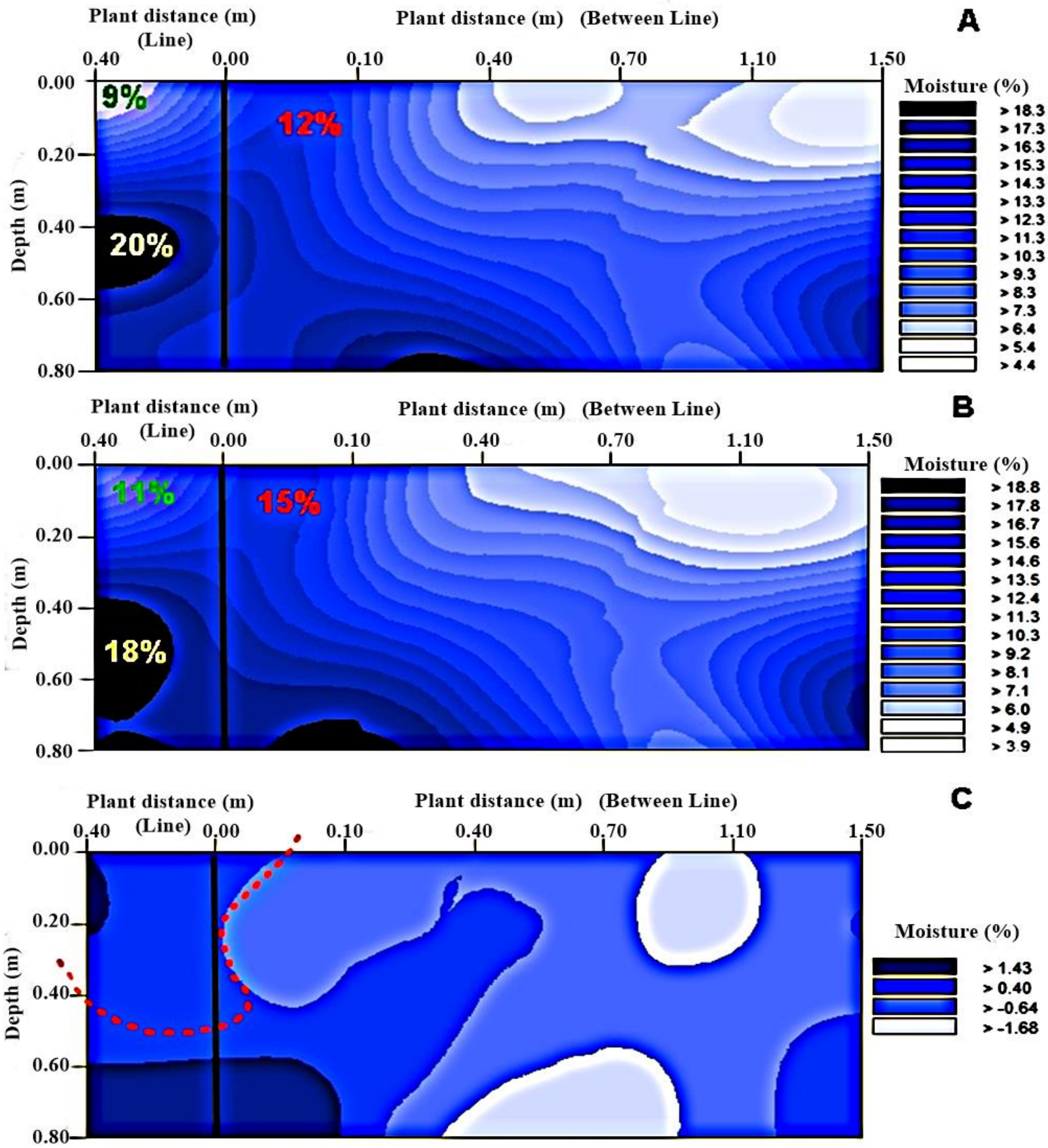
After one hour of irrigation, there was little increase in soil moisture, occurring increase in soil moisture below a depth of 0,30 m (Figure 1B), an important fact, since in this area the farmer was not irrigating as recommended due to the scarcity of hydric resources in the region during the evaluation period, showing that the change of the irrigation management affected the bulb formation and the increase in soil moisture, making the crop vulnerable to stress by hydric deficit, compromising the coffee productivity, but this fact did not occur in the region.

Figure 1. Soil moisture before and after irrigation and wet bulb formation in the Conilon coffee line in medium to sandy texture soil.



It is worth pointing out that the crop was pruned in area 1, having a lower leaf area, in other words, a higher soil exposure, increasing soil water loss per evaporation in the first soil depths, especially in high temperature periods as it happened in the period evaluated in this study. In another scene was observed a higher soil moisture before irrigation below a depth of 0,20 m, which decreased between rows from the plant (Figure 2A). Thus, as well as in the previous scene, there was a low increase in soil moisture (Figure 2B), being that this increase occurred in the coffee row until 0,40 m and expanded until 0,05 m of the plant, occurring wet bulb formation. The increase of soil moisture occurred in the depth studied, being that there was soil moisture loss in all the depth from 0,10 m of the plant between rows (Figure 2C).

Figure 2. Soil moisture before and after irrigation and wet bulb formation between rows of coffee Conilon in medium to sandy texture soil.

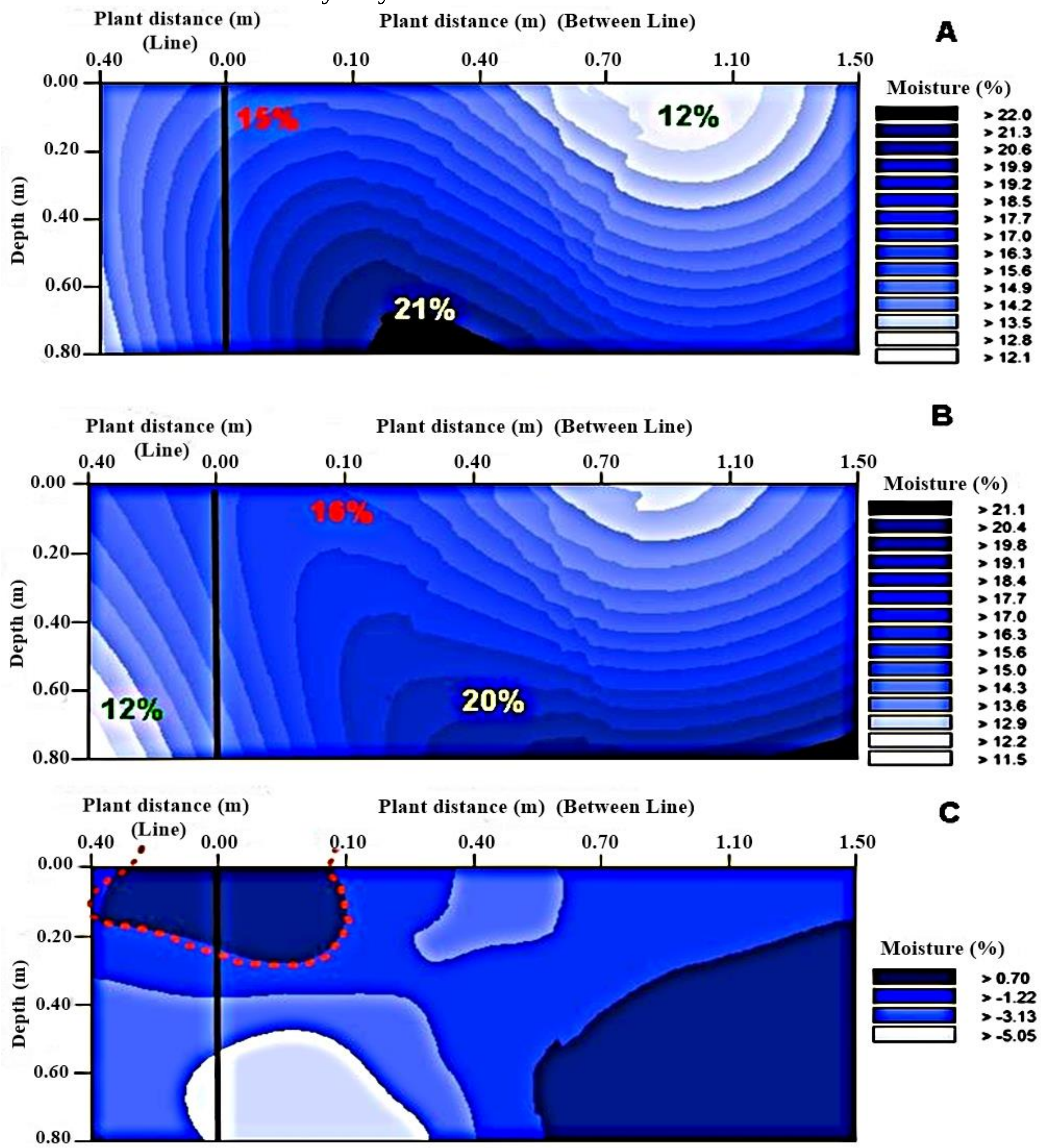


It is worth pointing out that there is an increase in the bulb depth than bulb diameter on the presented scenes, whose fact may be related to Siyal and Skaggs (2009) reported, which studied four textures and observed that water penetrated deeper into more sandy soils than more fine soils because of higher hydraulic conductivity of sandy soils. This same observation was reported by Schwartzman and Zur (1986) that an increase in the water total quantity in soft soils contributes more for an increase in wet depth than for an increase in diameter.

The soil of the area 2 before irrigation was below field capacity, but the values were not close to permanent wilting point, whose values were found from 0.15 m of the plant between rows and the depth of 0.30 m. The coffee row with depth of 0,60-0,80 m was observed in the soil moisture close to permanent wilting point

(Figure 3A), but it is not harmful to the coffee plant because higher part of the root system volume is found in superior depths, as observed by Souza et al. (2018).

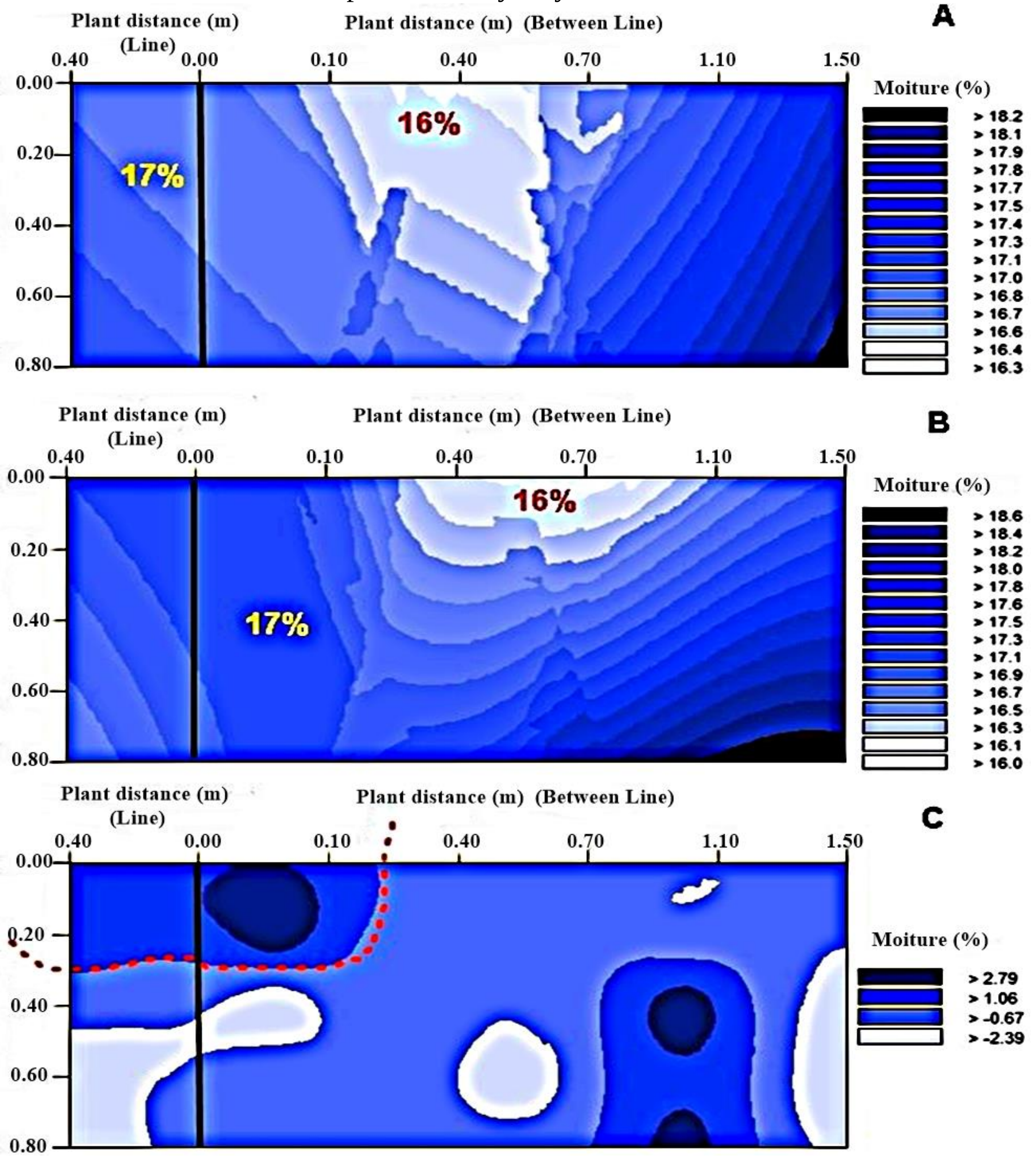
Figure 3. Soil moisture before and after irrigation and wet bulb formation in the Conilon coffee line in sandy clay texture soil.



After irrigation, the region of the soil that showed moisture close to permanent wilting point expanded until depth of 0,40 m (Figure 3B), due to water movement to other points and depths, and pointing out that this area had a little soil slope. The formed wet bulb in this area after irrigation reached close to 0,10 m distant of the plant between rows and 0,40 m in the coffee row, reaching a depth of 0,20 m of the soil (Figure 3C).

In another scene under irrigation was observed wet bulb formation until 0,15 m distant of the plant between rows, reaching a depth of 0,30 m, being that a higher increase of soil moisture occurred until 0,10 m of the plant and a depth of 0,20 m (Figure 4C). It is worth pointing out that the soil initial conditions (Figure 4A) showed superior values of soil moisture than on the previous scene, but both had little increase of soil moisture before irrigation.

Figure 4. Soil moisture before and after irrigation and wet bulb formation between the lines of the Conilon coffee plant in sandy clay texture.



The wet bulb in area 2 was different, whose bulb depth into sandy soils exceeds its own diameter, as reported by Angelakis et al. (1993). In clay soils, due to lower infiltration rate, the bulb formation is higher on the horizontal dimension because of the higher influence of the matrix potential under gravity, corroborating with Maia and Levien (2010).

These results show that the horizontal and vertical extension in front of wetting in clay soil move with speed approximately equal, but the vertical speed component of the front of wetting is higher than horizontal component in sandy soil, making the percolation deeper into this type of soil in terms of water application, according to NAFCHI, MOSAVI and PARVANA (2011).

Therefore, the antecedent soil water content and water application time play an important role for projecting a drip irrigation system in clay soils because these factors are the main powertrain to water movement and redistribution and solute in the soil profile, besides the influence of impact location such as drainage flow and groundwater pollution. Despite these factors, the changes in the moistened volume also depend on the soil flow and properties (PHOGAT et al., 2012).

The results of this work demonstrate the importance of studying the wet bulb on the field, since the water distribution pattern in the soil is a characteristic which influences significantly the project and operation of drip irrigation systems, and because of its width, depth and diameter, the volume must correspond the plant root system (CRUZ-BAUTISTA et al., 2016), corroborating with Souza et al. (2015), which reported the importance of studying wet bulb and root system development on the field, especially in Brazil, whose information in literature is scarce.

6 CONCLUSÕES

For the area with sandy texture, the wet bulb showed a vertical behavior, reaching a depth between 0.40 to 0.50 m, with a range of up to 0.10 m between the lines of the coffee tree.

For the sandy clay texture, bulb formation occurred in the horizontal direction, reaching a depth between 0.20 to 0.30 m, with a range of 0.10 to 0.15 m between the lines of the coffee tree.

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