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Spatial 2D Distribution and Depth of Sugarcane Root System in a Deep Soil

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ABSTRACT

Sugarcane root system depth is a key parameter for water and mineral uptake but it is still very little known. Rooting depth of sugarcane (variety R570) has been determined in a deep soil in Reunion Island. In depth, it is therefore difficult to use the soil core method. Over a 1.5 m wide soil profile, roots were counted down the root front using a 5cmx5cm mesh grid to spatialize results. Data were entered into the *RACINE2* software. It calculates root length density (RLD) and from RLD, distances between roots (ARD), producing, 2D root distribution maps and depth-related RLD profiles. Below 2 m, RLD was weak but not nil, and root fronts on the 4 measurement sites were 405, 390, 400, and 325 cm deep. RLD decreases with depth from .6 to .01 $cm.cm^{-3}$ at a 2-m depth. There was a power relationship between depth and RLD. ARD values are lower than 10 cm at 2-m depth. Below 3 meters, they fluctuated between 10 and 50 cm. If roots in the soil can absorb water up to 5 cm, roots below 1.5 meter may allow survival in case of drought. The study was carried out in good crop conditions, in deep soil. Findings bring new important information for Reunion Island, where it was thought that RF was less than 2 m in depth (data used in crop models). These results also contribute to a better understanding of the sugarcane root system.

KEYWORDS: Root front, Reunion Island, Root length density, Root distribution, Root spatial variability, Sugarcane root system.

INTRODUCTION

The depth of the root system determines the usable soil depth for water and mineral uptake. It is particularly useful in modeling and for decision-making about fertilizing and irrigation. According to Evans (Evans, 1936, taken up by van Dillewijn, 1952), sugarcane roots can grow down to a depth of 6 meters in favorable conditions. These estimations have been partially challenged for modern varieties (Blackburn, 1984). A review of recent results (Smith et al., 2005) indicates that the depth of sugarcane’s root system is not yet well known, and that there have been no recent publications relating to the observation of sugarcane roots below a depth of 2 meters since the 1930s. Similarly, in the Island of Reunion, where sugarcane is the main crop, some unpublished studies of roots have never studied beyond a 2-meter depth, which is currently considered locally as the maximum depth of sugarcane’s root system in optimal conditions. Modeling work carried out in Reunion Island retains a value of 1.5 m as root system depth. The aim of this study is to estimate this root system depth in local conditions. The first use of this is for entering more precise root front depth values into irrigation models and decision support tools. Knowledge of sugarcane’s root front is also essential for nutrient and water balance as it determines the limit in the soil between the zone where the nutrients are fertilizers and the one where they become potential pollutants of the groundwater.

MATERIALS AND METHODS

Root system measurements were taken on an experiment located in the south of Reunion Island (lat: 21° 15' S, long: 55° 29' E). The soil was a deep (over 5 meters), clayey cambisol, free of coarse elements, with a homogenous bulk density of 1.1. The sugarcane (variety R570, 5th ratoon) was cultivated with additional irrigations if required and fertilized according to needs. Neither sunshine during the crop cycle, nor air temperature (mini. 13.5°C, maxi. 32.7 °C), nor soil moisture, measured close by, were limiting factors of the growth of the aerial parts and roots. The measurements were taken in 2008, after a crop cycle of eight months, when the cane had reached full vegetation.

Figure 1. View of the soil profile opened up for the study (depth of 4.5 m).

The measurement method used is that of the grid adapted by Chopart (Chopart, 1999, 2009) of the trench-profile method (Böhm, 1976). On a soil profile, the intersections between the roots and a plane formed by the surface of the soil profile are counted using a grid with meshes of 5 x 5 cm. Measurements of four soil profiles were carried out, with each having a width of 1.5 m (an inter-row) and a depth corresponding to the disappearance of roots of over 20 cm. The intersection counts were entered in the RACINE2 software program (Chopart et al., 2008) so as to calculate the root length density (RLD), and then the average root distance (ARD), using Newman’s formula (1966), these being the two root system characteristics retained for describing the profile as far down as the root front.

RESULTS AND DISCUSSION

Figure 2 enables visualization of root distribution in the profile. There was a gradient between row and inter-row in the first 60 to 80 centimeters. Deeper down, the distribution was far more random, according to the variations in mechanical resistance to root penetration, with the roots taking advantage of zones of weaker resistance (former crevices). Below a depth of 2 meters, root density was weak but clearly present on each profile, and the root front observed ranged between 325 and 405 cm. (Fig.1). At these depths, the roots were alive (white, turgescent and flexible).

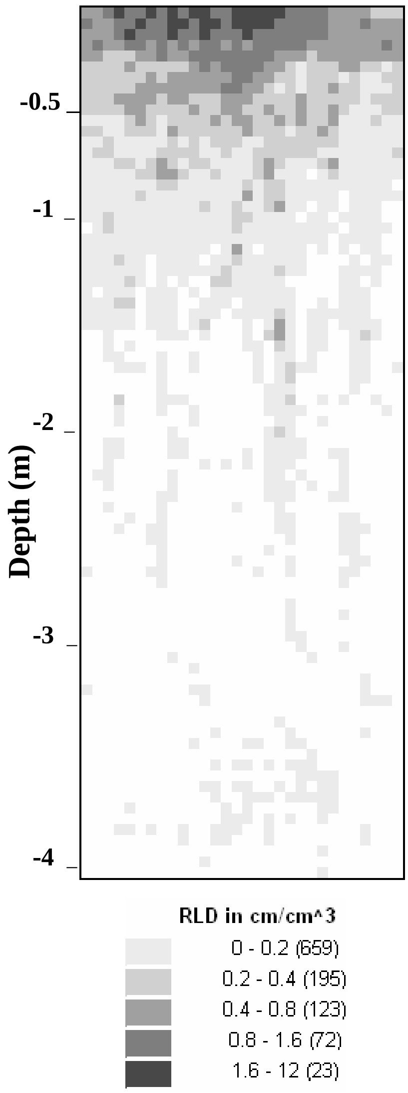

Figure 2. Average profile of root length density (RLD).

Profiles of root length density (RLD)

By calculating the average of the RLD in each of the meshes of the four profiles, a "virtual" map of root distribution (Fig.2) was obtained, enabling better visualization of the average extent of the profile's colonization and the vertical gradients. RLD profiles can also be drawn up in a more classic form, from the mean values per 20-cm soil trench, by averaging the four profiles (Fig. 3A). Root profile showed a standard decrease between the surface and approximately 2 meters, at which depth it reached a value of 0.01 cm per cm^3, i.e. 10 meters of roots per square meter of soil on a trench of 10 cm. This is weak, but not negligible. This level of root density was then more or less maintained between 2 and 4 meters, with strong variability.

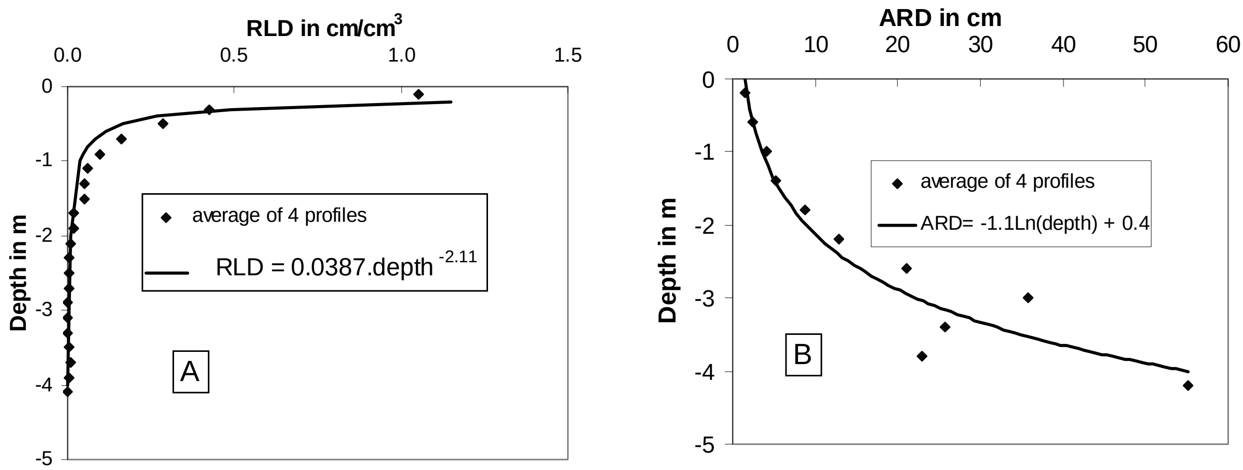

Figure 3. A: Root length density per trench of 20 cm; B: Average root distances (cm) per 40-cm trench (Mean of four profiles).

Average root distance (ARD)

From these RLD values, it was possible to infer values of average root distance (ARD). Between the surface and a depth of approximately 2 meters (Fig. 3B), the mean distance between the roots increased more or less linearly with greater depth, going from 1 cm between the roots to 10 cm. Below 2 meters, the ARD values per layer of 40 cm fluctuated between 10 and 50 cm. In spite of this heterogeneity at depth, an adjustment to an exponential function was obtained, with an R^2 of 0.93 for 11 points (Fig. 3B). However, this empirical function can only be used within its scope of validity, between depths of 20 cm and 4 meters. Roughly, 80% of the RLD was located in the first 60 cm of soil. This part of the root system ensures the bulk of both mineral and water uptake when the climatic conditions are favorable. If water supply dries up, however, the roots beneath a depth of 2 meters (2%) can make a contribution to stabilizing growth and production.

CONCLUSION

This study, made on only one site, was carried out in conditions that were representative of the ratoon sugarcane crop in Reunion Island as regards: (i) variety, (ii) climatic environment, (iii) crop practices. The only atypical feature of the experimental conditions was the significant depth of the soil. The root front of 4 meters thus corresponds to a kind of local potential, without any major physical barrier to root growth at depth.

The depth observed of the root system suggests that values of maximum available water storage (MAWS) generally used in Reunion should be reviewed. This is important for use of growth modeling tools or irrigation decision-support tools such as OSIRI-Run (Chopart et al., 2007) and FIVE-CoRe (Chopart et al., 2007), which also use the concept of MAWS. A study is planned in order to investigate the evolution of a plant cane root front, to find out if this depth can be reached from the first crop year or if the observed depth is the result of a progression accumulated over several years.

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