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DIGITAL IMAGE ANALYSIS OF ROOT DISTRIBUTION TOWARDS IMPROVED IRRIGATION WATER AND SOIL MANAGEMENT: GRAPEVINE AND DATE PALM STUDY CASES

by

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Abstracts:

It is presented two study cases about the approach in root analysis at field and laboratory conditions based on digital image analysis. Grapevine (*Vitis vinifera* L.) and date palm (*Phoenix dactylifera* L.) root systems were analyzed by both the monolith and trench wall method aided by digital image analysis. Correlation between root parameters and their fractional distribution over the soil profile were obtained, as well as the root diameter estimation. Results have shown the feasibility of digital image analysis for evaluation of root distribution.

Keywords:

image analysis, root distribution, *Vitis vinifera* L., *Phoenix dactylifera* L.

1. Introduction

Digital image processing techniques can offer advanced analysis of root measurement. The feasibility, accuracy and procedures to estimate root area, root length and root diameter by digital image analysis have been discussed intensively (Ruark & Bockeim, 1988; Commins *et al.*, 1991; Tagliavini *e. al.*, 1993; Murphy & Smucker, 1995; Kaspar & Ewing, 1997; Dowdy *et al.*, 1998; Bauhus & messier, 1999; Kimura *et al.* 1999).

Images of roots exposed on a trench wall or in the laboratory are acquired and the root area and length are estimated. Root density values are obtained to yield complete root system characterization in a soil profile. Results with grapevine (*Vitis vinifera* L.) and date palm (*Phoenix dactylifera* L.) are presented in this work. Measurements were performed by both the monolith method (Bohm, 1979) and the trench wall method using digital image analysis (Crestana *et al.* 1994). The objective of this study was to compare both methods with different root systems from those previously presented by Bassoi *et al.* (1999).

2. Material and Methods

<u>Sampling area - grapevine</u>

In an experimental area of Brazilian Agricultural Research Coorporation (Embrapa), in Petrolina, northeastern Brazil, two trials were carried out to evaluate the root distribution of grapevines cv. Italia on rootstock IAC-313 planted in a 4 x 2 m grid spacing in September 1991, in a red yellow latosol, coarse texture. Grapevines were irrigated by microsprinkler spaced every 4 m along the plant row and centered between two plants, and by drip emitters spaced 1 m apart along a double drip line. In both irrigation systems, a 1 m deep and 2 m wide trench was dug between plant rows to expose one half root system of four grapevines in October 1995 and two grapevines in April 1996. The distance between the trench wall and the plant row was 1 m, A thin layer of soil (1-2 cm) was removed from the soil profile along the whole trench, and visible roots (greater than 1 mm) were painted with white ink to enhance color contrast between the roots and the soil. A 1 x 1 m wire-wood frame with a grid of 0.2 x 0.2 m was pressed on the trench wall and video images were collected for each 0.04 m^2 area along the whole trench. The image collection procedure was repeated for distances 1.0, 0.8, 0.6, 0.4, and 0.2 m from the plant rows.

After the image collection at every trench wall, monoliths (0.2 x 0.2 x 0.2 m) corresponding to the filmed area were sampling from two plants in 1995 and another two plants in 1996, whereas each vine in opposite side of the trench. So, monoliths were collected at distances of 0.2-0.4, 0.4-0.6, 0.6-0.8, and 0.8-1.0 m from the plant rows.

In a commercial growing area in 1997, the root distribution of cv. Piratininga on rootstock IAC-313 was determined using only the trench wall method combined with the digital image analysis, to demonstrate its application in a farmer's field. Grapevines were planted in 1990 using a 3.5 x 2 m grid spacing, in a clayey soil. The vines were irrigated using furrows on either side of the vine row. Two trenches (1 m deep and 2 m long) were excavated to expose the rooting system of one vine trunk in the center of each trench. Images were captured as described earlier at distances of 1.0, 0.8, 0.6, 0.4, and 0.2 m from the plant row.

Sampling area - date palm

In the Embrapa's experimental area, an experiment with date palm cv. Zahidi was carried out in March 1997, in a germoplasm bank. Crop was planted in April 1982 in a 5 x 4 m grid spacing and it has been irrigated by furrows (one in each side of the rows). A 1 m depth trench was excavated in a longitudinal direction to rows to expose half root system from one plant, at 1m distance form the trunk. The procedure in this experiment was similar to that described for the grapevine's trials in the experimental area, except that roots were shot and the corresponding monolith were sampled in a 1 x 1 m area, at one side of the trunk.

Field image

The images collected in the field with a video camera were digitized by a board (resolution of 640 x 480 pixels). The image analysis was performed by SIARCS 3.0 (Integrated System for Root and Soil Coverage Analysis). For grapevine, root area (A_p, cm^2) was measured in both trial's sites, while the root length (L_p, cm) was measured only in the commercial growing area. For date palm, both root parameters were measured.

Laboratory data

Roots from grapevine and date palm crops were separated from soil by 4 mm smash sieving. In the laboratory, roots were washed and classified in four diameter intervals (d): $d \leq 2$ mm, $2 < d \leq 5$ mm, $5 < d \leq 10$ mm, $d > 10$ mm. Roots were dried in a 65°C oven to dry weight measurement (D_w, g).

For grapevine roots, the length inside the monolith (L_m, cm) was estimated based on the number of root intersection with the lines of a grid (1 x 1 cm for roots with $d \leq 10$ mm, and a 2 x 2 cm for roots with $d > 10$ mm), multiplied by a factor (Tennant, 1975).

For date palm crop, roots from different diameter intervals presented in each monolith were divided in so many parts as necessary and put on a color contrast background with delimited area, to be shot by a digital camera (resolution 480 x 240 pixels) and transferred to a microcomputer. Root area (A_m, cm^2) and the root length (L_m, cm) inside the monolith were measured by SIARCS 3.0. Values from each diameter interval were summed to obtain the total value for each parameter.

Data analysis

For grapevines in the experimental area (1995 and 1996 trials), D_w and L_m from monolith were correlated with the averaged A_p, obtained from the front and back walls of the corresponding monolith. In addition, the vertical distribution for both the monolith and trench wall method was compared, using fractional weight, length or area values, averaged for each horizontal 0.2 m layer along the trench. For grapevines in the commercial growing area (1997 trial), correlation was made between A_p and L_p. The A_p / L_p ratio was used to derive the root diameter in each trench wall (d_r, mm), and the averaged value was obtained from two subsequent soil profiles.

For date palm crop, D_w, A_m and L_m from monolith were correlated with the averaged A_p and L_p obtained from the front and back walls of the corresponding monolith. The A_p / L_p ratio was also used to estimated d_r, and the averaged value obtained from the front and back walls of the corresponding monolith was compared with the root diameter measured directly from the monolith.

The root length density (L_v) was calculated using the data obtained in the monolith method:

$L_v = L_m / 20 * 20 * 20$ $(cm.cm^{-3})$

According to Bassoi *et al.* (1999), and using trench wall data, it was assumed that the areal root fraction (ARF, area of root/area of soil) is approximately equal to the volumetric root fraction (VRF, volume of root/volume of soil). So, the root length density (trench L_v) can be estimated from:

$AFR = VFR = [(A_{p1}+A_{p2}) / 2] / 20 * 20$ $(cm^3.cm^{-3})$
$L_v = VFR / \pi [(d_{r1}+d_{r2})/2]^2$ $(cm .cm^{-3})$

where A_{p1} and A_{p2} are the front and the back wall in relation to each monolith, and d_{r1} and d_{r2} are the root diameter in the front and in the back wall, as estimated from A_p / L_p.

The L_v calculated by monolith data were obtained for both crops in the experimental area, while L_v estimated using trench wall data was obtained for grapevine trial in 1997 and for date palm crop.

3. Results

Grapevine

Correlation obtained between D_w, L_m and averaged A_p from 1996 trial were slightly better than 1995 ones, but in both years the r^2-values were not so high, even those between parameters measured inside the monolith (D_w and L_m). Otherwise, correlation performed between the averaged fractional distribution of the root parameters for each 0.2 m soil layer along the trench wall, considering each plant and each soil profile, were higher (Table 1). L_v calculated by monolith data ranged from 0.001 to 0.273 $cm.cm^{-3}$. In the 1997 trial, a similar trend in the correlation between parameters and fractional distribution was showed (Table 2). Values of d_r were 2.7 ± 1.1, 2.7 ± 1.3, 2.5 ± 1.2, and 2.3 ± 0.9 mm for 0.2-0.4, 0.4-0.6, 0.6-0.8, and 0.8-1.0 m soil profiles, respectively, and estimated L_v using trench wall data varied from 0.0001 to 0.093 $cm.cm^{-3}$.

Table 1: Correlation ($p < 0.05$) of grapevine root parameters and distributions measured by monolith and trench wall methods in the experimental area in 1995 and 1996.

	D_w x L_m	D_w x A_p	L_m x A_p	D_w x L_m	D_w x A_p	L_m x A_p
		1995			1996	
			parameter			
microsprinkler	0.562	0.417	0.599	0.592	0.602	0.687
drip	0.614	0.646	0.567	0.724	0.663	0.783
			distribution			
microsprinkler	0.855	0.698	0.744	0.869	0.913	0.946
drip	0.916	0.870	0.873	0.866	0.741	0.893

D_w – root dry weight inside the monolith; L_m – root length inside the monolith; A_p- average root area in the soil profile

Table 2: Correlation ($p < 0.05$) of grapevine root parameters and distributions measured by trench wall method aided by digital image analysis in a commercial growing area in 1997.

A_p x L_p	A_p x L_v	L_p x L_v	A_p x L_p	A_p x L_v	L_p x L_v
	parameter			distribution	
0.858	0.535	0.585	0.968	0.745	0.771

A_p- average root area in the soil profile; L_p – average root length in the soil profile; Lv - root length density estimated by trench wall data

Date palm

The correlation values from parameters have varied from medium to high, but they were better for fractional distribution (Table 3). L_v values obtained from monolith (range from 0.020 to 0.169 $cm.cm^{-3}$) were higher than those obtained by trench wall data (range from 0.001 to 0.004 $cm.cm^{-3}$), and correlation between them was 0.567 ($p < 0.05$). The root diameter estimation by (A_p / L_p) ratio was 2.4 ± 0.4, 2.4 ± 0.6, 2.5 ± 0.6, and 2.5 ± 0.4 mm, for 0.2-0.4, 0.4-0.6, 0.6-0.8, and 0.8-1.0 m soil profiles, respectively.

Table 3: Correlation ($p < 0.05$) of date palm root parameters and distributions measured by monolith and trench wall methods in the experimental area in 1997.

D_w x A_m	D_w x L_m	D_w x A_p	D_w x L_p	A_m x L_m	A_m x A_p	A_m x L_p	L_m x A_p	L_m x L_p	A_p x L_p
				parameters					
0.962	0.771	0.719	0.686	0.872	0.742	0.721	0.616	0.640	0.959
				distribution					
0.986	0.873	0.870	0.840	0.925	0.850	0.846	0.676	0.753	0.962

D_w – root dry weight inside the monolith; A_m – root area inside the monolith; L_m – root length inside the monolith; A_p- average root area in the soil profile; L_p – average root length in the soil profile

4. Discussion

For both crops, results related to root parameters can be considered reasonable, but fractional distribution of root parameters over the entire 0.2 m soil layer were much better. For the $d \leq 2$ mm interval, grapevines showed up a range from 32.8 to 73.0 % of D_w, but it corresponded from 84.7 to 96.4 % of L_m. For date palm, 8.8, 30.0, 56.2, and 5.0 % of D_w were within $d \leq 2$, $2 < d \leq 5$, $5 < d \leq 10$, and $d > 10$ mm, while for the same intervals, 28.1, 23.3, 24.1, and 24.6% of L_m were found, respectively.

The estimated root diameter (d_r) in the grapevine commercial area can be considered as reasonable accurate in comparison with root diameter measured by monolith method in the experimental area. Greater percentage of grapevine roots was found within $d < 0.5$ mm (van Zyl, 1998), $d < 1$ mm (Morlat & Jacquet, 1993) and $d < 2$ mm (Morano & Kliewer, 1994; Padgett-Johnson, 1999). L_v estimated by monolith was much higher than L_v estimated by trench wall data. For date palm, it seems that (A_p / L_p) ratio underestimated the root diameter, and L_v calculated by data from monolith was also much higher, and poorly correlated with L_v estimated by trench wall data.

Bassoi *et al.* (1999) presented higher correlation for peach palm (parameter and distribution r^2 higher than 0.9) and asparagus (parameter and distribution r^2 higher than 0.8), as well as more accurate root diameter estimation. As 87.8 % of peach palm roots were within $d \leq 5$ mm, and 87.8 % of asparagus roots were within $2 < d \leq 5$ mm, it leads to believe that finer root systems can provided better correlation between the monolith method and the trench wall method aided by digital image analysis.

5. Conclusions

For grapevine and date palm crops, the correlation between root parameters estimated by both monolith and trench wall method aided by digital image analysis was reasonable. But correlation was much better for fractional distribution of the same parameters over the soil profile. The higher presence of grapevine roots within the lower diameter interval probably has contributed for a better correlation between parameters, distribution and root diameter estimation than date palm crops. Results have shown the feasibility of digital image for root distribution evaluation.

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