GUIDELINES FOR IRRIGATION SCHEDULING OF BANANA CROP IN SÃO FRANCISCO VALLEY, BRAZIL[1]. I – ROOT DISTRIBUTION AND ACTIVITY

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ABSTRACT - In order to establish guidelines for irrigation water management of banana cv. Pacovan (AAB group, Prata sub-group) in Petrolina County, northeastern Brazil, the root distribution and activity were measured on an irrigated plantation, in a medium texture soil, with plants spaced in a 3 x 3 m grid. Root distribution was evaluated by the soil profile method aided by digital image analysis, while root activity was indirectly determined by the changing of soil water content and by the direction of soil water flux. Data were collected since planting in January 1999 to the 3rd harvest in September 2001. Effective rooting depth increased from 0.4 m at 91 days after planting (dap), to 0.6 m at 370, 510, and 903 dap, while water absorption by roots was predominantly in the top 0,6 m.
Index terms: *Musa* spp, semi-arid, microsprinkle.

ORIENTAÇÕES PARA O MANEJO DA IRRIGAÇÃO DA BANANEIRA NO VALE DO SÃO FRANCISCO. I- DISTRIBUIÇÃO E ATIVIDADE RADICULAR

RESUMO – Em Petrolina – PE, a distribuição e a atividade radicular da bananeira cv. Pacovan (grupo AAB, subgrupo Prata) foram obtidas em uma área irrigada, com solo de textura média e com plantas espaçadas em 3 x 3 m. A distribuição radicular foi avaliada pelo método do perfil auxiliado pela análise de imagens digitais, enquanto a atividade radicular foi indiretamente estimada pela variação da umidade do solo e pela direção do fluxo de água no solo. O período de observação compreendeu desde o plantio, em janeiro de 1999, até a terceira colheita, em setembro de 2001. A profundidade efetiva das raízes foi de 0,4 m até os 91 dias após o plantio (dap), aumentando para 0,6 m aos 370; 510 e 903 dap. A absorção de água ocorreu predominantemente na camada superficial de 0,6 m.
Termos para indexação: *Musa* spp, semi-árido, microaspersão.

INTRODUCTION

Banana show a wide adaptability to a range of environments (Turner, 1994) and has been cultivated under different conditions in the tropics and in the subtropics, specifically in South and Central America, Israel, Australia, South Africa, Canary Islands, Egypt, India, Philippines, and China (Robinson, 1995). Consequently, different plant responses have been found due to the diversity of environment and crop systems.

The knowledge of the banana root system can greatly assist for irrigation scheduling (Araya et al., 1998). The effective rooting depth together with the water holding capacity of the soil, percentage of depletion of total available water allowed before irrigation, and the crop coefficient are essential for irrigation purposes (Robinson, 1995).

In overall form the banana root system is widely spreading, with abundantly branching shallow roots giving rise to a dense mat, typical of monocotyledons (Price, 1995). Banana root system is sensitive to physical factors, i.e., soil mechanical resistance, drainage, aeration and water availability. It may reach depths up to 1.5 m or not exceed 0.2 m (Champion, 1968). Most commonly, however, banana roots seldom reach depths below 0.6-0.8 m (Lahav & Kalmar, 1981) and are usually confined in the top 0.3-0.4 m (Trochoulias & Murison, 1981; Moura et al., 1986; Araya et al, 1998). The soil moisture regime has a direct effect on both the amount and growth of banana roots (Champion, 1968). High water table reduce the banana yield, amount of roots and root growth (Ghavami, 1976). Banana roots utilize water only at low suction values in soils, demonstrating a poor ability to water absorption (Hedge, 1988). This condition indicates that banana is sensitive to even slight variations in soil water content and that irrigation scheduling is critical (Robinson, 1995). Some studies have demonstrated that root extension growth is highly correlated to soil temperature. In the summer, with soil temperatures between 25-30^{o}C, root extension rates (160-200 mm week^{-1}) were greater than in other seasons (Robinson & Bower, 1988; Robinson & Alberts, 1989). Soil compaction affects the development of field-grown banana by reducing soil aeration, causing root asphyxiation, reducing the number of roots, and increasing the root diameter and root mass (Dorel, 1993).

In the São Francisco Valley, Northeastern Brazil, Petrolina County presents an irrigated banana growing area nearby 4,600 ha, most of them cropped with the cv. Pacovan (AAB group, Prata subgroup) (CODEVASF, 2001). Nevertheless, useful information about how the field-grown banana roots develop and their distribution and activity into the soil profile in this Brazilian fruit crop growing area are not well defined. Hence, the purpose of this research work was to obtain these guidelines to support the irrigation scheduling of the banana crop in Petrolina, Brazil.

MATERIAL AND METHODS

Site and soil

The experiment was carried out in an experimental field at Embrapa Semi-Árido, Petrolina, Pernanbuco State, Brazil (latitude 09^{o}09' S, longitude 40^{o}22' W, altitude 365,5 m), located in the Bebedouro Irrigation District. The soil is a red-yellow latosol, medium texture (Embrapa, 1999). Soil samples were collected and analyzed for physical and chemical characterization following the procedures described by Embrapa (1979). Results showed low water holding capacity, low cation exchange capacity, and low organic matter content (Table 1).

Cultural practices

The banana cv. Pacovan was planted in January 26th 1999 in a 3 x 3 m spacing grid. Doses of fertilizer were applied in accordance with soil analysis and guidelines presented by Gonzaga Neto et al. (1998) for irrigated banana. At planting, it was applied 20 L of manure, 100 g of lime,

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TABLE 1- Soil physical and chemical characteristics of the field experiment at Petrolina.

depth	sand	silt	clay	bulk density	water holding capacity - $m^3 m^{-3}$		total available water
m		$g\ kg^{-1}$		$Mg\ m^{-3}$	0.033 MPa	1.5 MPa	$m^3\ m^{-3}$
0-0,2	90	4	6	1.60	0.077	0.034	0.043
0,2-0,4	84	8	8	1.44	0.101	0.048	0.053
0,4-0,6	78	8	14	1.24	0.111	0.058	0.053
0,6-0,8	76	10	14	1.27	0.111	0.052	0.059
0,8-1,0	82	2	16	1.23	0.122	0.065	0.057

	pH	E.C.[1]	Ca^{++}	Mg^{++}	Na^+	K^+	H+Al	Al^{+++}	CEC[2]	BS[3]	o.m.[4]	P
	H_2O	$dS\ m^{-1}$				$cmol_c\ dm^{-3}$				%	$g\ kg^{-1}$	$mg\ dm^{-3}$
0-0,2	6.1	0.13	1.9	1.0	0.016	0.30	0.53	0.08	3.75	86	4.9	24
0,2-0,4	5.5	0.08	1.7	0.3	0.014	0.26	1.20	0.29	3.47	66	2.7	12
0,4-0,6	5.0	0.11	1.0	0.5	0.025	0.15	2.46	1.05	4.14	40	1.7	5
0,6-0,8	4.7	0.18	1.0	1.0	0.038	0.13	2.73	1.46	4.90	45	-	-
0,8-1,0	4.6	0.09	0.9	0.4	0.025	0.12	2.84	1.35	4.29	33	-	-

[1]electric conductivity 25°C saturation extract; [2] cation exchange capacity; [3] base saturation; [4] organic matter

20 g of N, 89 g of P_2O_5, 38 g of K_2O, 89 g of Ca, and 67 g of S per hole, using urea, simple super phosphate, and potassium sulfate as fertilizer sources. Also, 50 g of fritted trace elements (11.5% of ZnO, 7% of B_2O_3, 1% of CuO, 0,2% of MoO_3, 5,4% of Fe_2O_3, 5,5% of MnO_2) were added in each hole. The dose per plant of N, P_2O_5, and K_2O were, respectively: at 90 days after planting (dap), 40g, 40g, and 14 g; at 181 dap, 60g, 60g, and 21 g; at 274 dap, 80g, 80g, and 28g; at 364, 398, 430, 457, 491, 533, 547, 576, 609, 636, 716, 759, 786, 821, 850, 882, 912, and 944 dap, 99 g, 120 g, and 42 g. Also, at 430 dap, 50 g of P_2O_5 and 26 g of Ca (triple phosphate), and 20 L of manure were applied per plant. In the 1st and 2nd growing season, at 174 dap (July 1999) and at 603 dap (September 2000), respectively, the suckers for the following seasons were selected. Other undesirable suckers were permanently eliminated throughout the crop cycles.

Irrigation water application

The banana plants were irrigated by microsprinkler, with one emitter installed between two plants in the row. Field tests were performed to estimate the wetted ratio (2 m) and the flow rate (46 $L.h^{-1}$, at 130 kPa). The wetted ratio promoted the wetting of the total soil surface among plants. The soil water content (è, $m^3.m^{-3}$) was monitored by three tensiometer sets (devices installed at 0.2, 0.4, 0.6, 0.8, and 1.0 m depth). The values of è were known by the soil water retention curve, using the average values of soil matric potential.

The net irrigation amount (W_N, mm) was estimated by:

$$W_N = (\theta_{FC} - \theta_C).(\Delta z / 1000)$$

where θ_{FC} and θ_C were considered the soil water content ($m^3.m^{-3}$) at the field capacity matric potential (-10 kPa) and at the critical matric potential (-30 kPa), respectively, and Δz was the soil depth (0.4 m). The net amount of water to be applied (A_N, mm) was calculated by:

$$W_G = (W_N / E_f).100$$

where E_f is the irrigation efficiency (considered 90%).

The irrigation time (Ti, h) was calculated by:

$$Ti = (W_G.Sp.Sr) / (n.F)$$

where Sp and Sr are the spacing grid between plants and rows, respectively, n is the number of emitters per plant, and F is the microsprinkler flow rate ($L.h^{-1}$).

Root system analysis

At 91 dap (April 1999), 175 dap (July 1999), 286 dap (November 1999), 370 dap (January 2000), 510 dap (June 2000) and 903 dap (July 2001), the root system distribution of two randomized chosen plants was analyzed. In each time, two trenches (1 m deep, 3 m long, 1 m wide) were dug to expose a half root system of the banana plant. The initial distance between the trench wall and the plant row was 1 m, except at 510 and 903 dap, when this distance was increased to 1,4 m due to plant growing.

A thin layer of soil (1-2 cm) was carefully removed from the excavated vertical soil wall along the whole trench, and visible roots (generally with diameter larger than 1 mm) were painted with white ink to enhance color contrast of the roots and the soil. A 1 x 1 m wood frame with a wire grid of 0.2 x 0.2 m was pressed against the trench wall and pictures were collected with a digital camera (resolution of 640 X 480 pixels) for each of 0.04 m^2 areas along the whole trench. After ~~the~~ image collection of each trench wall, a soil thickness of 0.02 m was excavated and another trench wall was obtained. Thus, pictures were repeated at distances of 1.0, 0.8, 0.6, 0.4, and 0.2 m from the plant rows, and at 510 and 903 dap, additional pictures were collected at 1.4 and 1.2 m distances. The pictures were saved as BMP files and processed by the Integrated System for Root and Soil Coverage Analysis (SIARCS®) software (Crestana et al., 1994). From each image, the root length (L_p, m) was measured.

Root activity

The sum of the matric and gravitational potentials determines the hydraulic potential (ψ_h, kPa) of soil water. The hydraulic gradient ($\nabla\psi_h$, dimensionless) for the 0.4 , 0.6 , and 0.8 m depth was estimated by:

$$\nabla\psi_h = (\psi_{h\,above} - \psi_{h\,below}) / \Delta z$$

where Δz is the distance between two soil depths (m), one 0.2 m above and another 0.2 m below the soil depth considered. The hydraulic gradient indicated the direction of q, i.e., positive $\nabla\psi_h$ indicated downward flux, and negative $\nabla\psi_h$ indicated upward flux (Reichardt, 1996). We considered that upward fluxes throughout the growing season were closer related to a greater root presence in a specific soil layer.

The soil water content (è, $m^3.m^{-3}$) was measured on March 2001 (3rd season) by the neutron scattering technique at the distance of 0.2, 0.6, and 1.0 m from the plant row. Three access tubes were installed in each distance and neutron probe readings were taken at 0.15, 0.30, 0.45, 0.60, 0.75, 0.90, and 1.05 m depth. The device was previously calibrated for this soil condition. Measurements were taken within a 24 h interval and from 783 to 787 dap. No rain or irrigation water application occurred in this period of time. Hence, we consider: the changes of soil water content were caused by both the drainage and the evapotranspiration processes; the water absorption by roots as part of the transpiration.

RESULTS AND DISCUSSION

The phenologic stages of the three growing seasons of the banana plantation observed in the field were: 1st season – vegetative phase from planting to 211 dap, reproductive phase from 212 to 335 dap, harvest from 366 to 444 dap; 2nd season – vegetative phase from 174 to 379 dap, reproductive phase from 380 to 636 dap, harvest from 472 to 658 dap; 3rd season – vegetative phase from 603 to 886 dap, reproductive phase from 532 to 902 dap, harvest from 717 to 976 dap. The yield of banana was 10834.4 $kg.ha^{-1}$, 14705.7 $kg.ha^{-1}$ and 15457.4 $kg.ha^{-1}$, respectively, for the 1st, 2nd and 3rd harvests.

The total amount of roots increased continuously in the most part of the tree growing seasons, with a rapid increase of the relative rate. The higher rates were observed between 172 and 182 dap, when it started to decrease smoothly (Figure 1). In the fourth root evaluation (370 dap), just 80 days after the end of the flowering, the harvest of the 1st growing season was going on. The increase of banana root amount is due to the fact that root generation and growing cease just after the flowering (Champion, 1968). A rhizotron study demonstrated that roots are produced continuously until flowering (Lavigne, 1987), and Sobhana et al. (1989) observed that banana root development was faster during the first five months after planting. The first sucker selection was performed at 174 dap, and it probably contributed for this rapid increase until the fourth evaluation. At 510 dap, in the fifth root evaluation performed within the harvesting period of the 2nd season, both plants evaluated were already bloomed and the total root amount reduced a little. Between 174 and 510 dap, the undesirable suckers were eliminated in four dates (301, 358, 427 and 468 dap). The 2nd sucker selection was made at 609 dap and in the sixth evaluation at 903 dap the root presence increased again. As we have decided not to continue with the experiment for a longer time, the total desuckering was done at 721, 750, 793, 812, 842, 875, 892 dap.

Figure 2 shows the banana root distribution in both vertical (soil depth) and horizontal directions (distance from the plant row) in the six evaluations. At 91, 175 and 286 dap, the effective rooting depth was 0.4 m with 90, 95, and 89% of the whole root system, respectively. The effective depth changed to 0.6 m at 370 dap, with 88% of the total roots. This root distribution was not modified in 510 and 903 dap evaluations, with 78 and 87%, respectively. The maximum depth observed was around 0.6 m until the 175 dap, and at 286 dap the roots reached the 1 m depth. Also, at 175 dap and inside the plant row, roots reached the 1.5 m distance from the steam, showing a root crossing over inside the plant row. These results have similarity with those found by Moura et al. (1986) in a medium texture soil of northeastern Brazil, where most of the banana roots, ten months after planting, were concentrated in the upper 0.15 m soil depth and until 0.30 m from the pseudostem; and with those reported by Lahav & Kalmar (1981) in Israel, where drip irrigated bananas, two years after planting, presented a 1 m depth rooting in a clayey soil, but around 60% of roots were found until 0.6 m depth. In the horizontal direction (toward the inter row), roots reached the 0.8, 1.0, and 1.4 m distance from plant rows at 91, 175 and 286 dap, respectively, indicating a root crossing over by neighbor plants of different rows in the upper 0.4 m soil layer already in the 3rd root evaluation; at 903 dap it became deeper, i.e., until 0.6 m depth (data not shown).

During the 3rd growing season of banana cv. Pacovan, it was observed a predominantly presence of downward soil water flux at 0.4 m depth, due to the irrigation water application, and the presence of upward flux at 0.6 m and 0.8 n depth, showing the contribution of these soil depths to the evapotranspiration process due to the root presence (Figure 3). Within the 783 to 787 dap period, when no rainfall or water application occurred, a greater change of soil water content was observed until the 0.6 m depth, and from the 0.6 m distance of the pseudostem (Figure 6), as a consequence of the greater root presence previously discussed.

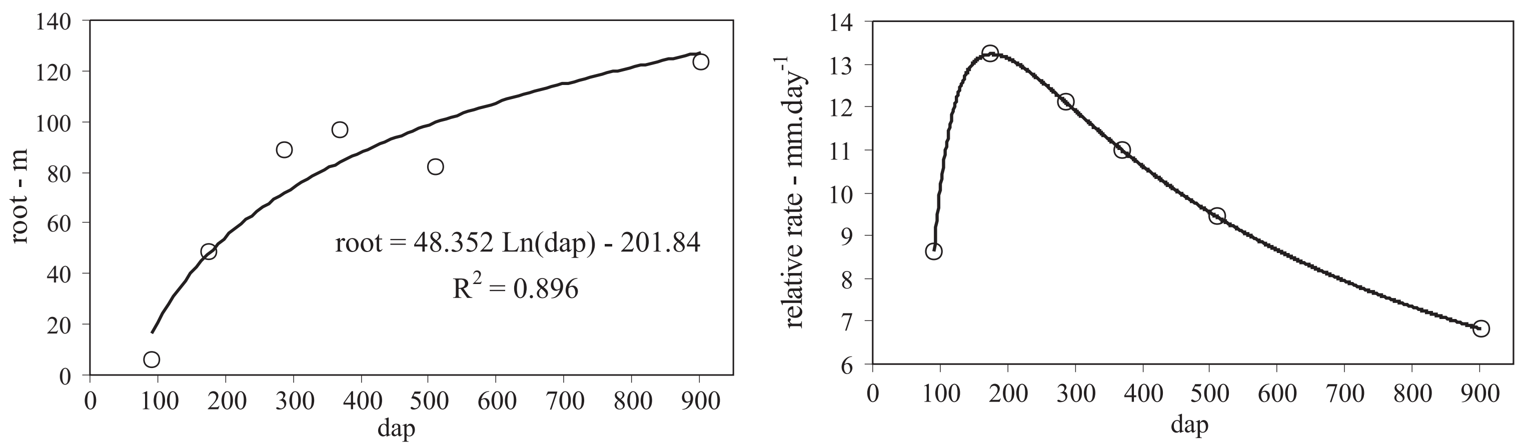

FIGURE 1 – Total root length and relative rate of root growth of banana cv. Pacovan. Circles mean the time of root evaluation.

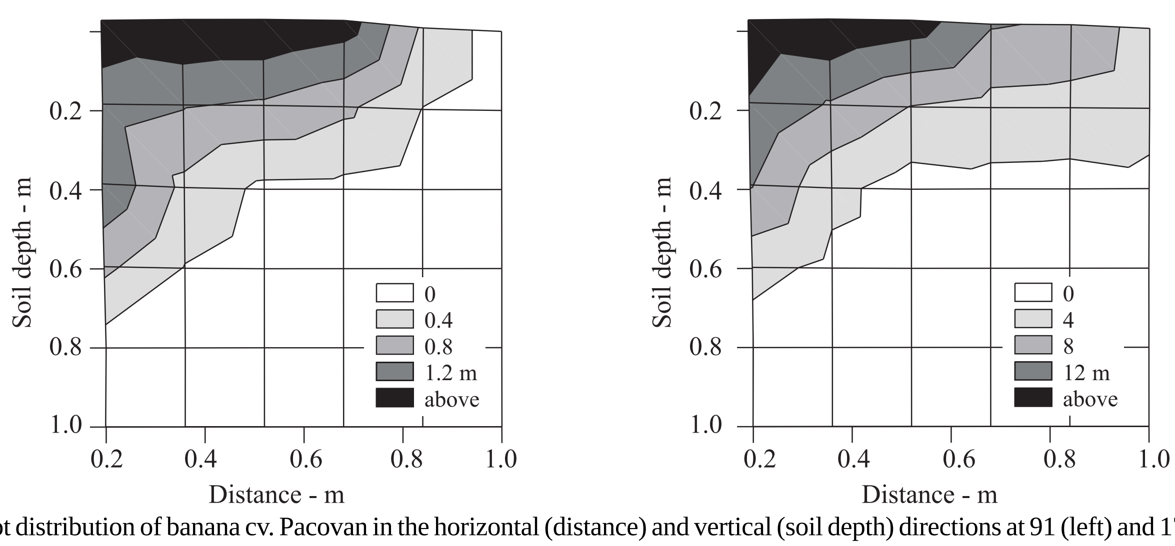

FIGURE 2 – Root distribution of banana cv. Pacovan in the horizontal (distance) and vertical (soil depth) directions at 91 (left) and 175 (right) days after planting.

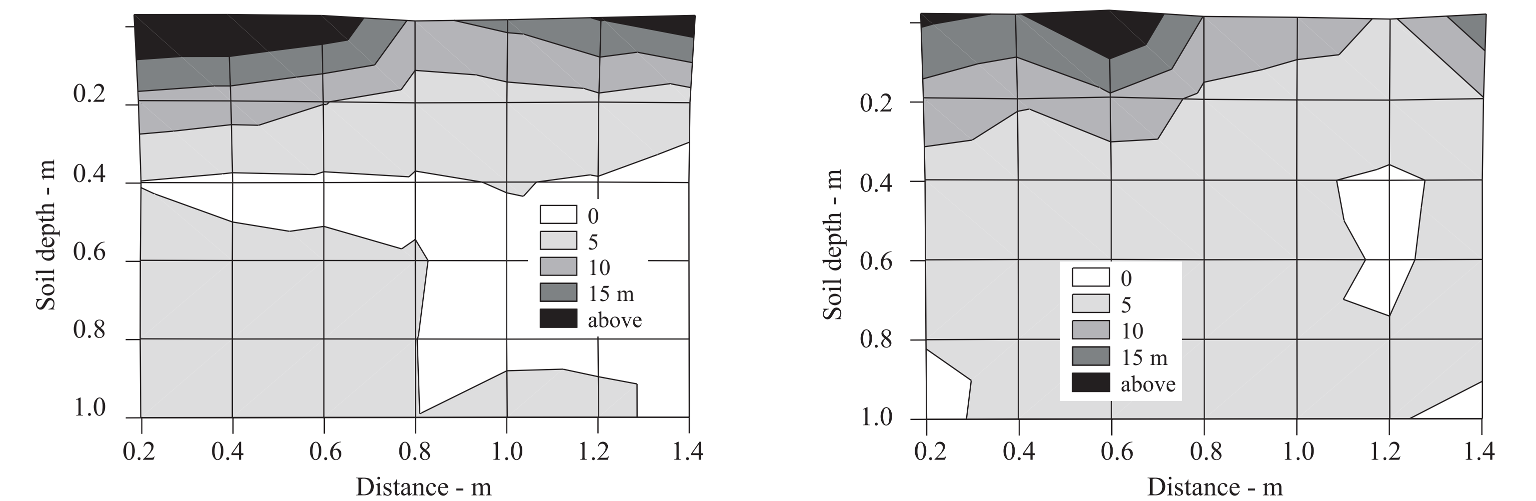

FIGURE 3 – Root distribution of banana cv. Pacovan in the horizontal (distance) and vertical (soil depth) directions at 286 (left) and 370 (right) days after planting.

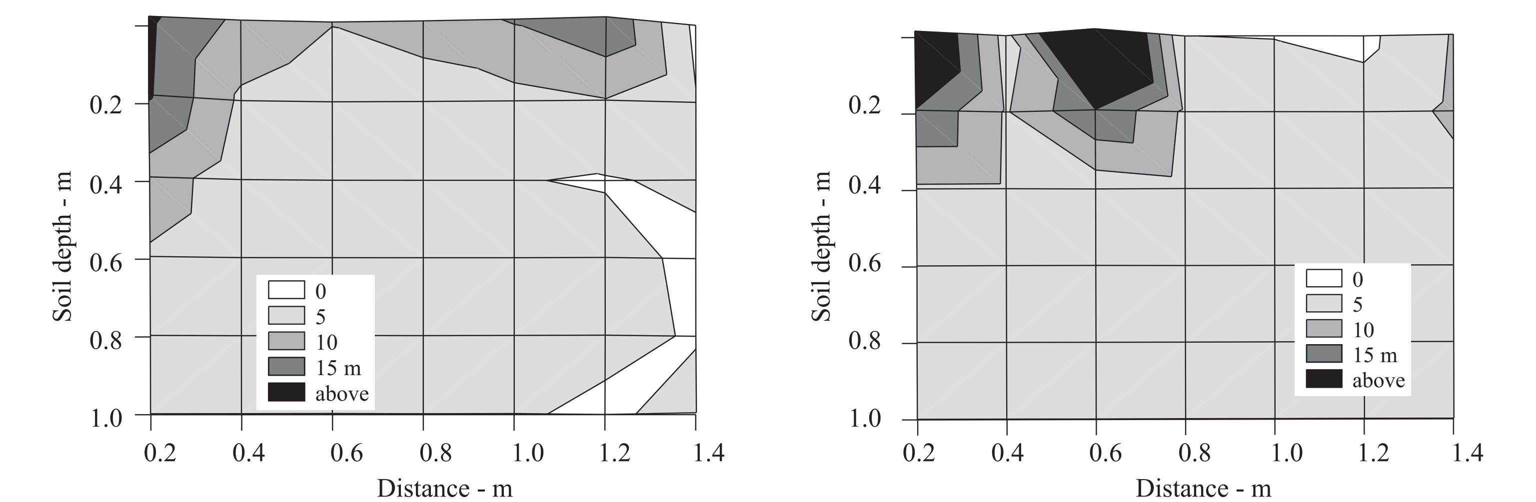

FIGURE 4 – Root distribution of banana cv. Pacovan in the horizontal (distance) and vertical (soil depth) directions at 510 (left) and 903 (right) days after planting.

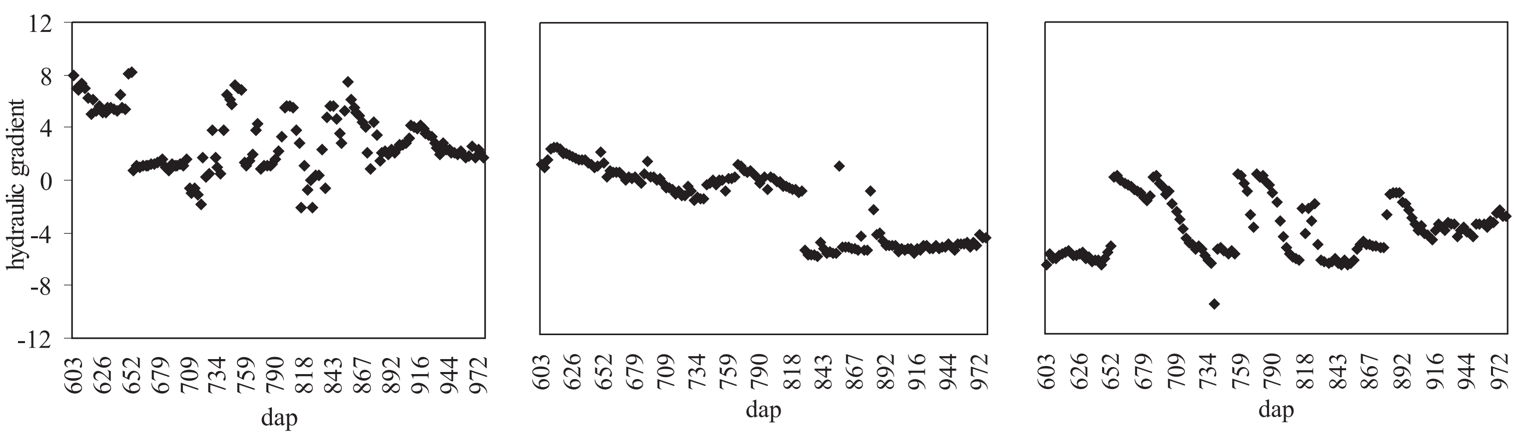

FIGURE 5 – Hydraulic gradient of soil water at 0.4 m (left), 0.6 m (center) and 0.8 m (right) soil depth throughout the 3rd growing season of banana cv. Pacovan.

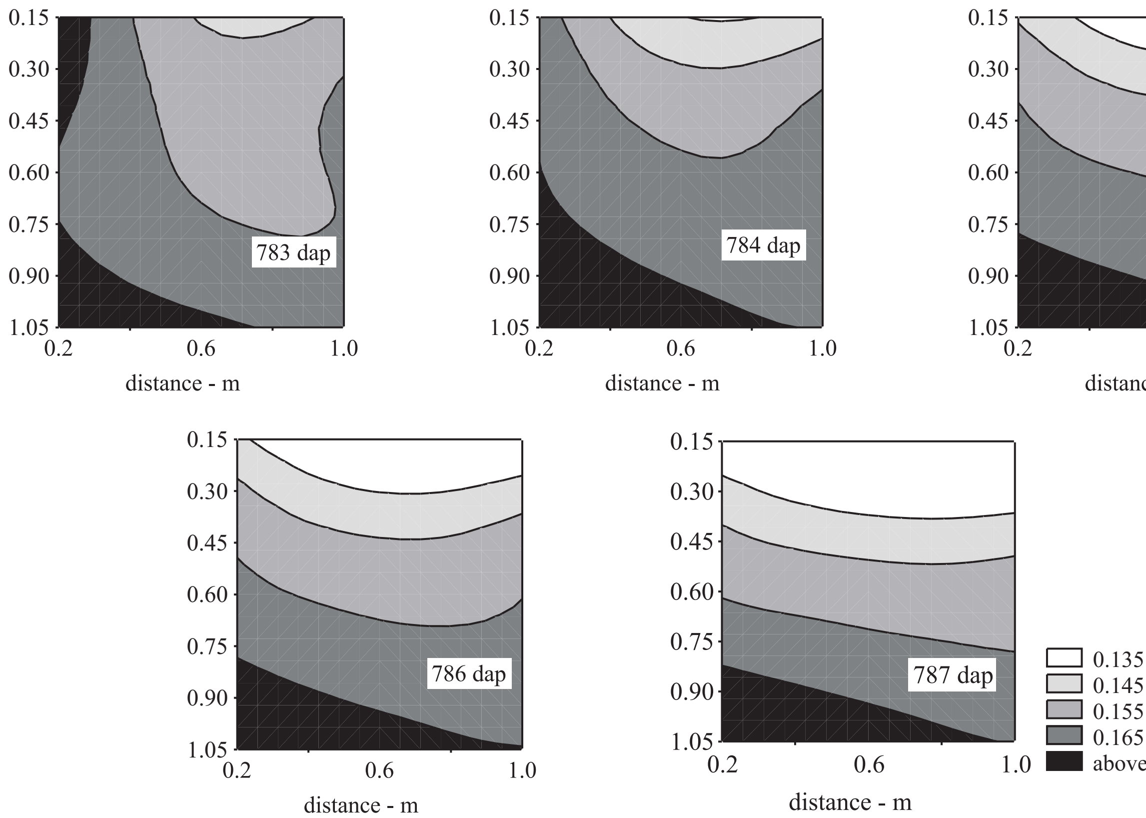

FIGURE 6 – Soil water content ($m^3.m^{-3}$) changing within the banana root zone in the 3rd growing season, with measurements within 24 h intervals.

CONCLUSION

The soil depth to be taken in account for irrigation management purposes of a banana plantation in Petrolina is 0.4 m until the 9th month after planting, and after that, 0.6 m depth. The 0.6 m distance from the pseudostem is recommended for installation of soil water measurement devices.

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