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Root distribution analysis of irrigated grapevines in northeastern Brazil by digital image processing
Etude par analyse d'image de la distribution des racines de vigne irriguée dans le nord-est du Brésil

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Summary

Root distribution analysis of grapevines cv. Italia on rootstock IAC-313 irrigated by microsprinklers and by drippers were performed by profile method aided by digital image processing. In trenches with 1m depth and 2m width values of root density (root area / soil area) obtained at five soil profiles (1.0, 0.8, 0.6, 0.4, and 0.2m distance from trunk in a perpendicular direction to plant row) showed that microsprinkler irrigated plants had greater root dispersion than those irrigated by drippers in a yellow red latosol.

Introduction

Root system is a vital part of grapevine that has important phisyologic and biochemical functions and grape yield and its quality are dependent of healthy roots (Morlat & Jacquet, 1993). Root distribution is affected by planting distance, frequency and depth of soil tillage, mulching, soil horizons (Richards, 1983), soil texture, organic matter content (Morlat & Jacquet, 1993), soil acidity (Kirchhof *et al*., 1991), rootstock (Perry *et al*.,1983) and by irrigation systems (Van Zyl, 1988). Knowledge of root distribution is importamt for soil and water management and irrigation evaluation but its analysis is difficult, laborious and time consuming. Jointly with root studies methods digital image processing techniques can substitute qualitative analysis of root on a trench wall by a quantitave measurement. Root density calculation can be obtained by image filtering and calibration of SIARCS (Integrated System for Root and Soil Coverage Analysis) based on color level of each pixel. That method can be refered as a profile method aided by digital image processing and allow root quantification in a less laborious and time consuming way with more replications (Crestana et. al., 1994). It can offers quickness and precision and makes possible to analyse roots according presence, size, volume, and surface (Fante Jr *et al*., 1994). Root activity estimation based on water dynamics measured by neutron probe and by tensiometer showed good correlation with root distribution analysis by digital image processing (Bassoi *et al*., 1994).

The objective of this work was to analyse root distribution of grapevines by image processing at five soil profiles in perpendicular direction to plant row as a function of soil depth, distance from trunk in a longitudinal direction to plant row, and irrigation system.

Material and Methods

In the experimental field of Brazilian Enterprise for Agricultural Research - Agricultural Research Center in the Semi-Arid Tropic (EMBRAPA-CPATSA), located at Petrolina, Pernambuco State, northeastern Brazil, a trial was carried out in 1995 and 1996 to observe root distribution of grapevines cv. Italia on rootstock IAC-313 planted in a 4 x 2m spacing in September 1991 in a yellow red latosol, medium texture (Pereira & Souza, 1967). Grapevines were irrigated by microsprinkler (emitters spaced in 4 m on plant row and between two plants) and by drippers (emitters spaced in 1 m on a double line). Root distribution was analysed by profile method aided by digital image processing in twelve plants (six microsprinkler irrigated plants and six drip irrigated plants). In each irrigation system trenches with 1 m depth and 2 m width were dig between plant rows to expose half root system of two grapevines (side by side) in 1995 and one grapevine in 1996 in both sides of the trench. Root system were observed at five soil profiles (1.0, 0.8, 0.6, 0.4, and 0.2 m of distance from trunk in a perpendicular direction to plant row). Each soil profile was escarified and roots were painted with white ink to enhance color contrast between them and soil. A 1 m^2 grid subdivided in 0.2 x 0.2 m areas was put in the soil profile and each small area was filmed. Root images were digitized by digitizing board installed in a microcomputer and processed by SIARCS 3.0 for Windows™, developed by Brazilian Enterprise for Agricultural Research - National Center for Development and Research of Agricultural Instrumentation (EMBRAPA-CNPDIA). In each image of 0.2 x 0.2m area, roots were selected by color contrast with soil and their area were accounting by SIARCS. The ratio root area / soil area originated the root density values of each image. Soil samples were collected to chemical and physical analysis according to procedures described by EMBRAPA (1979) and tensiometers were installed at 0.2, 0.4, 0.6, 0.8, and 1.0 m depth to determine matric potential of soil water. A 2 m PVC tube was installed also to observe water table depth during 1996 growing season (Figure 1).

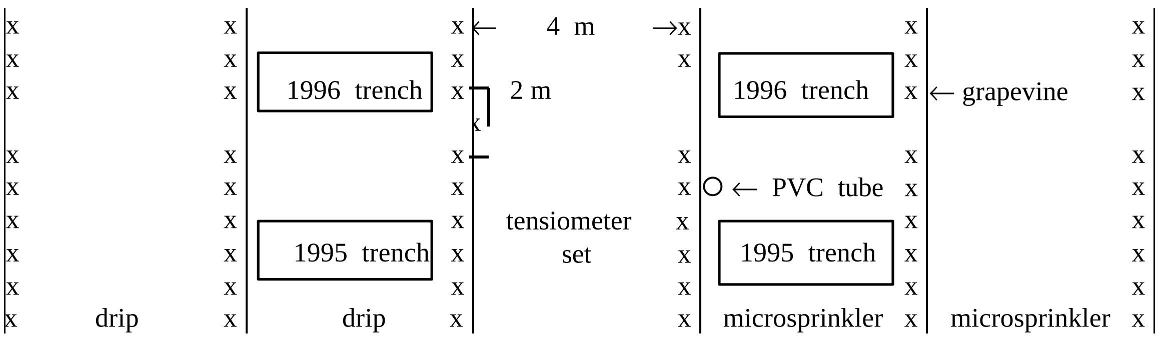

Figure 1: Field trial lay-out

Results and Discussion

Soil texture, water retention and bulk density were similar for both years and irrigation system. Soil water retention was low and the highest values of bulk density were found at upper soil layers of 0.2-0.4 and 0.4-0.6 m depth (Table 1). Soil pH was higher than 6.0 at soil layers of 0-0.2 and 0.2-0.4 m depth in 1995 trial, but were lower in the next one. Potassium and phosphorus contens were a little higher in 1995 than in 1996. In both years, soil showed low values of electric conductivity of soil water, calcium, sodium, aluminium and organic matter content, base saturation, and cationic change capacity (Table 2).

Table 1: Physical characteristics of yellow red latosol cultivated with microsprinkler and dripper irrigated grapevines cv. Italia/IAC-313 in 1995 and in 1996 at Petrolina, northeastern Brazil.

depth	sand	loam	clay	soil water $g\ kg^{-1}$		bulk density $kg\ dm^{-3}$	
m		$g\ kg^{-1}$		0.01 M Pa	1.5 MPa	1995	1996
				microsprinkler			
0-0.2	830	100	70	88.4 ± 1.6	31.2 ± 0.5	1.54 ± 0.07	1.55 ± 0.12
0.2-0.4	830	90	80	92.2 ± 0.8	30.1 ± 2.0	1.61 ± 0.21	1.65 ± 0.16
0.4-0.6	780	70	150	124.7 ± 8.8	46.7 ± 0.9	1.63 ± 0.06	1.65 ± 0.04
0.6-0.8	730	80	190	146.6 ± 6.3	56.4 ± 1.7	1.57 ± 0.04	1.60 ± 0.04
0.8-1.0	690	80	230	163.0 ± 8.7	67.7 ± 2.2	1.56 ± 0.05	1.60 ± 0.04
				drip			
0-0.2	840	100	60	100.2 ± 2.3	23.7 ± 0.4	1.51 ± 0.11	1.55 ± 0.07
0.2-0.4	860	70	70	97.4 ± 19.1	24.2 ± 0.8	1.60 ± 0.11	1.67 ± 0.06
0.4-0.6	790	80	130	120.9 ± 8.7	43.0 ± 1.6	1.60 ± 0.11	1.65 ± 0.06
0.6-0.8	730	80	190	165.2 ± 13.8	59.1 ± 0.8	1.60 ± 0.05	1.60 ± 0.06
0.8-1.0	690	80	230	185.2 ± 5.7	66.3 ± 1.2	1.61 ± 0.04	1.54 ± 0.38

Table 2: Chemical characteristics of yellow red latosol cultivated with microsprinkler and dripper irrigated grapevines cv. Italia / IAC-313 in 1995 at Petrolina, northeastern Brazil.

depth	pH	E.C.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	H + Al	Al^{+3}	V	C	P
m		$dS\ m^{-1}$			$mmol_c\ kg^{-1}$				%	$g\ kg^{-1}$	$mg\ kg^{-1}$
					microsprinkler						
0-0.2	6.2	0.33	16	13	0.1	4.0	19.8	0.5	63	0.36	69.60
0.2-0.4	6.2	0.49	16	9	0.1	3.5	14.9	0.5	66	0.22	59.40
0.4-0.6	5.1	0.84	15	9	0.2	3.2	23.1	2.0	54	0.19	57.30
0.6-0.8	4.4	0.73	9	10	0.2	3.2	29.7	8.5	43	-	-
0.8-1.0	4.2	0.57	10	11	0.2	2.5	33.0	10.5	42	-	-
						drip					
0-0.2	6.5	1.21	15	11	0.2	4.3	11.6	0.5	72	0.28	77.40
0.2-0.4	6.0	0.87	18	6	0.2	4.0	9.9	0.5	74	0.20	76.80
0.4-0.6	5.4	1.18	16	13	0.3	4.0	16.5	1.0	67	0.17	58.50
0.6-0.8	4.6	1.19	21	6	0.3	3.8	14.9	2.5	68	-	-
0.8-1.0	4.4	1.49	17	13	0.3	3.1	18.2	3.5	65	-	-

E.C. - electric conductivity   C - organic carbon

Table 3: Chemical characteristics of yellow red latosol cultivated with microsprinkler and dripper irrigated grapevines cv. Italia / IAC-313 in 1996 at Petrolina, northeastern Brazil.

Depth m	pH	E.C. dS m^{-1}	Ca^{2+}	Mg^{2+}	Na^{+} mmol$_c$	K^{+} kg^{-1}	H + Al	Al^{+3}	V %	C g kg^{-1}	P mg kg^{-1}
					microsprinkler						
0.0-0.2	4.5	0.87	6	4	0.1	1.5	26.4	3.0	31	0.47	23.71
0.2-0.4	4.7	0.75	10	3	0.1	1.7	28.1	4.0	34	0.54	41.75
0.4-0.6	5.3	0.74	12	7	0.1	2.3	21.5	1.5	50	0.37	35.74
0.6-0.8	5.0	0.91	16	6	0.2	3.0	18.2	1.5	58	0.34	51.77
0.8-1.0	5.4	1.57	19	11	0.7	4.3	9.9	1.0	78	0.23	43.42
					drip						
0.0-0.2	5.0	0.63	13	6	0.3	1.8	21.5	1.5	50	0.52	50.10
0.2-0.4	4.9	0.56	10	3	0.1	1.5	23.1	2.0	39	0.38	57.45
0.4-0.6	4.5	0.69	11	7	0.2	2.1	29.7	4.0	41	0.31	76.82
0.6-0.8	5.2	0.90	16	8	0.3	2.4	3.3	1.0	89	0.33	49.43
0.8-1.0	5.6	1.30	22	8	0.6	3.8	9.9	0.5	78	0.40	21.04

E.C. - electric conductivity   C - organic carbon

Most of 50% of root density was found until 0.4 m depth in both years and irrigation systems. Except for 1.0m soil profile, drip and microsprinkler irrigated grapevines presented greater root density in 0-0.4 m and 0.4-1.0m depth, respectively, in 1995 (figure 2). In 1996, until 0.4m depth, plants irrigated by microsprinkler had greater values at 1.0 and 0.8m soil profiles while drip irrigated ones showed higher root density at 0.6 and 0.4m soil profiles. In an opposite way, in 0.4-1.0m depth, grapevines irrigated by drippers had higher values at 1.0 and 0.8m soil profiles, while those irrigated by microsprinkler presented greater root density at 0.6 and 0.4m soil profiles. In that year root density values at 0.2 m soil profile showed a certain equilibrium between both irrigation systems (figure 3). The results suggested that differences were more clear in 1995 than in 1996.

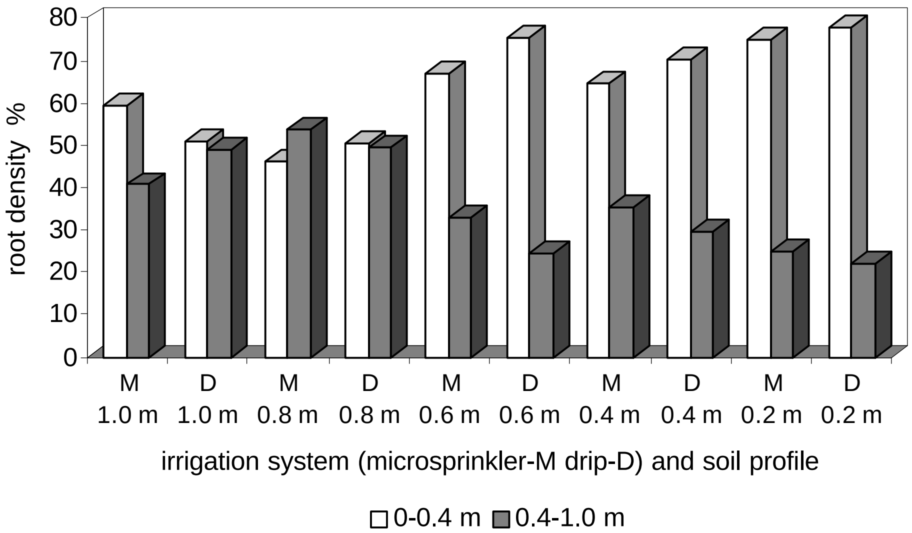

Figure 2: Root density distribution in relation to soil depth in 1995

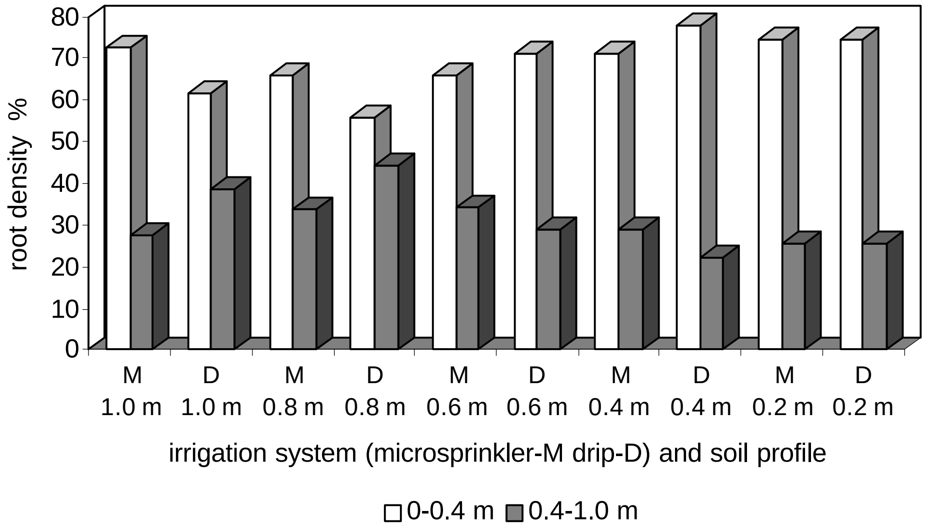

Figure 3: Root density distribution in relation to soil depth in 1996

In a longitudinal direction to plant rows and in both sides of the grapevines, the differences between irrigation systems were minimum in both years. In 1995 there was a certain equilibrium at five soil profiles (figure 4). In 1996, except at 0.8m profile, drip and microsprinkler irrigated plants showed lightly higher values at 0-0.6m and 0.6-1.0m distance from trunk, respectively (figure 5). The 0-0.6m distance from trunk presented more than 50% of root density but the diffrence in relation to 0.6-1.0m distance was more pronounced in 1996 than in 1995.

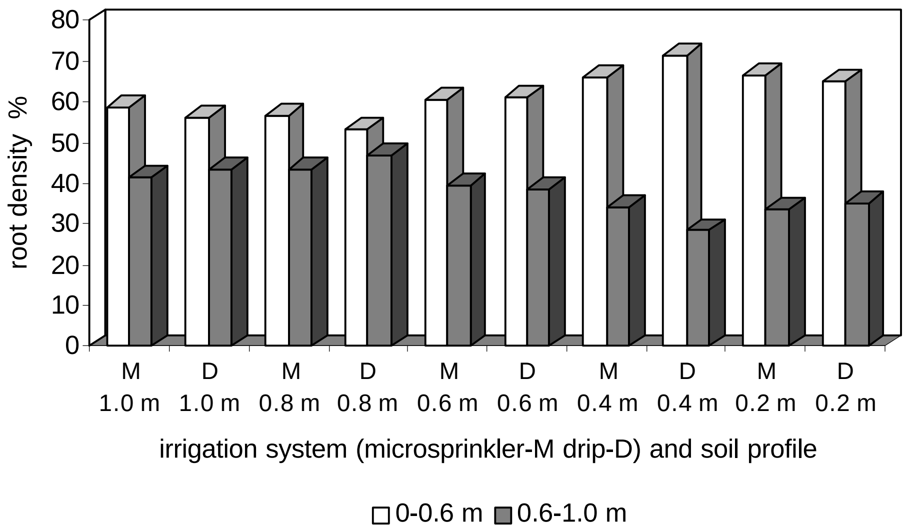

Figure 4: Root density distribution in relation to distance from trunk in 1995

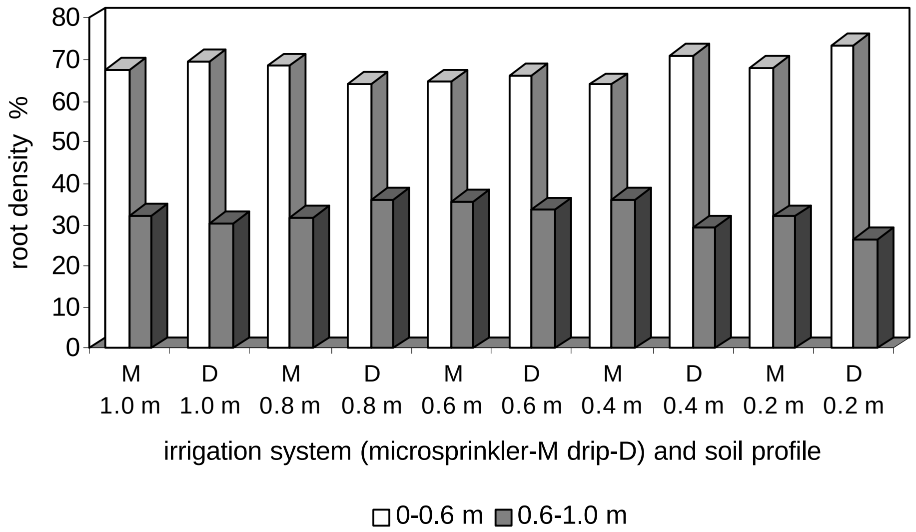

Figure 5: Root density distribution in relation to distance from trunk in 1996

In 1995 at 1.0 and 0.8m soil profiles, the differences were smaller between 0-0.4m and 0.4-1.0m soil depth and between 0-0.6 and 0.6-1.0m distance from trunk (longitudinal direction to plant row) in comparison with those occurred at 0.6, 0.4, and 0.2m soil profiles (figure 2 and 4). In 1996 there was a great difference between most of soil profiles (figures 3 and 5).

Estimation of soil water dynamics by gradient of hidraulic potential showed upward fluxes at 1.0m depth in three growing season of grapevines partly due to water table presence. During about six months in 1996 (july to december), water table depth varied between 1.48 and 1.87 m. That shallow water table depth probably contributed to minimize root development differences under the two irrigation systems analysed.

Conclusion

Irrigated grapevines cv. Italia on rootstock IAC-313 cultivated in a yellow red latosol, medium texture, showed roots until 1.0m depth and 1.0m distance in the perpendicular and longitudinal direction to plant row. Most of 50% of roots was found until 0.4 m depth and at 0-0.6m distance from trunk (longitudinal direction to plant row). Root density values were higher to plants irrigated by dripper at 0-0.4m depth and 0-0.6m distance from trunk while those irrigated by microsprinkler had higher values at 0.4-1.0m depth and 0.6-1.0m distance from trunk.

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