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Wet bulb and Conilon coffee root distribution under drip irrigation

Bulbo molhado e sistema radicular do cafeeiro Conilon sob irrigação localizada

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ABSTRACT

Knowledge of the wet bulb and the root system of the Conilon coffee plant is highly important for the correct management of irrigation. Therefore, the aim of this work was to characterize the wet bulb and Conilon coffee root distribution under drip irrigation. The experiment was conducted in the city of São Mateus, ES, Brazil with five replications of a completely randomized design of a 4 x 6 split-plot scheme, which represents four points located according to plant location and six depths. Two points were located in the plant line and two points between lines. For row spacing, we used a split-plot scheme 5 x 6 with five points in relation with plant location and six depths with five replications. The coffee roots were analysed by volume, superficial area, length and diameter. The wet bulb was measured with tubes located in six points near the plants with two points in the plant row (between two plants) and five points between rows. The measurements were conducted at four depth ranges with three replications. The wet bulb reached a depth of between 0.40 and 0.50 m, providing an excess of water in depth, evidencing the importance of this characterization for the irrigation management of drip-irrigated Conilon coffee. The depth of the radicular system for better irrigation management efficiency of drip-irrigated coffee is 0.30 m, exhibiting 67.4% of root volume and 68.0% of surface area.

Index terms: *Coffea canephora*; soil moisture; irrigation management.

RESUMO

O conhecimento do bulbo molhado e do sistema radicular do cafeeiro Conilon é de suma importância para o manejo correto da irrigação. Diante disso, objetivou-se caracterizar o bulbo molhado e o sistema radicular do cafeeiro Conilon sob irrigação localizada. O experimento foi realizado em São Mateus-ES, em um delineamento inteiramente casualizado em parcela subdividida 4 x 6, sendo quatro pontos em relação à planta e seis faixas de profundidade, com cinco repetições. Sendo dois na linha e sete na entre linha com distância entre si de 0,20 m. E na entre linha do cafeeiro em parcela subdividida 5 x 6, sendo cinco pontos em relação à planta e seis faixas de profundidade, com cinco repetições. Foram avaliados volume, área superficial, comprimento e diâmetro de raiz. O bulbo molhado foi determinado usando tubos 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, sendo as medições realizadas em quatro faixas de profundidades, com três repetições. O bulbo molhado atingiu profundidade entre 0,40 a 0,50 m, proporcionando excesso de água em profundidade, evidenciando a importância dessa caracterização para o manejo da irrigação do cafeeiro Conilon irrigado por gotejamento. A profundidade do sistema radicular para melhor eficiência do manejo da irrigação do café Conilon irrigado por gotejamento é de 0,30 m, tendo apresentaram está profundidade 67,4% do volume de raiz e 68,0% de área superficial.

Termos para indexação: *Coffea canephora*; umidade do solo; manejo da irrigação.

INTRODUCTION

Irrigation is one of the practices that strongly affects agricultural production. However, to become economically successful, three key questions are important: when, how and how much to irrigate. Answers to these questions are established based on the water holding capacity of the soil and water consumption by plants (Rocha Neto et al., 2015). Globally, irrigation management decisions are mostly based on local experience using limited technical data. The primary reason that many useful and available technical procedures are not adopted is the producers' belief that the current approaches are sufficient (Cuello et al., 2015).

Conilon coffee plantations have been increased in areas where water scarcity is the primary constraint on agricultural production (Araujo et al., 2011; Partelli et al., 2013; Silva et al., 2010), where irrigation is thus required (Covre et al., 2015). Among the most-commonly used irrigation systems in coffee cultivation in the northern region of Espírito Santo State, localized systems (drip irrigation, micro sprayers and micro sprinklers) and sprinkler systems (central-pivot, conventional-irrigation and fixed-head) stand out (Bonomo et al., 2014).

Localized systems have been installed in many properties due to their potential to increase water-use efficiency, minimizing water loss and saving energy (Prado; Nunes; Tinos, 2014) and, according to Varona and Zavast (2015), to enhance productivity and profitability in coffee production.

"Localized irrigation" refers to watering only a fraction of the cropland, under high frequency and low volume in order to maintain the soil of the root zone of plants close to the water holding capacity. The water applied by these systems enters the soil and makes up the wet bulb. The system's shape and size depends on the flow rate, the types of emitters, the duration of irrigation and the type of soil (Pizarro, 1996).

The water distribution pattern in the soil is a feature that substantially influences the project and the operation of drip irrigation systems, the volume of which should fit the plant root system (Cruz-Bautista et al., 2016). According to Nafchi, Mosavi and Parvanak, (2011), the estimation of water distribution in the soil using a drip irrigation system is underrated in practical situations. While demonstrating that this method is often supported empirically, the approach often underestimates water content in the soil, which is unfavourable to the coffee root system.

In addition to the factors affecting the wet bulb formation and its characteristics, another important aspect for irrigation management is the development of the coffee root system, because it is directly related to the real irrigation calculation. The aim of this paper is to characterize the wet bulb and the Conilon coffee root system under drip irrigation.

MATERIAL AND METHODS

Experimental area

The experiment was realized in a Conilon coffee (*Coffea canephora* Pierre ex A. Froehner) plantation, cultivar "Vitória Incaper 8142", fertirrigated by drip irrigation. The evaluation was based on the genotype 02, one of the most productive and planted Conilon coffee clones in the region. The properties are located in the São Mateus city, Espírito Santo State, 39 metres above sea level.

The soil in the study area was classified as a Red-Yellow Latosol with sandy to medium texture, typical from coastal tablelands, according to the Brazilian Agricultural Research Corporation's (Embrapa's) methodology (2013), predominating in all plain areas with declivity under 1%.

The coffee trees were seven years old with a spacing of 3 x 0.80 m. The area was pruned using the cycle scheduled pruning technique in 2014, leaving three main stems per plant, reaching 12.500 main stems per hectare. The drip irrigation system was used with emitters spaced one half-meter from each other.

Irrigation was carried out using weather-based information, with an irrigation depth of 10 mm twice a week with a flow rate of 2 L/h^{-1} and Christiansen's Uniformity Coefficient (CU) and Water Distribution (WD) of approximately 91% and 90%, respectively.

Soil samples were collected to evaluate physical-hydric characteristics and soil texture. Disturbed and undisturbed soil samples were collected in two positions, on the line and between the lines, at four different depths (0.00-0.20 m; 0.20-0.40 m; 0.40-0.60 m; 0.60-0.80 m), using four replications. Soil density, macroporosity and microporosity, water holding capacity and permanent wilting point were measured according to Embrapa's methodology (2011). The results are shown in Table 1.

Wet bulb characterization

Wet bulb characterization was executed using Tecanat's access tube, 4.4 cm diameter and 1 m depth, to measure the soil moisture by time-domain reflectometry (TDR).

The tubes were vertically installed, separated by 0.20 m, using a rubber hammer and a soil core sampler. After each depth increase, a Dutch auger was used to collect the soil inside the tube. Finally, the tubes were internally cleaned using a sponge in the soil auger. To seal the tube, a rubber ring was placed at the bottom end of the tube, and a lid was placed in the upper end.

The tubes were placed at six different points - one in the coffee tree line, between two plants, and five in positions between the lines (0.10 m; 0.40 m; 0.70 m; 1.10 m and 1.50 m from the plant) - and the measurements were performed at four depths (0.00-0.20 m; 0.20-0.40 m; 0.40-0.60 m and 0.60-0.80 m) with three replications.

The TDR moisture measurement was done with a model TRIME-PICO IPH T3/44, connected to a Bluetooth module, with a probe of 0.20 m and a measurement volume of 3 L. The TDR sensor was inserted in the access tubes displaced 0.20 m from each other and activated by a Bluetooth system that generates an electromagnetic pulse to measure the soil moisture and send its value as volume percentage to a Palm-Talk.

Table 1: Soil texture and physical-hydric characteristics at four depths and two positions in Conilon coffee plantation area in São Mateus, Espírito Santo State.

Position	Depth (m)	Sand	Clay	Silt	Sd (g cm^{-3})	Ma	Mi	WHC	PWP
			g Kg^{-1}				(%)		
Line	0.00-0.20	737.21	258.04	4.75	1.47	27.25	17.21	20.3	7.5
	0.20-0.40	734.92	260.06	5.02	1.55	26.79	18.51	19.8	8.1
	0.40-0.60	678.39	314.76	6.85	1.65	16.47	22.34	19.6	8.1
	0.60-0.80	668.33	325.89	5.78	1.68	14.78	26.67	19.6	8.2
Between line	0.00-0.20	727.15	267.10	5.75	1.65	16.89	22.04	19.8	7.6
	0.20-0.40	725.77	269.15	5.08	1.68	15.90	22.53	19.7	8.0
	0.40-0.60	673.16	319.79	7.05	1.68	15.85	22.78	19.5	7.9
	0.60-0.80	663.72	330.97	5.31	1.70	12.60	23.89	19.5	7.9

In which: Sd – Soil bulk density; Ma – Macroporosity; Mi – Microporosity; WHC – Water Holding Capacity (% vol); PWP – Permanent Wilting Point (% vol).

Soil moistures were adjusted by regression using the gravimetric method in the same sampling conditions and areas. Specifically, 50 undisturbed samples were collected using a Uhland soil sampler with a diameter of 0.05 m and height of 0.03 m at the same distance from the Tecanat's tubes in adjacent plants.

Samples were dried in an oven (105 °C) for 24 hours to determine the dry soil weight and to calculate the moisture gravimetrically, establishing regression curves for the adjustment of the soil moisture, as seen in Figure 1.

Root system characterization of Conilon coffee

The root system was characterized by means of soil samples from nine positions from the plant and in six depth layers (0.00-0.10 m; 0.10-0.20 m; 0.20-0.30 m; 0.30-0.40; 0.40-0.50 and 0.50-0.60 m).

Two positions were located in the tree line distanced 0.20 m and 0.40 m from the tree trunk. Between the lines, there were seven positions, ranging from 0.20 m to 1.40 m from the plant. For this evaluation, plants close to those where the Tecanat tubes were installed and without any phytosanitary or nutritional issues were evaluated.

The samples were collected using a 283 cm³ soil core, labelled, stored in plastic bags and kept in a cold chamber (approximately -10 °C) until washing; roots were separated under running water, using 30 mesh and 60 mesh sieves, respectively.

The washed roots were scanned, and by the images produced, it was possible to determine the volume, surface area, length and diameter of the roots. The images were submitted to Safira software version 1.1 for analysis of fibres and roots (Jorge; Silva; Rodrigues, 2010). Roots with diameter smaller than 1 mm were analysed and the data estimated in dm³ of soil.

Statistical analysis

For the characterization of the wet bulb profile in the soil in two dimensions, in the different distances from the plant and in different depths, isoline graphs were produced with GS+ software, version 10 (Robertson, 2008) using the average values of soil moisture from the three replicates.

The coffee root system was evaluated in a split-plot design, 4 x 6, consisting of four positions from the plant and six depths with five replicates. It was also assessed between the tree lines in a split-plot design, 5 x 6, consisting of five positions from the plant and six depths, with five replicates.

All of the data were submitted to analysis of variance and compared by the Scott-Knott test at 5% probability. The data between plants and up to 0.40 m between lines, and in another comparison, the data from 0.60 to 1.40 m between the lines were compared.

RESULTS AND DISCUSSION

Analysis of the characteristics of the Conilon coffee root system under localized irrigation shows that it is possible that an interaction effect occurred between the distance from the plant and the soil depth in both study areas, affecting volume, surface area, length and diameter of the root system (Table 2).

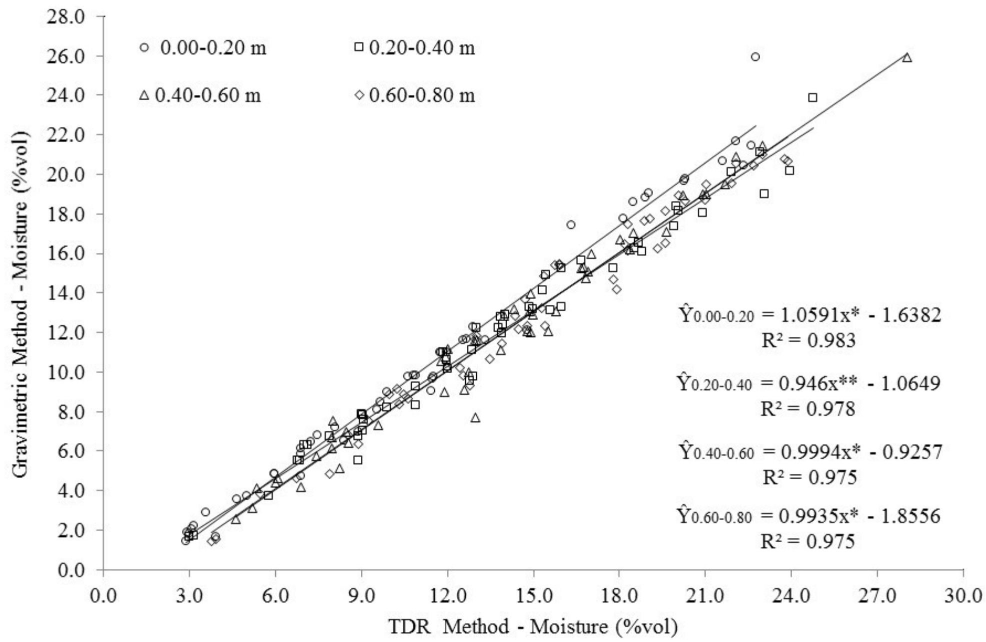

Figure 1: Linear regression adjustment between soil moisture by the TDR method and the gravimetric method for three areas and four depths.

Table 2: Conilon coffee's root system characteristics under drip irrigation, two locations from the tree in the tree line (L) and two locations from the tree between the lines, five locations between the lines and six depths.

Distance from the tree (m)	Depth (m)					
	0.00-0.10	0.10-0.20	0.20-0.30	0.30-0.40	0.40-0.50	0.50-0.60
			Volume (mm^3)			
0.40 L	2303.74aA	933.51cB	100.52cC	300.74cC	329.10bC	415.80aC
0.20 L	1513.02bA	1264.64bA	1249.66bA	873.39bB	537.58bC	498.20aC
0.20	1714.53bB	2146.45aA	1975.94aA	1162.22bC	565.31bD	476.36aD
0.40	1691.77bA	786.76cC	1889.02aA	1477.42aA	1763.21aA	336.68aD
			Surface Area (cm^2 dm^{-3})			
0.40 L	217.70bA	104.76bB	17.78cD	43.21cD	38.41cD	65.54aC
0.20 L	183.14cA	142.09bB	168.05aA	100.10bC	77.30bC	69.32aC
0.20	124.68dC	284.53aA	112.69bC	158.78aB	82.98bD	74.36aD
0.40	251.77aA	131.57bC	181.27aB	190.19aB	151.42aC	53.42aD
			Length (m dm^{-3})			
0.40 L	21.92aA	7.54bB	4.12bC	6.02bB	3.52cC	6.85aB
0.20 L	17.12bA	9.79bB	11.86aB	7.98bC	7.20bC	7.95aC
0.20	10.67cB	17.11aA	11.89aB	8.95bB	7.45bC	4.45aC
0.40	16.03bA	9.04bC	13.21aB	12.49aB	18.74aA	5.70aD

Continue...

Table 2: Continuation...

Distance from the tree (m)	Depth (m)					
	0.00-0.10	0.10-0.20	0.20-0.30	0.30-0.40	0.40-0.50	0.50-0.60
			Diameter (mm)			
0.40 L	0.646aA	0.642aA	0.674aA	0.670bA	0.656bA	0.634aA
0.20 L	0.648aB	0.648aB	0.638aB	0.718aA	0.692aA	0.664aB
0.20	0.652aA	0.608aB	0.652aA	0.670bA	0.662aA	0.682aA
0.40	0.624aA	0.614aA	0.666aA	0.636bA	0.646aA	0.636bA
			Volume (mm³)			
0.60	1250.01cB	1619.24aA	1654.21aA	825.68aC	238.36bD	405.90cD
0.80	1994.88bA	1326.56aB	349.50cC	429.87aC	216.05bC	287.09cC
1.00	2348.40aA	945.42bC	1369.11aB	770.40aC	699.56aC	826.78bC
1.20	1895.21bA	1443.44aB	882.89bC	747.16aC	658.80aC	1264.68aB
1.40	1399.06cA	891.49bB	925.74bB	707.30aB	931.78aB	580.23cB
			Surface Area ($cm^2\ dm^{-3}$)			
0.60	179.12bB	232.10aA	196.93aB	100.80aC	41.14bD	61.53aD
0.80	327.81aA	187.12bB	57.78dC	70.74aC	73.87bC	57.77aC
1.00	312.17aA	167.66bC	219.48aB	87.77aD	90.94aD	77.28aD
1.20	194.55bA	228.37aA	157.05bB	96.77aC	67.17bD	44.88aD
1.40	181.16bA	143.70bB	129.71cC	118.43aC	100.81aC	84.45aC
			Length ($m\ dm^{-3}$)			
0.60	12.67cA	10.98bA	11.81bA	5.05bB	4.52aB	3.65aB
0.80	28.75aA	11.37bB	8.36cB	4.83bC	6.19aC	6.04aC
1.00	19.71bA	15.56aB	16.15aB	9.65aC	4.98aD	5.57aD
1.20	13.25cA	15.36aA	12.05bA	9.42aB	5.64aB	7.79aB
1.40	16.60bA	11.98bB	9.62cC	11.49aB	7.68aC	4.73aD
			Diameter (mm)			
0.60	0.654aA	0.612bA	0.650bA	0.644bA	0.666aA	0.644bA
0.80	0.644aA	0.658aA	0.628bA	0.628bA	0.664aA	0.658bA
1.00	0.652aA	0.626bA	0.632bA	0.664aA	0.670aA	0.650bA
1.20	0.624aB	0.634bB	0.678aA	0.686aA	0.676aA	0.696aA
1.40	0.670aA	0.674aA	0.696aA	0.658aA	0.670aA	0.676aA

The mean values followed by the same small letter in the column and the same capital letter in the line are not significantly different from each other. Scott-Knott test at 5% probability.

These results show a distinct behaviour of Conilon coffee's root system in terms of position towards the plant and depth, indicating that understanding these characteristics is a key irrigation management tool.

Partelli et al. (2014) conducted a similar study with different positions and depths in smaller quantities, but their results did not indicate the interaction between position towards the plant and depth for data related to root surface area, length and volume.

Conilon coffee under irrigation of 10 mm expressed the biggest root volume at the depth range of 0.00 to 0.10 m in the tree line 0.40 m away from the tree. The biggest root volume was found at the depth ranges of 0.10 to 0.20 and 0.20 to 0.30 m, 0.20 m away from the tree in between line, with both being statistically equal (Table 2).

Roots up to 0.30 m deep are the ones most responsible for water absorption in coffee plants, which accords with the classical definition of absorbent roots as having a diameter smaller than 1.0 mm (Rena; DaMatta, 2002), i.e., the group of roots evaluated in this paper. An exception was that for the spot located 0.40 m away from the plant, the biggest root volume up to 0.50 m was observed, unlike the other spots in this study.

Partelli et al. (2014) also verified that in a *C. canephora* plantation, the fine roots concentration occurred distantly from the orthotropic branch, where soil fertilization was conducted. However, this pattern may be not expressed at all times, given that Barreto et al. (2006) demonstrated that in fertirrigated crops, the root density was significantly higher in spots further than the wet bulb, but still under the tree top.

According to Zur (1996), the wet bulb should reach the end of the effective root zone, and a deeper watering would mean a waste of water and a badly managed irrigation, which is in keeping with the results of this study.

Root surface area (Table 2) was larger at 0.40 m away from the plant between lines for the depth range of 0.00 to 0.10 m. Analysing the spots closer to the plant, the larger surface area found was at 0.10-0.20 m deep and 0.20 m away from the plant between line.

Analysis of the depth ranges showed that the larger surface areas were obtained at 0.00-0.10 m, as the spot at 0.20 m away from the plant in the tree line has statistically the same that at 0.20-0.30 m deep (Table 2). Partelli et al. (2006) verified that the surface area was statistically the same up to 0.60 m when at 0.50 m distant from the plant and up to 0.40 m deep when at 0.25 m distant from the plant, being statistically the same for the depth ranges above.

In opposition to the findings in this work about the distance from the plant, Covre et al. (2015) observed a reduction of the surface area as the distance from the tree increases for Conilon coffee, chiefly in the region of the between line and as the depth increased.

In the between line, the root surface area was higher, at 0.00-0.10 m deep, which is statistically the same as that found at 0.10-0.20 m at 1.20 m away from the plant. The highest root surface area values were observed at 0.80 and 1.00 m, which are statistically equal to each other. The remaining locations were inferior and equal between them.

The largest root length was found at 0.00-0.10 m deep, being 0.40 m away from the plant in the between line. For 0.20 m away from the plant in the between line, the largest root length was observed at 0.10-0.20 m in depth. For 0.40 m away from the tree line, the highest root length was found at 0.40-0.50 m. At a depth of 0.20 to 0.30 m, the results showed that the values 0.20 m away from the plant in the tree line and 0.20 m and 0.40 m away in the between line were statistically equal.

The results showed that for the values away 0.60 and 1.20 m from the plant in the between line, the three first depth layers had statistically the same values, differing from the ones observed in the values located 0.80 m, 1.00 m and 1.40 m away from the plant in the between line, where the largest length was at 0.00-0.10 m. At 0.00-0.10 m deep, the location at 0.80 m away from the plant in the between line showed the largest length. It is worth noting that as the depth layer became deeper, the results tended to be statistically equal (Table 2).

Several authors have claimed that the largest root length indicates a larger occupied and explored soil volume (Zonta et al., 2006) and that genotypes with larger root length promote bigger nutrient absorption once the roots reach deeper in the soil (Alves et al., 2002; Clarkson, 1985).

At the depths of 0.00 to 0.10 m, 0.40 to 0.50 m and 0.50 to 0.60 m, the root diameters were statistically the same among the locations analysed. For the depth of 0.10 to 0.20 m, the larger diameters were observed at 0.20 m and 0.40 m away from the plant in the tree line and at 0.80 m and 1.40 m away from the plant in the between line, being statistically equal. On the other hand, at the depth of 0.20 to 0.30 m, those same results were observed at 0.40 m, 1.20 m and 1.40 m away from the plant in the between line (Table 2).

The first three depth layers had statistically the same root diameter for the locations near the plant. The deeper depth layers also showed the same behaviour, with an exception at 0.20 m away in the tree line, where the lowest diameters up to 0.20-0.30 m were observed (Table 2).

The results differ from those found by Ronchi et al. (2015) and Partelli et al. (2014), who observed that average root diameters reduced as the soil profile got deeper, due to soil fertility impoverishment. However, numerically, the average root diameters for studies were superior to the studies mentioned.

Evaluating the diameter in the between line of the coffee plantation, at 0.00-0.10 m deep, the values located from 0.60 up to 1.40 m away from the tree showed statistically equal results. The same occurred for 0.10-

0.20 m between 0.80 to 1.40 m, which had the highest values. The remaining values in the same depth layer had the lowest diameters.

Soil 1.20 m away from the plant in the between line had the lowest root diameters in terms of depth layer, with distances of 0.00-0.10 m and 0.10-0.20 m being statistically the same (Table 2). Partelli et al. (2006) verified that for the root diameter, there were no differences according to horizontal position (distance from the plant trunk) or vertical position (depth) in the soil sampling.

Before irrigation, it was possible to observe low soil moisture up to 0.30 m depth, where the biggest root volume can be found. At 0.60-0.80 m in depth, the soil moisture values were closest to the water holding capacity, although still lower (Figure 2A and Table 1). At 0.00-0.20 m depth and 0.40 m away from the plant in the tree line, and between the tree lines up to 0.40 m apart from the plant, the soil moisture was very close to the permanent wilting point (Figure 2A).

After irrigation of 10 mm, an increase in the soil moisture occurred in the shallow layers, reaching values close to the water holding capacity (Figure 2B). This irrigation amount promoted a gain of 2.4% v/v of soil moisture up to 0.15 m from the plant in between the lines and up to 0.50 m depth (Figure 2C).

The largest increase on the soil moisture was observed at 0.10 m from the plant at a depth range of 0.15 to 0.40 m. A soil moisture decrease occurred starting from 0.15 m from the plant in between line and at all depths (Figure 2C). Reichardt and Timm (2004) showed that as the soil dries, water absorption by plants becomes more difficult because retention forces rise and water availability in the soil diminishes.

In another situation with irrigation of 10 mm, it was verified that the soil moisture values were lower than in the previous case before the irrigation, reaching permanent wilting point values at 0.00-0.30 m in depth, 0.40 m away from the coffee tree on the growing line, and up to 0.90 m away from the plant in between line (Figure 3A).

Irrigation promoted a significant gain in the soil moisture, however, below the water holding capacity (Figure 3B). The significant increment of approximately 10% v/v was at 0.00-0.30 m in depth, creating a wet bulb up to 0.20 m away from the plant in the tree line and 0.10 m away from the tree line (Figure 3C).

In related cases, there is a larger increase in the depth than in the diameter of the bulb. This increase can be explained by studies by Siyal and Skaggs (2009), who examined four different soil textures and observed that water penetrated more deeply in sandier soil textures than in finer soil textures, once hydraulic conductivity is higher in sandy soils. Schwartzman and Zur (1986) also concluded that for light soils, a water gain increased the depth more than the diameter of the wet bulb.

According to Keller and Bliesner (1990), smaller irrigation intervals with small amounts of water produce a small wet area, limiting water absorption at lower parts of the root system and excess watering.

Larger irrigation intervals promote water penetration under the root system, contributing to percolation and leaching; nutrients that would be readily available for the plants are carried to deeper layers. With the aim of homogeneous irrigation, irrigation intervals become an important tool in wet bulb determination (Keller; Bliesner, 1990).

It is worth pointing out that the soil moisture increased in depth to 0.30 m away from the coffee tree (Figure 3C). In that region, the majority of the root system is found, with volume, surface area and root length up to 0.40 m in the between line, contributing in this way to enhanced water and nutrient absorption.

Instead of the significant quantity of roots observed in those spots and soil depth ranges, inappropriate irrigation management, as shown in Figures 2A and 3A, can result in inefficient use of this water by compromising absorption of water and nutrients once the irrigation water cannot reach such depths, which keeps soil moisture values low.

However, it is important to emphasize that a moisture increase in deeper depth ranges occurred, which was probably due to water movement on the soil or to water percolation.

In this case, it becomes a concern due to the use of fertirrigation in that area; nutrients are being carried down to deeper depth ranges, and water use is inadequate. There is a reduction in root system characteristics at those depths with the exception of locations 0.40 m away from the tree in the tree line, where a significant root system up to 0.40-0.50 m can be observed.

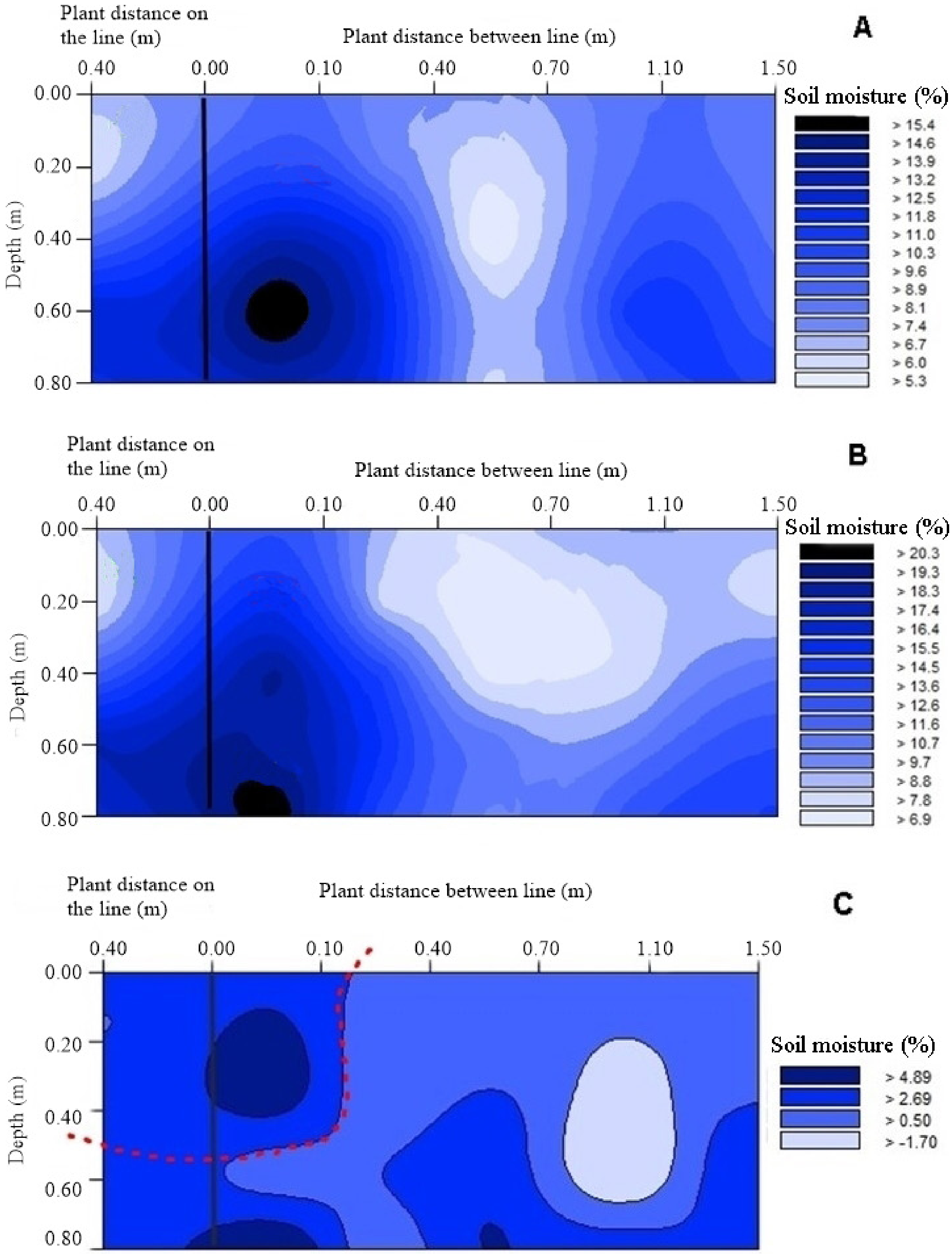

Figure 2: Soil moisture before (A) and after (B) irrigation and wet bulb formation (C) after irrigation of 10 mm.

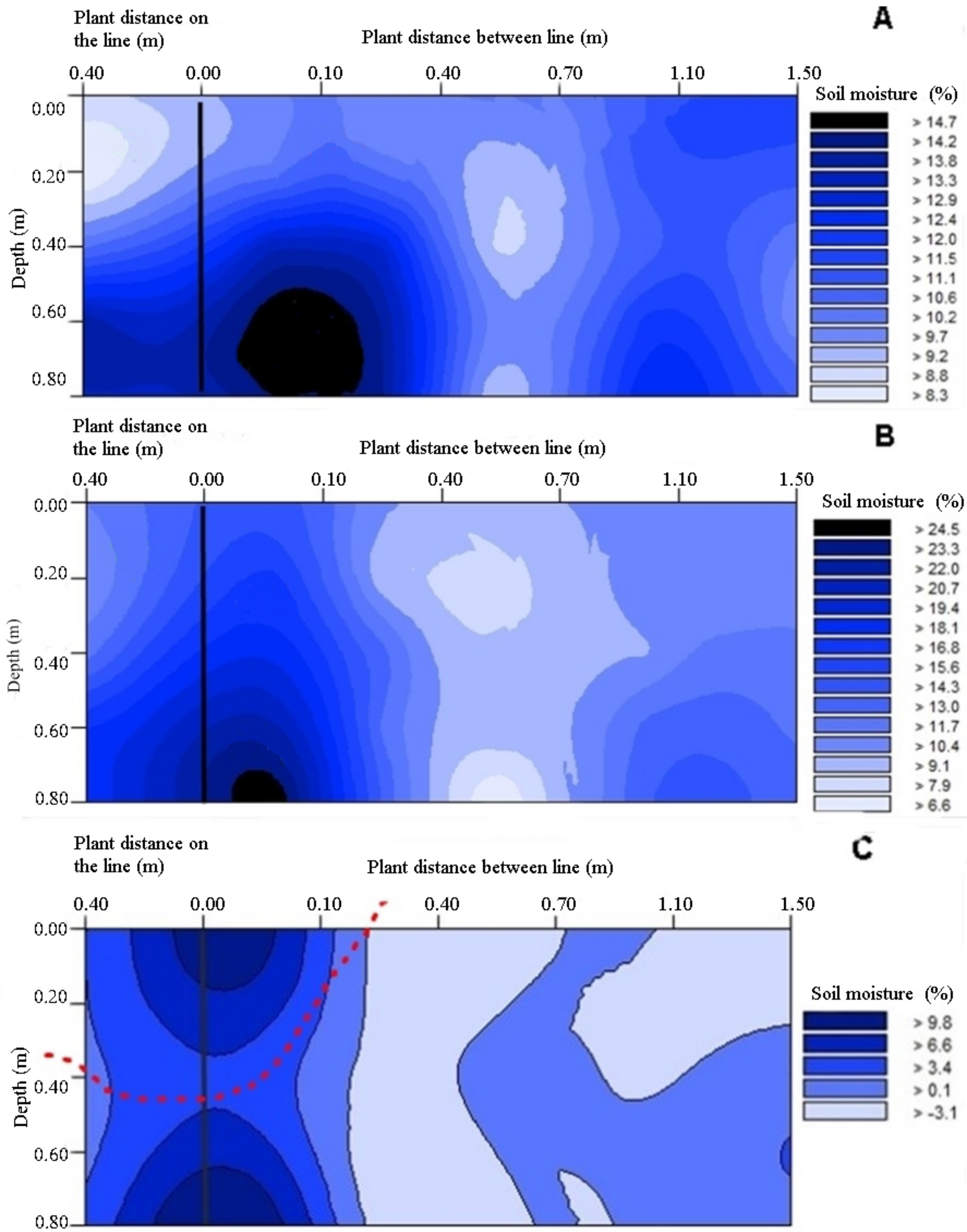

Figure 3: Soil moisture before (A) and after (B) irrigation and wet bulb formation (C) after irrigation of 10 mm.

CONCLUSIONS

The wet bulb reached a depth between 0.40 and 0.50 m, providing excess water depth in the soil, considering the root system of the coffee tree, evidencing the importance of this characterization for the irrigation management of drip-irrigated Conilon coffee. The depth of the root system for better irrigation management efficiency in drip-irrigated Conilon coffee is 0.30 m. The Conilon coffee (*Coffea canephora*) tree genotype 02 revealed that 67.4% of the root volume and 68% of the surface area were concentrated at up to 0.30 m depth, and 57.5% of the root volume and 53.9% of the surface area at up to 0.60 m from the tree trunk. The largest root length was observed in the superficial soil depth range, decreasing while the depth increased. The same behaviour was identified for the diameter.

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