MEASUREMENT OF AVAILABLE WATER AND ROOT DEVELOPMENT ON AN IRRIGATED SUGAR CANE CROP IN THE IVORY COAST

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ABSTRACT

Work was undertaken on the water — soil — plant relations on an overhead irrigated sugarcane crop in Ivory Coast.

A neutron probe was used to measure the depth of soil used by the roots and the available water in this soil, with a view to assessing the optimum irrigation frequency.

Soil was shown to be involved in the water nutrition of the plant to a depth of at least 2 m. In the soil used by the roots the available water was 181 mm, which represents only 9% of the total volume of soil used.

For this study, irrigation frequencies of 7, 14 and 21 days were used. Root development in the lower horizons was found to be greater when the crop was irrigated less frequently.

No significant difference was found between yields in Tc/ha or recoverable sugar/ha, in spite of the differences in rooting depth.

According to chemical analysis, the agricultural potential of these soils is average and in trials, yields of 200 tons of cane/ha have been obtained. In view of the high cost of overhead irrigation, soils should be chosen according to the depth to which sugarcane roots penetrate.

INTRODUCTION

In the comprehensive agricultural investigations carried out in Ivory Coast, to obtain the basic data required for an agro-industrial sugar complex using overhead irrigation, special attention was paid to water — soil — plant relations.

The first irrigated trials, set up in 1967, showed that sugarcane responded satisfactorily to supplementary irrigation, as was quite foreseeable from climatic factors, since potential evapotranspiration exceeds rainfall by an average of 700 mm per annum.

The results of 2 trials harvested at the beginning of the 1970 harvesting season, which involved study of water nutrition rationing, and irrigation rates and frequencies, gave the impression that the available water in the soil had been underestimated. It was therefore necessary to discover the real depth to which soil was involved in providing water for the plant, to measure the available water, and at the same time to confirm the measurements to be made by studying root distribution.

These different points were studied during the 1971 - 72 season.

EXPERIMENTAL PROCEDURE

Site: Northern Region of Ivory Coast, longitude 5° 15 E, latitude 9° 30 N, altitude : 310 m.
Climate: humid tropical. Rainfall and minimum and maximum temperatures are given in Fig. 1.

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Soil: medium desaturated ferralitic soil; loamy sand on sandy clay loam.

The following 2 tables give the results of texture and chemical analysis.

**TABLE 1.** Soil texture (%).

<table>
<thead>
<tr>
<th>Depth</th>
<th>0 - 30 cm</th>
<th>30 - 60 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay = 2 μ</td>
<td>11,3</td>
<td>29,7</td>
</tr>
<tr>
<td>Silt = 2 - 50 μ</td>
<td>18,1</td>
<td>14,5</td>
</tr>
<tr>
<td>Fine sand = 50 - 200 μ</td>
<td>30,1</td>
<td>19,6</td>
</tr>
<tr>
<td>Coarse sand = 200 - 2000 μ</td>
<td>40,5</td>
<td>36,2</td>
</tr>
</tbody>
</table>

**TABLE 2.** Chemical analysis

<table>
<thead>
<tr>
<th>Depth</th>
<th>Organic matter P₂O₅ (ppm)</th>
<th>Absorbing complex meq per 100 g S water</th>
<th>pH S water</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>Na</th>
<th>Sx</th>
<th>T²</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>0,53</td>
<td>240</td>
<td>16</td>
<td>1,35</td>
<td>0,39</td>
<td>0,25</td>
<td>0,10</td>
<td>2,09</td>
<td>3,60</td>
<td>58</td>
</tr>
<tr>
<td>30-60</td>
<td>0,48</td>
<td>290</td>
<td>23</td>
<td>1,80</td>
<td>0,57</td>
<td>0,22</td>
<td>0,11</td>
<td>2,70</td>
<td>5,52</td>
<td>48</td>
</tr>
</tbody>
</table>

Sx = sum of the exchangeable bases (%)

T² = exchange capacity (%)

**Irrigation:** The trials were irrigated without wastage by using PVC pipes to each row. The output was measured by meters accurate to within 1 litre. The amount of water applied each month was equal to: K x Class A Pan Evaporation - Rainfall; K varies from 0,6 to 1,2 according to the age of the cane. Irrigation stopped 2 months before the cane was cut.

**Type of trial:** Fisher Block with 6 replications.

**Variety:** B 37 172, planted on 19/3/70 and harvested (plant cane) on 1/4/71.
Measurement of available water

Moisture and hydrodynamic characteristics were measured with a Neutron Probe, CEA licence, type HP 310, using an EC 310 type scale.

In each of the plots, probe tubes were set in the row and in the middle of the inter-row over areas of 10 m² surrounded by border levees and guard rings. Each measurement was made in 2 tubes 0.50 m apart.

When the probe tubes were set and also when the soil study trenches were dug, soil samples were taken to measure the weight moisture percentage. Apparent density was measured with a membrane densitometer.

With the weight moisture percentage and apparent density, a rating curve was drawn up relating the number of impulses/second to the volumic moisture content. The relation obtained was corrected after chemical analysis of the samples.

a) Measurement of the moisture profile at wilting point

As the soil dried out before harvesting, moisture profiles were measured every 7 days until the cane was cut.

b) Measurement of maximum field capacity (MFC)

Maximum field capacity moisture profiles were measured on ratoons on the same plots, where the soil had not been retilled. The soil was saturated by heavy irrigation. Once the water had seeped into the soil, dewatering was at first very rapid and then slower. There are two successive kinetics, the first corresponding to the influence of the force of gravity and the second to capillary action.

Maximum field capacity is defined as the ordinate for the slow kinetic. This corresponds to the generally accepted definition of maximum field capacity, that is to say the amount of water that can be stored in the soil to the advantage of the plants.

Study of the root system

Root samples were taken at the end of the first crop on 12 month plant cane.

For the 3 irrigation frequencies used (7, 14, and 21 days) the horizontal sampling technique was used. The soil sample formed a parallelepiped measuring 20 cm x 10 cm x 10 cm. The samples were taken:

horizontally — under the row, 25 - 35 cm from the row, and in the middle of the inter-row (65 - 75 cm).

vertically — at 6 or 7 levels, depending upon whether it was in the furrow or the ridge; these levels correspond to the limits of the soil study profiles (Fig. 6).

Five series of samples were taken, 15 - 20 cm apart. One of the series under the row of cane was systematically taken under a plant.

RESULTS

Available water

a) Measurement of the profile at wilting point

The moisture profiles of the plot irrigated every 7 days were found to change only very slightly below a depth of 1.50 m. At depths of more than 1 m, the soil moisture contents of the other 2 plots (14 and 21 days) dropped continually. Wilting point was therefore not reached
in any of these cases. As a result, the available water calculated seems to have been underestimated.

b) Measurement of maximum field capacity
The different kinetics are given in Fig. 2.
The figures given in i/s represent the sum of the values found at each level, that is to say every 0.10 m.

c) Available water
No common depth values were found for the moisture profiles of each of the plots studied (Fig. 3). The cane, therefore, made use of the available water to a depth of at least 2 m.
The results obtained are given in Table 3:

<table>
<thead>
<tr>
<th>Plot studied</th>
<th>i/s at field capacity</th>
<th>i/s at the driest</th>
<th>Difference</th>
<th>mm of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6652</td>
<td>4212</td>
<td>2440</td>
<td>222</td>
</tr>
<tr>
<td>2</td>
<td>5775</td>
<td>4150</td>
<td>1625</td>
<td>148</td>
</tr>
<tr>
<td>3</td>
<td>6240</td>
<td>4352</td>
<td>1888</td>
<td>172</td>
</tr>
<tr>
<td>Average</td>
<td>6222</td>
<td>4238</td>
<td>1984</td>
<td>181</td>
</tr>
</tbody>
</table>

Root distribution
The values obtained are given in °/00 (grams of dry roots per kilogram of dry soil).
The results are given in Figs. 4 and 5.
FIGURE 3. Texture and moisture profile.
distance to the row (cm) 0-10 25 - 35 65 - 75


**Observations**

Irrespective of the irrigation frequency:
Vertically, the roots are found to go deep (the limit is not known), which means that good use is made of the available water in the soil.
No clearly unfavourable effect was caused by the early stages of hydro-morphic conditions in the indurated horizon (0.95 - 1.70 m) or the horizon that is becoming cemented (1.70 - 2.00 m).
Horizontally, root density drops rapidly once away from the row of cane.

According to the irrigation frequency:
Under the row of cane, root density is found to vary in the ratio of one (21-day and 14-day frequencies) to two (7-day frequency), in the first 20 cm.
At 25 - 35 cm from the base of the plant, root densities are classified slightly differently. Higher values are found for the 14-day frequency than for the 7-day frequency, but only in the higher horizons.
In the inter-row, the root density for the 21-day irrigation frequency is much lower than for the other two frequencies.
Root distribution, expressed as a percentage of the total amount of root,
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shows a relation between root development and the irrigation frequency; 67.9%, 59.9% and 50.3% of the roots are found in the 0-35 cm horizon (0 being the top of the ridge) for the 7, 14 and 21-day frequencies, respectively, giving a difference of almost 20% between the two extremes (Fig. 4 and Fig. 5).

For the 21-day frequency, almost a third of the total roots (30.7%) is found between depths of 0.95 and 2.00 m.

Proportionally deeper root development reduces the effects of possible soil moisture deficits without causing significant drops in yield, as can be seen from Table 4 below.

**TABLE 4. Yields and irrigation frequencies.**

<table>
<thead>
<tr>
<th>Frequencies</th>
<th>Yield (Tc/ha)*</th>
<th>Pol % c*</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days</td>
<td>164.2</td>
<td>14.8</td>
</tr>
<tr>
<td>14 days</td>
<td>155.4</td>
<td>15.2</td>
</tr>
<tr>
<td>21 days</td>
<td>153.5</td>
<td>15.7</td>
</tr>
</tbody>
</table>

* The differences between treatments are not significant.

**DISCUSSION**

**Method**

The method used for measuring water reserves has the advantage that it can be used on the soil *in situ*.

For the upper limit of the water content in the soil, a fairly good estimate could be obtained by various laboratory methods.
Greater difficulties would arise, however, in measuring the lower limit of the soil moisture content in relation to root density, and the depth of soil used. The neutron probe is an attractive method since it enables the soil to be studied in situ.

The maximum variation in available water, compared with the average, is 22.6%. Deviations result from differences in the soil texture of the plots, due to the alluvial origin of the soil (Fig. 3).

For this trial, the soil is uniform, since the variation coefficient is 7.88%. The results were obtained from 8 probe tubes. This type of study seems to require a fairly high number of replications.

The amounts of water that can be stored in the soil and be available for sugarcane appear to be high. In fact, it is the amount of soil used by the roots which is the determining factor since the available water only represents on average 9% of the total volume of soil.

The part played by the lower soil horizons increases proportionally according to the root density found in them.

With a 7-day irrigation frequency, although the roots penetrate fairly deeply, they are distributed in patterns similar to those mentioned by Van Dillewijn. In fact, almost 70% of the roots are found in the first 35 cm below the surface. When supplemental irrigation is applied every 21 days, the same proportion is reached only at a depth of 95 cm. In addition, the root system is redistributed to make better use of the 0.95 m – 2 m horizon.

The induration of this horizon and the first stages of cementation in the underlying horizon do not seem to have formed an obstacle to root development. The minimum depth at which horizons of this type would interfere with proper root development could not be specified within this study.

CONCLUSION

On the soil studied, which is of medium agricultural potential, it has been possible to obtain good yields. On other plots where water requirements were met completely, several trial yields amounted to 200 tons of cane per hectare.

The fertilizer formula, 150 kg/ha N, 100 kg/ha P₂O₅, and 150 kg/ha P₂O₅, corresponds closely to the amounts removed by the crop (a slight phosphorus excess and potash deficit). If ammonium sulphate, dicalcium phosphate and potassium chloride are used, the total fertilizer rate will be 1,150 kg per hectare. The amount of cane produced was obtained with a total supplementary irrigation of about 800 mm.

Since the cost of irrigation is high compared with the cost of fertilizer, the most desirable soils are those on which the intervals between irrigations are the longest. This means that cane production can be more economical on a soil that is of average fertility but has a high available water content, due to deep root development, than on a soil that has high potential fertility level but a low available water content, due to superficial root development.

REFERENCES


MEDICION DE AGUA DISPONIBLE Y DESARROLLO RADICULAR EN UNA COSECHA DE CAÑA DE AZÚCAR IRRIGADA EN UN SUELO EN LA COSTA DE MARFIL

R. Baran, D. Bassereau y N. Gillet

RESUMEN

Se emprendió trabajo sobre las relaciones de agua — suelo — planta en una cosecha irrigada por aspersión de caña de azúcar en la Costa de Marfil.

Se utilizó una sonda de neutron para medir la profundidad del suelo usado por las raíces y el agua disponible en este suelo, con miras a fijar la frecuencia óptima de irrigación.

Se mostró que el suelo estaba envuelto en la nutrición de agua de la planta hasta una profundidad de por lo menos 2 m.

En el suelo usado por las raíces, el agua disponible se encontró ser 181 mm, lo que solamente representa 9% del volumen total del suelo utilizado.

Para este estudio, se usaron frecuencias de riego de 7, 14 y 21 días. El desarrollo radicular en los horizontes más bajos se encontró ser mayor cuando la cosecha era irrigada menos frecuentemente.

No se encontró ninguna diferencia significativa entre los rendimientos en t/ha o azúcar recuperable/ha, a pesar de las diferencias en la profundidad radicular.

De acuerdo a los análisis químicos, el potencial agrícola de estos suelos es promedio.

En ensayos, se han obtenido rendimientos de 200 toneladas de caña/ha en estos suelos.

En vista del alto costo de irrigación por aspersión, los suelos se deben escoger de acuerdo a la profundidad que las raíces de la caña de azúcar puedan penetrar.