

ROOT DENSITY AND DIAMETER OF SUGARCANE CULTIVARS ACROSS THREE LOCATIONS IN CUBA

By

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Abstract

THE OBJECTIVE of the present work was to study the density and distribution of sugarcane root systems in a multi-environment trial. Experiments were planted at three locations in the South-Eastern region of Cuba, with 11 sugarcane cultivars. Measurements of root diameter and root density (root numbers/cm³) for fine (FD), thick (ThD) and total (TD) roots were taken using the profile wall method. The root system was evaluated in squares of 20 × 100 cm up to 80 cm depth below the ground surface. Cane yield data (t/ha) and its relations with root system measurements were analysed. Genotype by environment interaction was identified using the AMMI model. Results showed significant (p<0.05) response for root density across genotypes, locations, depths and all interactions. Root depth was the major source of variation. Percentage of total root density was variable from 42.6–55.5% for 0–20 cm depth, dropping to 5.6–11.7% for 60–80 cm depth. Genotypes C86-12, C86-156, B7274 and C88-380 showed similar patterns for t/ha and TD. Moderate but significant (p<0.01) correlations were found between t/ha and FD, ThD and TD.

Introduction

The root system serves important physiological and biochemical functions. A deep-root system should be a desirable characteristic for sugarcane cultivars for the low rainfall regions because this would ensure an ability to endure depletion of soil water (Smith *et al.*, 2005).

However, quantitative information on root distribution in sugarcane is limited. The objective of the present work was to study the density and distribution of sugarcane root systems comparing genotypes across environments in a multi-environment trial.

Materials and methods

The trial was carried out in the South-Eastern region of Cuba at three locations across the sugarcane production zone (Table 1).

Therefore, data from a multi-environment trial were analysed. Eleven sugarcane cultivars: C86-12, B7274, C323-68, C90-317, C86-156, C86-503, C86-531, C88-380, C90-530, C90-647 and C89-250, released in the last 10 years by the Cuban National Institute for Sugarcane Research (INICA) were evaluated.

Experiments at each location were planted in a randomised block design with three replications.

Data were collected from the plant and first ratoon crops. Root evaluation was performed in the first ratoon crop within 12 months. Cane yields (t/ha) for the first ratoon cropping season were recorded.

Table 1—Information of the three test locations of the multi-environment trial.

Location			Year planted	Years of harvests	Soil type	Rain per annum (mm)
County	Name	Code				
Santiago de Cuba	Paquito Rosales	PR	2006	2008–2009	Cambisol Eutrico	1156.7
Santiago de Cuba	Julio A. Mella	ME	2006	2008–2009	Acrisol Alúmico	1031.1
Granma	Enidio Díaz	ED	2006	2008–2009	Feozem Calcárico	1130.4

For assessing root diameter (mm) and density (root numbers/cm³), the profile wall method was used (Vasconcelos *et al.*, 2003). Evaluations were made at 0.8 m depth and 1.0 m wide trenches (Figure 1). The profile was divided in squares of 20 x 100 cm up to a soil depth of 80 cm below the ground surface (0–20, 20–40, 40–60 y 60–80 cm). Roots were classified as fine (FD) (0.5–1 mm), thick (ThD) (>1 mm) and total (TD = FD + ThD).

Analysis of variance (ANOVA) was performed to determine the significance of the main effects of genotype, environment and depth. The effect of genotype-environment interaction (GE) was also determined using AMMI models (Gauch *et al.*, 2008), and regression analysis.

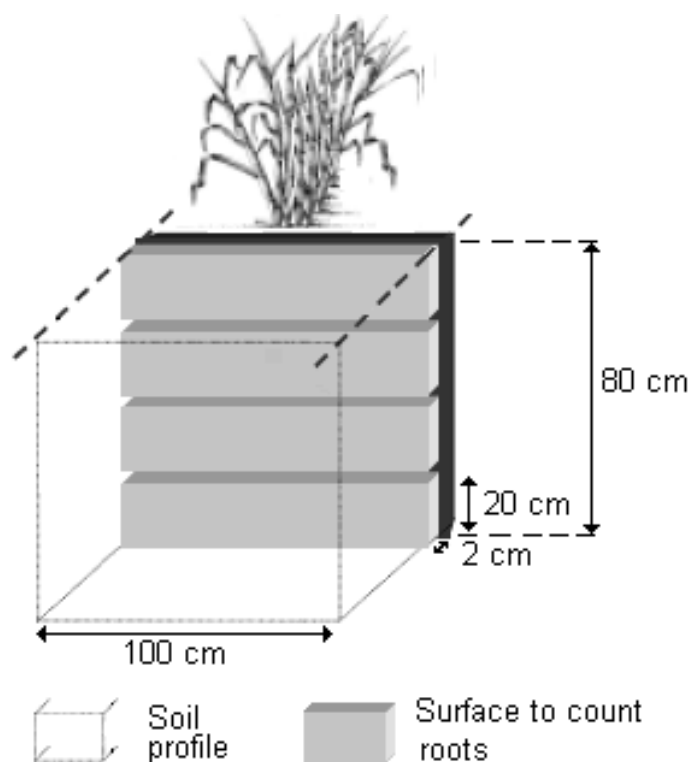


Fig. 1—Profile wall method used for assessing sugarcane root diameter and density.

Results and discussion

Results of analysis of variance (Table 2) showed significant differences for all effects (genotypes, locations and depths) and its interaction. For root density (FD, ThD and TD), depth was the most important source of variation accounting for 42.5, 63.1 and 58%, respectively.

Root diameter also showed significant differences for all effects and every interaction. Root diameter was different from root density for magnitudes of the variance terms. Results showed a lower variance contribution for depth for root diameter.

Table 2—Analysis of variance for root density and diameter.

Source	DF	FD		ThD		TD		Diameter (mm)	
		M.S.	PSS	M.S.	PSS	M.S.	PSS	M.S.	PSS
Location (L)	2	0.000772 *	4.0	0.000893 *	5.0	0.003063 *	4.8	1.66 *	6.0
Rep.(within L)	3	0.000031	0.2	0.000040	0.3	0.000141	0.3	0.03	0.2
Genotype (G)	10	0.000408 *	10.6	0.000112 *	3.1	0.000770 *	6.1	0.92 *	16.6
Depth (D)	3	0.005388 *	42.0	0.007574 *	63.1	0.025724 *	60.9	4.17 *	22.7
GxL	20	0.000111 *	5.8	0.000053 *	2.9	0.000223 *	3.5	0.63 *	22.7
GxD	30	0.000172 *	13.4	0.000088 *	7.3	0.000415 *	9.8	0.14 *	7.7
LxD	6	0.000516 *	8.0	0.000468 *	7.8	0.001769 *	8.4	0.32 *	3.4
GxLxD	60	0.000056 *	8.7	0.000038 *	6.3	0.000135 *	6.4	0.11 *	11.7
Error	129	0.000021	7.1	0.000016	4.1	0.000048	4.9	0.04	8.9

* indicates significant differences at $p < 0.05$, PSS =Percent of total sum of squares

As shown in Figure 2, the highest mean total root density (TD) was recorded at Enidio Díaz, and this was significantly different to the other locations. Root density and percent of total roots were different for locations and depth. The Enidio Díaz location had the highest percent total root density in the first 20 cm (55.5%), going down progressively with depth to 5.6% at 80 cm, which was the lowest of the three locations.

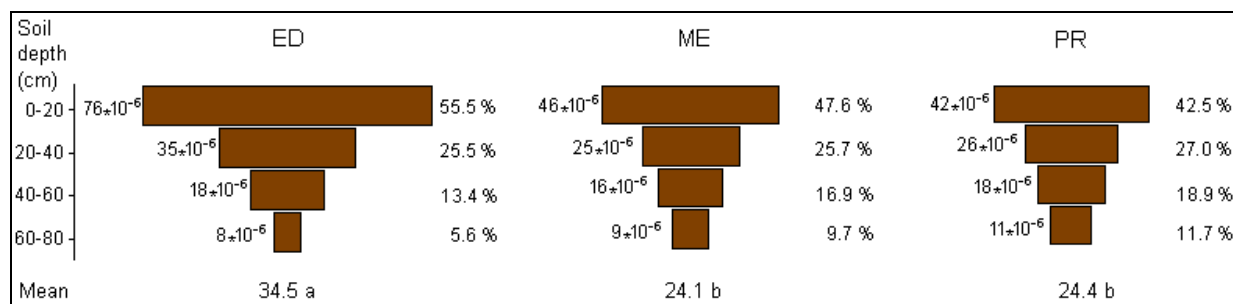


Fig. 2—Root density and percent of total roots recorded at each location.

Leyva *et al.* (2000), found a negative relation between depth and root numbers. Vasconcelos *et al.* (2003) reported 72% of total roots in the first 40 cm of soil depth. Physical-chemical properties of the soils at the three locations are shown in Table 3. The Enidio Diaz location has the lowest value for bulk density (BD) and the highest concentration of organic matter (OM). These characteristics seem to improve the development of the sugarcane root system. However, the Mella location, with a sandy soil, has the highest value for BD, the lowest concentration of OM and the poorest root system development.

Table 3—Physical-chemical characteristics of the soils at the three locations.

Location	Physicals		Chemical characteristics									
	BD (g/cm ³)	P (%)	OM (%)	P ₂ O ₅ mg/100g Soil	K ₂ O	pH H ₂ O	pH KCL	CaCO ₃ %	Ca ²⁺ mEq/100 g Soil	Mg ²⁺	K ⁺	Na ⁺
ED	0.95	61.4	5.51	0.89	8.36	7.80	6.60	10.28	61.29	5.79	1.39	2.67
ME	1.35	49.6	1.02	5.06	9.25	6.40	5.10	0.00	28.00	8.40	0.21	9.46
PR	1.12	54.5	3.8	0.70	15.75	7.20	6.80	0.32	64.00	12.60	0.32	0.35

BD–Bulk density *P*–Porosity *OM*– Organic matter

A regression analysis for cane yield (t/ha) and root density (FD, ThD and TD) (Figure 3) showed a moderated and significant correlation, with the highest R^2 value for ThD. These results demonstrate that sugarcane root densities are influenced by the environment and genotype, as their relation with yield is not completely proportional. This suggests genetic differences for root system efficiency.

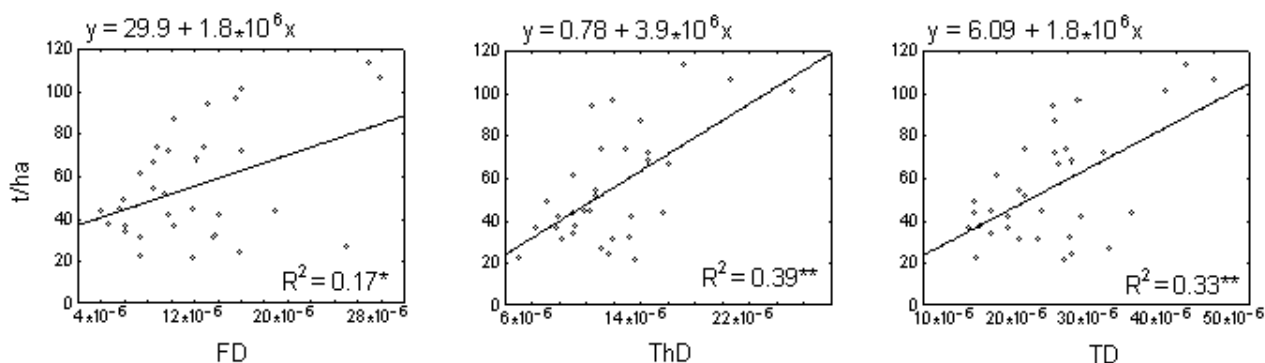


Fig. 3—Regression analysis for root density (fine (DS), thick (DP) and total (TD)) and cane yield (t/ha). (** indicates significant differences at $p < 0.01$ and * $P \leq 0.05$)

The pattern of genotype by environment interaction for cane yield and total root density was analysed using the AMMI model. For cane yield (Figure 4a), AMMI analysis indicated differences for the three test locations.

At Mella location, C89-250 was the highest yielding genotype. At Enidio Diaz location, the best yielding genotypes were C90-530 and C88-380. At Paquito Rosales, the best performing genotype was C323-68.

The pattern of GE for total root density (Figure 4b) showed differences between the three locations, but genotypes clustered differently compared to cane yield. Genotypes with the best performance across all locations were the same for cane yield and DT: C86-12, C86-156, B7274 and C88-380.

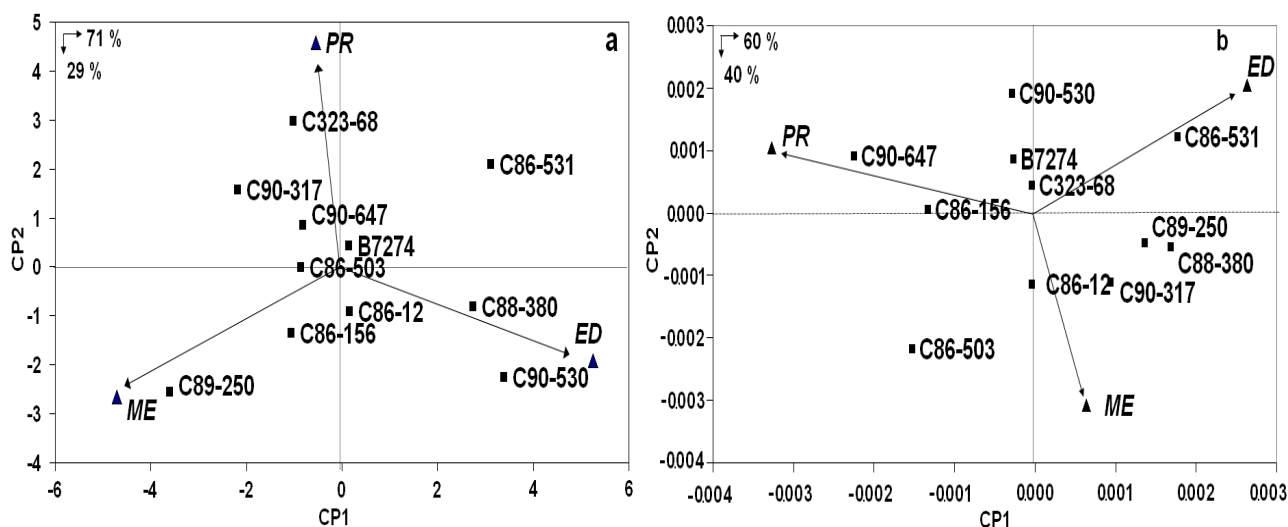


Fig. 4—Biplot of genotype by environment interaction using AMMI model for (a) cane yield (t/ha) and (b) total root density.

Root diameter (Figure 5) showed differences among locations, genotypes and depth. Enidio Díaz location had the lowest mean value for root diameter, significantly different to the other locations. There were also significant differences among genotypes for root diameter. The highest root diameter values were found in the upper soil layer and reduced with soil depth (see colour scale).

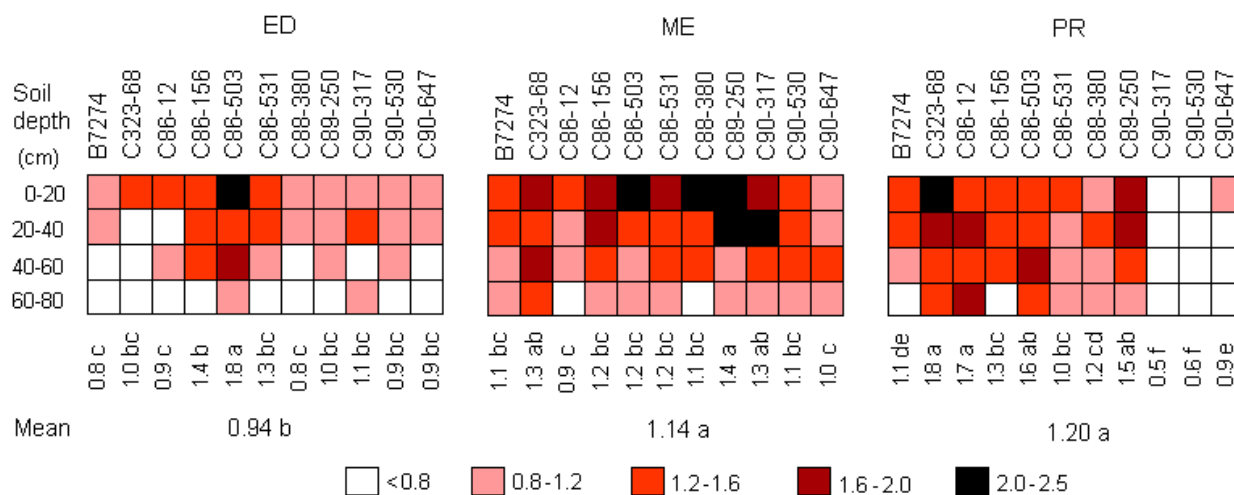


Fig. 5—Genotypes root diameter and its distribution on soil profile at the three locations.

Results indicate differential performance of genotypes for root density (FD, ThD and TD) across location and soil depth. The highest root density is found in the upper soil layer (0–20 cm) and directly below the plant. On the other hand, genotypes with high homogeneity for root system distribution in the soil profile could take advantage of soil water. Relationship between root density and agricultural yield is not always direct. It depends on several environmental factors where it is developed. In the future, we will focus on water uptake and shoot eco-physiological traits such as biomass, leaf area, stalk length, etc.

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**DENSITÉ ET DIAMÈTRE DES RACINES DES CULTIVARS DE
LA CANNE À SUCRE DANS TROIS SITES À CUBA**

Par

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norge@inica.minaz.cu***MOTS-CLÉS: Canne à Sucre, Système Radiculaire,
Technique du Profil Cultural, Génotype par Environnement.****Résumé**

LE BUT de ce travail consistait à étudier la densité et la distribution du système racinaire de la canne à sucre de 11 cultivars dans des essais multi-locaux établis dans trois sites dans la région du sud-est de Cuba. Une mesure du diamètre et de la densité des racines (nombre de racines par cm³) pour les racines fines (FD), épaisses (ThD) et totales (TD) ont été prélevés par la technique du profil cultural. Le système racinaire a été évalué en utilisant des grilles de 20 × 100 cm d'une profondeur allant jusqu'à 80 cm. Le rendement de canne (t/ha) et sa relation en fonction des mesures du système racinaire ont été analysés. Les interactions génotype × environnement ont été identifiées grâce à la modélisation AMMI. Les résultats ont démontré une réponse significative ($p < 0.05$) pour la densité des racines à travers les génotypes, les sites, la profondeur ainsi que pour toutes les interactions. La profondeur des racines a été la source principale de variation. Le pourcentage de la densité totale des racines a varié de 42.6–55.5% pour une profondeur de 0–20 cm, déclinant à 5.6–11.7% pour une profondeur de 60–80 cm. Les génotypes C86-12, C86-156, B7274 et C88-380 ont montré une tendance similaire pour le rendement de canne et la mesure des racines totales. Des corrélations modérées, mais significatives ($p < 0.01$) ont été observées entre le rendement de canne et la mesure des racines totales ainsi que pour les racines épaisses et les racines totales.

ESTUDIO DEL SISTEMA RADICULAR DE LA CAÑA DE AZÚCAR EN TRES LOCALIDADES DE CUBA

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**PALABRAS CLAVES: Caña de Azúcar, Raíces,
Perfil de Suelo, Interacción Genotipo-Ambiente.**

Resumen

EL OBJETIVO del presente trabajo fue el estudio de la densidad y distribución del sistema radicular de la caña de azúcar en experimentos multiambientales. Los estudios se plantaron en tres localidades de la región sur oriental de Cuba, con 11 cultivares. Se determinó la densidad (no. raíces/cm³) de las raíces activas finas (DF), gruesas (DG) y total (DT) y su diámetro (mm). Se utilizó el método del perfil de suelo, dividiéndose en áreas de 20 cm × 100 cm, hasta 80 cm de profundidad. Se determinó el rendimiento del cultivo (t caña/ha) y su relación con las variables analizadas, así como, análisis de interacción genotipo-ambiente (IGE) por el modelo AMMI. Los resultados mostraron, que para todas las variables de densidad de raíces, una respuesta diferenciada y significativa ($p < 0.05$) de los genotipos, localidades, y profundidades, así como de sus interacciones. Para el diámetro, la mayor variación fue debida a la profundidad. Los porcentajes de la densidad total de raíces por profundidad y localidad disminuyen desde 42.6–55.5% para la profundidad de 0–20 cm hasta 5.6–11.7% para los 60–80 cm. Los genotipos C86-12, C86-156, B7274 y C88-380 presentaron similar patrón de IGE para las t caña/ha y la DT. Se obtuvieron correlaciones moderadas y significativas respecto a las t caña/ha para la DF, DG y DT.