The Libyan Journal of Agriculture: volume 11, 1982.

Field Measurements of Soil Water loss patterns in the Presence of Established Orchard Grass

I. Determination of Hydraulic Properties of the Soil

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ABSTRACT

The soil water properties were determined in a field plot of 6- by 6-metres. The plot was irrigated and immediately covered by a plastic sheet. In spite of the cover, the zero flux plane could not be kept, for a long period, at the soil surface.

The soil moisture and the hydraulic-head were measured respectively, using a neutron moisture probe and a set of tensiometres. The hydraulic condicutivity was obtained from flux and hydraulic-head data. At the lower depths, the changes of soil moisture with the time could not be observed which obligated us to determine the flux only to a depth of 120 cm.

The relationship of water content to matric suction and to hydraulic conductivity are presented. At four different depths, relationships of hydraulic conductivity with moisture content were obtained. In addition, the moisture characteristics show the hystersis phenomena at a depth of 15 cm.

INTRODUCTION

The moisture characteristics and the relationships of hydraulic conductivity with moisture content are required in the study of the retention and movement of soil water.

This type of study is practically only possible on disturbed soil samples which is certainly unrepresentative of the actual soil in the field.

Rose *et al.* (5) proposed a method for a field measurement of the soil water properties in uniform soils. This method is described in detail by Hillel *et al.* (3). Its application in non-uniform soils requires previous knowledge of the non-uniformities in the soil profiles as recognised by Poulovassilis *et al.* (4), Van Bavel *et al.* (8), Arya *et al.* (1) and Vachaud *et al.* (7).

MATERIALS AND METHODS

Experimental plot was located on the ecological experimental station of the phytosociological and ecological Center of Louis Emberger in Montpellier in France. Some characteristics of the soil are illustrated by Fig. 2 and Fig. 3.

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The soil texture profile (Fig. 2) denotes that the soil is silty clay at the surface and becomes clay soil with depth.

The water content and the density profiles of three access tubes (two meters apart) are shown in Fig. 3. Comparison between these profiles indicates the existance of a small heterigenity in the soil.

Principal of internal drainage method

The method is used to follow the drainage process in a soil profile during which water is moving downwards only and the flux at the soil surface is zero. The method consists of measuring at time 't' the hydraulic gradient and at the same time the soil moisture content θ_z. The downward flux q_z at height 'z' relative to the soil surface can be determined by:

$$q_z = \int_z^0 \frac{\partial\theta}{\partial t}\,dz \qquad (1)$$

is the rate of soil moisture change with time. From Darcy's law

$$q_z = -K\,(\theta)\left(\frac{\partial\theta}{\partial z}\right)_z \qquad (2)$$

$K(\theta)$ is the hydraulic conductivity at the moisture content θ_z. ϕ is the hydraulic head (cm water) which is the sum of the suction head ψ and the gravitational head z. The sign of'z' is always negative.

Using eqns. (1 and 2) gives:

$$K = -\int_z^0 \frac{\partial\theta}{\partial t}\,dz \Bigg/ \left(\frac{\partial\phi}{\partial z}\right)_z \qquad (3)$$

To solve the problem of soil uniformity it is necessary to measure 'K' for each layer of soil profile.

Measurements of soil moisture and hydraulic head

A 6- by 6-m soil plot was irrigated during 3 days. The evaporation is prevented by a plastic cover. Simulated measurements of moisture content and hydraulic head have been carried out. The moisture content was measured in an access tube at 20 depths from 10 cm to 200 cm in 10 cm increments, using a neutron moisture meter. The hydraulic head was measured by a set of tensiometers of a mercury manometer, in depths of 15, 30, 60, 90, 120, 150 and 200 cm. As shown in Fig. 1 the tensiometers spaced around the access tube on a semi-circle of 50 cm and the distance between two tensiometers was 20 cm: like Daudet *et al.* (2).

RESULTS AND DISCUSSION

The mean values of the water content of the horizons of 0–30, 30–60, 60–90, and 90–120 cm are plotted as a function of time as shown on Fig. 4. The soil moisture reduction is very small because of the high percentage of clay as shown in Fig. 2. The

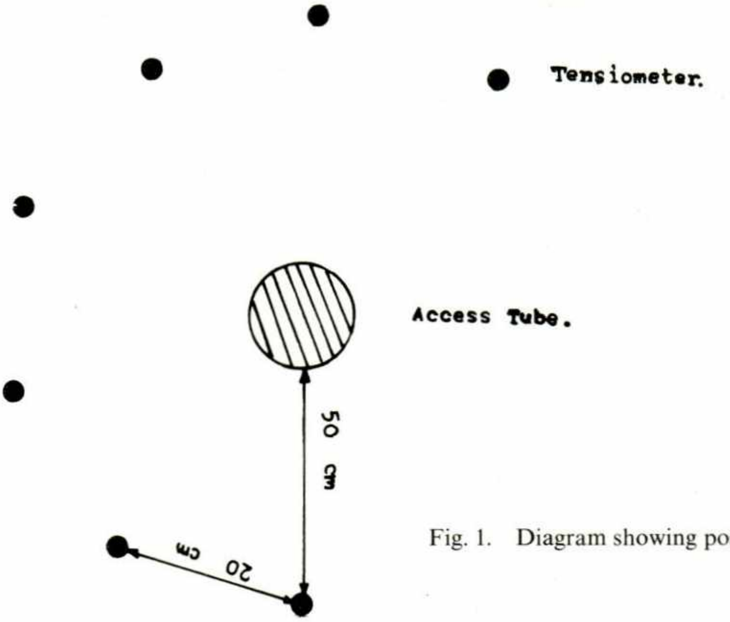

Fig. 1. Diagram showing position of tensiometers around access tube.

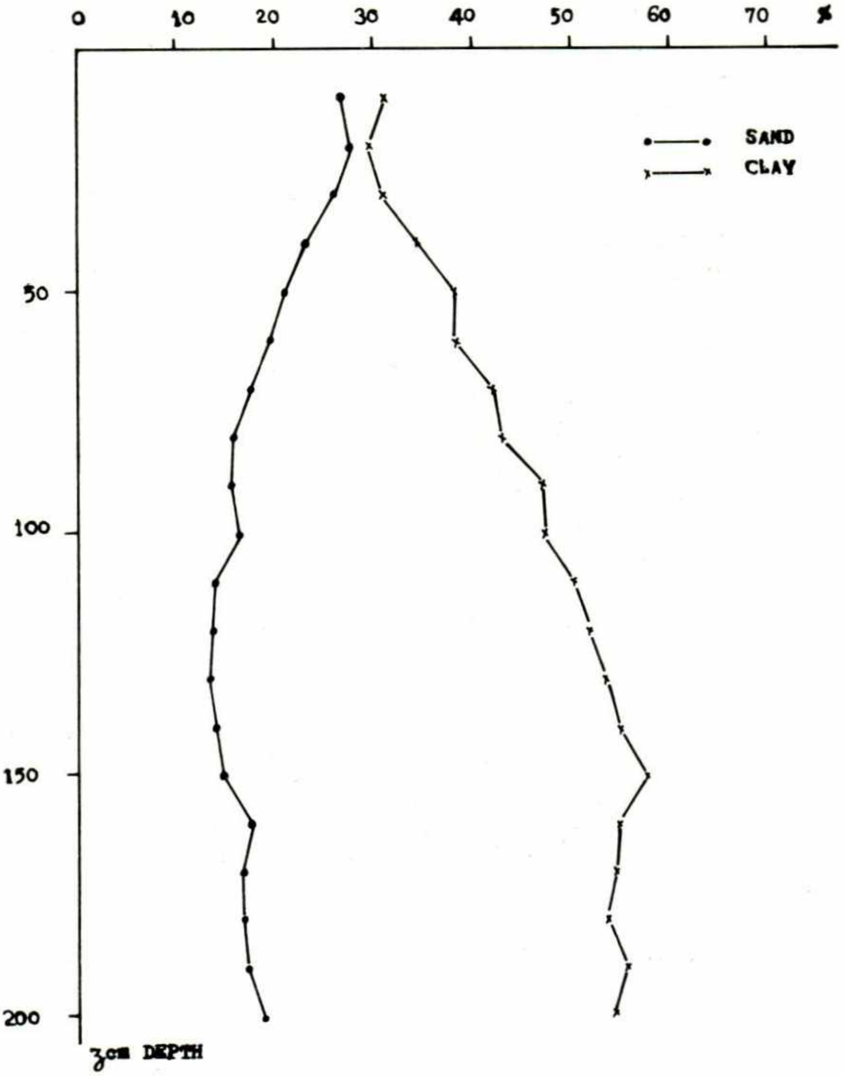

Fig. 2. Soil textural profile.

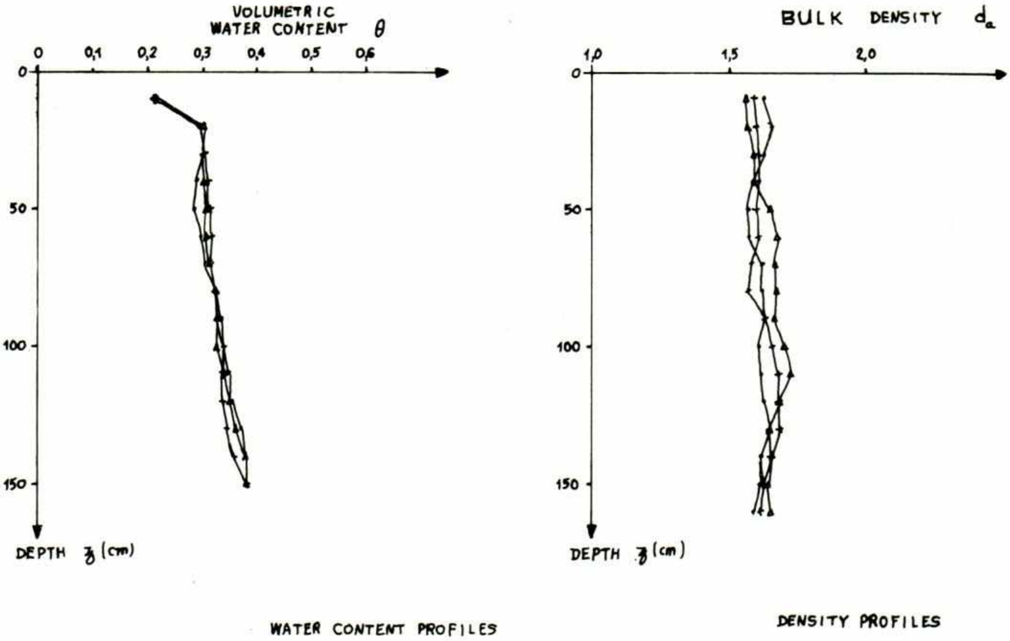

Fig. 3. Soil water content and density profiles measured in three access tubes—the distance from one tube to the other is two meters.

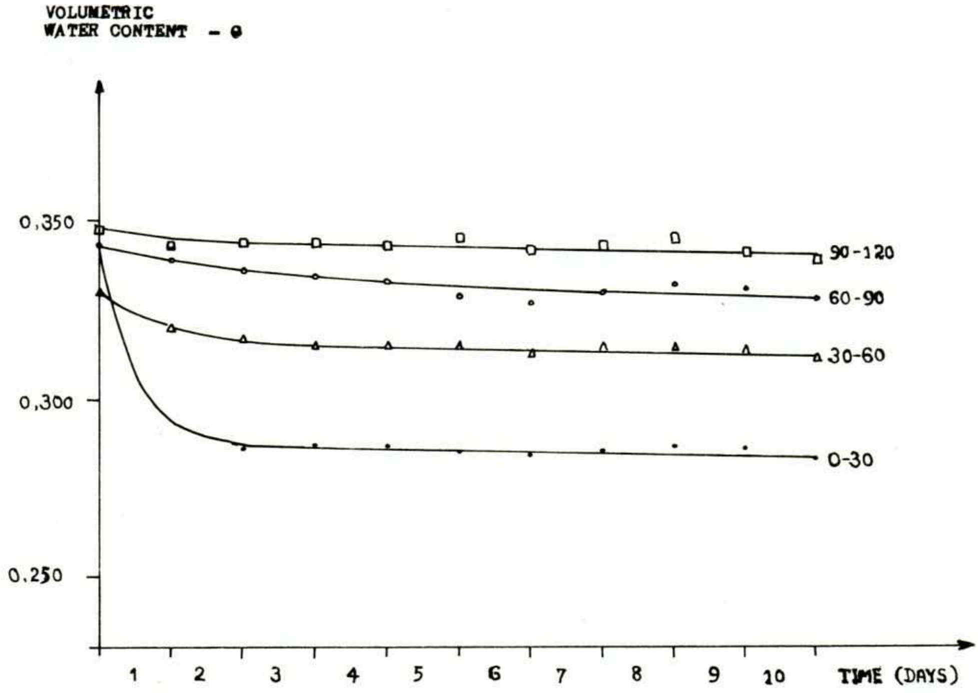

Fig. 4. Changes of soil water content of four horizons with time.

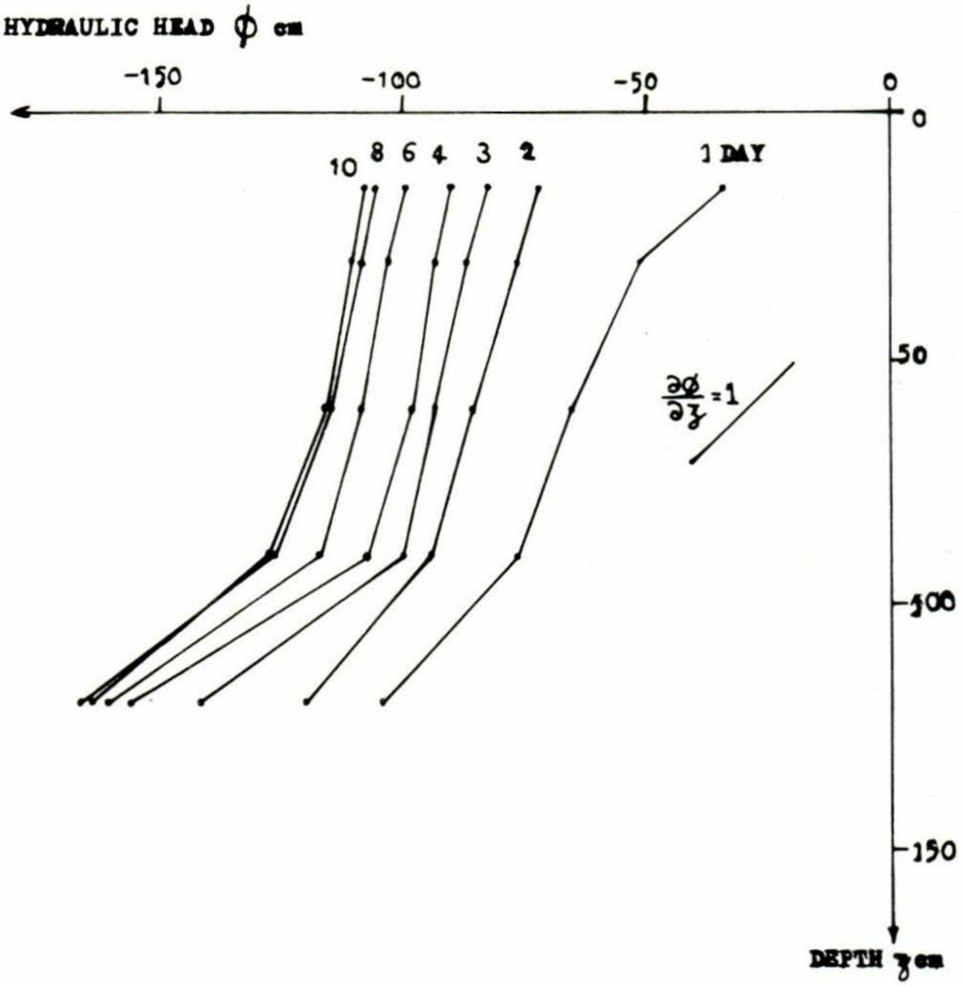

Fig. 5. Hydraulic head profits.

determination of the hydrodynamic characteristics of clay soil is difficult as recognized by Smiles (6).

From the curves of θ(t) Fig. 4, the water flux may be determined in each level by:

$$\int_{z_2}^{z_1} \frac{\theta_1(z)-\theta_2(z)}{t_1-t_2}\,dz$$

From the hydraulic head profiles (Fig. 5) the hydraulic gradient $\partial\phi/\partial z$ is determined by the measurement of the slope of these curves. The hydraulic conductivity is obtained by the hydraulic gradient measured at the same time and at the same level of θ(t).

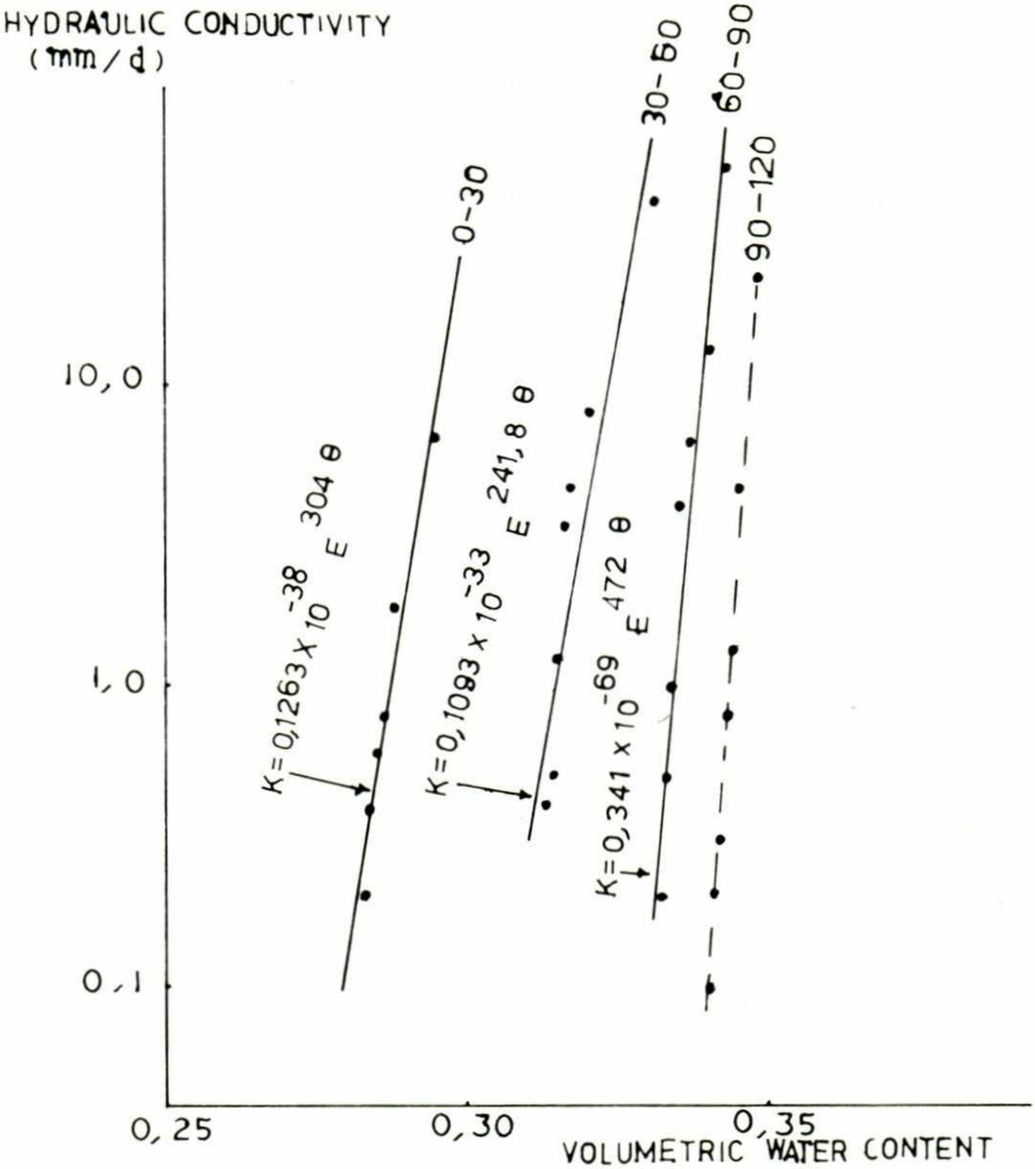

Fig. 6. Hydraulic Conductivity—Water Content Relationships.

Therefore:

$$\mathbf{K} = \int_{z_2}^{z_1} \left(\frac{\partial \theta}{\partial t}\right) dz \Big/ \left(\frac{\partial \phi}{\partial z}\right)$$

The results obtained are shown in Table 1.

The values of the hydraulic conductivity are plotted as a function of the soil water content (Fig. 6). As is shown in Fig. 6, where a semi-log plot is used, the relationship is

Table 1. Calculation of hydraulic conductivity of some depths.

0–30 cm				30–60 cm			
$q\frac{mm}{day}$	$\frac{\partial\phi}{\partial z}$	$K\frac{mm}{day}$	θ	q	$\frac{\partial\phi}{\partial z}$	K	θ
15.6	0.47	33.2	0.346	18.9	0.47	40.2	0.331
1.8	0.27	6.7	0.294	2.7	0.33	8.2	0.320
0.6	0.33	1.8	0.288	0.9	0.20	4.5	0.317
0.3	0.40	0.8	0.286	0.9	0.27	3.3	0.316
0.15	0.27	0.6	0.285	0.2	0.17	1.2	0.315
0.10	0.28	0.4	0.284	0.1	0.20	0.5	0.314
0.03	0.20	0.2	0.283	0.07	0.17	0.4	0.313

60–90 cm				90–120 cm			
q	$\frac{\partial\phi}{\partial z}$	K	θ	q	$\frac{\partial\phi}{\partial z}$	K	θ
19.8	0.37	53.5	0.343	20.7	0.93	22.3	0.348
3.6	0.27	13.3	0.340	3.9	0.87	4.5	0.345
1.5	0.23	6.5	0.337	1.8	1.40	1.3	0.344
1.2	0.30	4.0	0.335	1.5	1.80	0.8	0.343
0.3	0.30	1.0	0.334	0.5	1.47	0.3	0.342
0.2	0.40	0.5	0.333	0.3	1.33	0.2	0.341
0.08	0.40	0.2	0.332	0.1	1.27	0.08	0.340

linear and can be described by an equation of the type:

$$K = ae^{b\theta}$$

Where ‘a’ and ‘b’ are the constants of the soil.

Figure 6 shows that the soil profile is characterised by four linear functions. The reason for this difference can be explained by the textural profile (Fig. 2) in which the clay content increases with the depth.

Soil water characteristics for the four soil depths can be shown in Fig. 7, the depths of 15 cm and 30 cm show the processes of wetting and drying. In these depths we note the appearance of the hysteresis phenomena which is more strong at the depth of 15 cm than at 30 cm. For example at a suction of 80 millibars, the corresponding moisture content varies from 0.250 to 0.30.

$\mathbf{K}(\theta)$ and $\Psi(\theta)$ relations permit to obtain directly the real evapotranspiration. This point will be treated in a companion paper.

As have been discussed above, the determination of the soil water properties in a clay soil is difficult. Most of the methods suggested are suitable for the light soils. Such types of research must be carried out in all soil types.

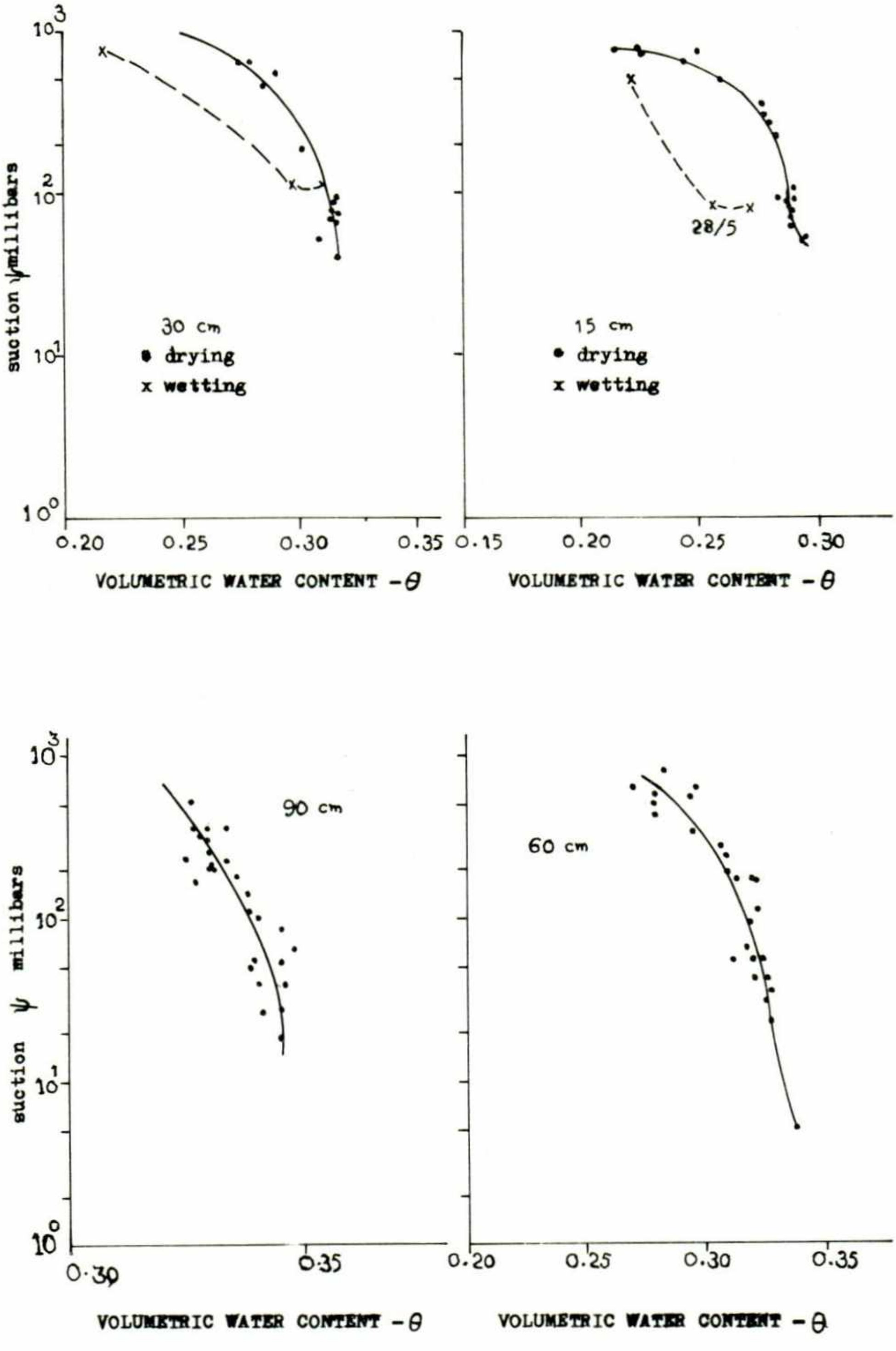

Fig. 7. Suction-water content relationships.

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خصائص علاقة التربة والماء
بالتربة الطينية

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المستخلص

تمت دراسة علاقة التربة بالماء على قطعة أرض مساحتها **٣٦** متر مربع بعد ريها جيداً وتغطيتها بقطعة من البلاستك لمنع التبخر. أخذت قياسات متتابعة ومتتالية لرطوبة التربة وقوة شدها وذلك بطبقات التربة المختلفة.

بتطبيق قانون دراسي تم تعيين التوصيل الهيدروليكي لكل طبقة من طبقات التربة المختلفة والنتائج توضح الآتي :—

- رطوبة التربة في أرتفاع متزايد مع العمق.
- التوصيل الهيدروليكي يتناقص مع العمق نظراً لارتفاع نسبة الطين.
- وجود ظاهرة التخليفية عند عمق **١٥** سم حيث أنه في حالة قوة شد ٨٠ ملبار فالرطوبة تتراوح بين **٠,٢٥** و**٠,٣٠**.

عليه ينصح بدراسة هذه العلاقة إما في حالة التجفيف أو في حالة التبلل حتى يتسنى تطبيقها عملياً في تعين إحتياجات النباتات من الماء تحت الظروف المختلفة.