Soil Water Studies on Oxisols and Ultisols of Puerto Rico: III. Capillary Conductivity[1]

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ABSTRACT

Values of capillary conductivity were calculated for the Humatas and Bayamón soils. These were found to be highly water content dependent. Using values of capillary conductivity, it was estimated that 10% of the water required for evapotranspiration might be supplied by upward water movement from the profile below the root zone.

INTRODUCTION

Wolf and Drosdoff (3, 4) reported previously on movement, retention, and availability of water on Oxisols and Ultisols of Puerto Rico.

This paper reports data on the capillary conductivity of the Humatas and the Bayamón soils as determined in the field. Data were not adequate to make similar calculations for the Torres and Catalina soils where rainfall, subsequent to irrigations, prevented calculation of vertical water flux.

METHODOLOGY FOR FIELD DETERMINATION AND CALCULATION OF CAPILLARY CONDUCTIVITY

Information on soils and on field and laboratory techniques can be obtained from Wolf and Drosdoff (3). Estimates of capillary conductivity were obtained in the field using the method of Richards et al. (2) and Ogata and Richards (1). Plots were instrumented with tensiometers at 7.5, 30, 60, 90, and 120 cm. Undisturbed cores were taken for laboratory determinations of the relationship between soil water content and tension. Due to horizontation and textural differences, soil water content

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versus tension was found to be depth dependent. Thus the need for a specific soil water release curve for each depth was established.

In order to determine the flux of water, after irrigation the plots were covered with 6 mil polyethylene plastic. Thus, water content changes were associated only with infiltration and drainage; there was no evaporation. The assumption was made that lateral water movement with time was slight and that all water content changes occurred in a vertical downward direction. This is to say that the amount of water passing through a given point in the profile for a certain period was the sum of all the water content changes above that point in the same period. Thus, the flux for drainage at 60 cm will always be equal to or exceed that at 30 cm, because all water stored and then lost from the upper part of the profile must drain through the depths below.

Flux was calculated by noting tensions $T(t_1,d_1)$ and $T(t_2,d_1)$ in which the subscripts refer to time and depth, respectively. Water contents from the water release curves were associated with the tensions. Change in water content for a certain time and depth was assumed to be the average change in water content for a zone of soil the midpoint of which was the tensiometer. Thus, for the tensiometer at 60 cm, water content changes were assumed to have occurred uniformly between 45 and 75 cm. An exception existed for the tensiometer at 30 cm where the representative zone was considered to be from 0 to 45 cm. Multiplying the change in water content by the vertical distance gave the amount of water passing through the bottom of the first zone. For example, a loss of 2% in water content in a day (as indicated by the tensiometer at 30 cm and the water release curve for 30 cm) would give a flux of 0.9 cm/day passing through the 45-cm depth. If during the same time interval the tensiometer at 60 cm had associated with it a loss of 1% in water content, the flux at 75 cm would be 1.20 cm/day (0.90+0.30).

Dividing flux by hydraulic gradient gave capillary conductivity. Since capillary conductivity was associated with a hydraulic gradient between two tensiometers, and water was conducted through this zone in order to pass from the point in the profile where the flux was caluclated, capillary conductivity was established for the zone between tensiometers, i.e., 7.5 to 30, 30 to 60, 60 to 90, 90 to 120 cm. Capillary conductivity was linked to water content by finding an average water content (average of four values) for two depths and times. Since capillary conductivity is highly water-content dependent, time intervals were kept short for calculations when water contents were rapidly changing.

In the Humatas soil, flux of water at the 120-cm depth on the day following the irrigation was approximately 0.75 cm/day. This decreased to approximately 0.12 cm/day 7 days after the irrigation. In the second irrigation of the Humatas soil, flux of water passing through the top 120 cm of soil was 0.32 cm/day, 8 days subsequent to irrigation and 3 days following a heavy rainfall. Thirteen days after the irrigation (8 days after the rain), drainage occurred at the rate of 0.12 cm/day. Thus, in the absence of rainfall drainage from the profile might be expected to occur at the rate of 0.1 cm/day after 10 days.

RESULTS AND DISCUSSION

Values of capillary conductivity for Humatas soil are shown in figure 1. Capillary conductivities descreased in relation to the soil layers as follows: 90 to 120, 60 to 90, 0 to 30, 30 to 60 cm. Thus, the top 60 cm of the profile was least permeable and the 90- to 120-cm depth, the most permeable. At the 120-cm depth a 2% reduction in water content resulted

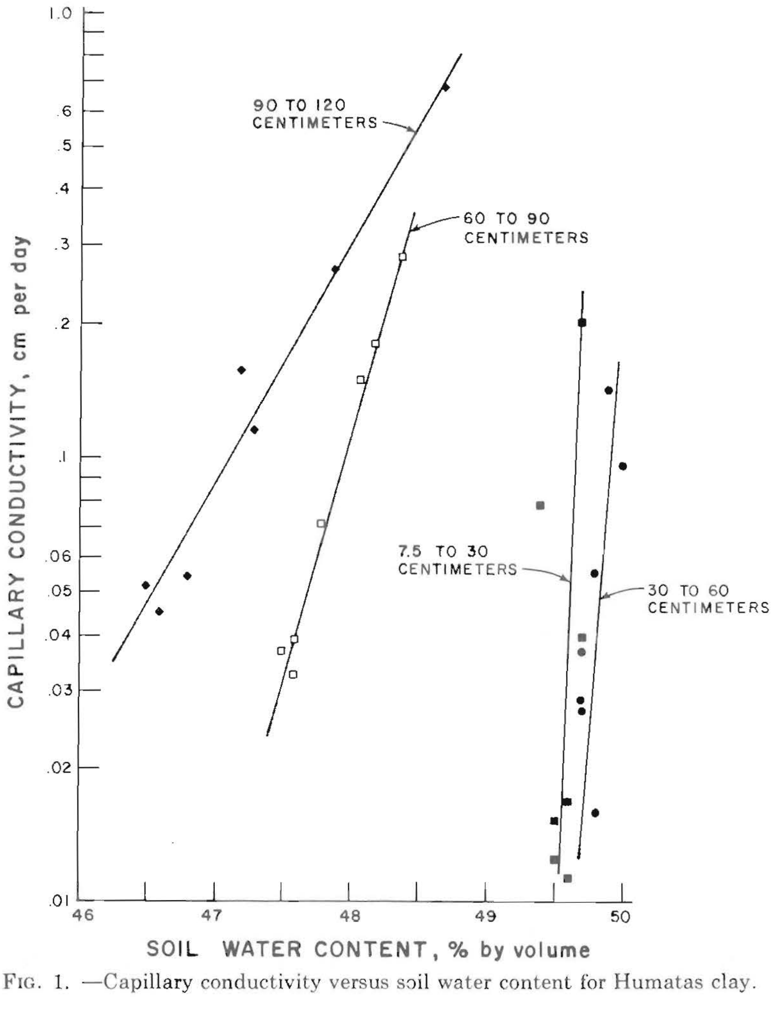

FIG. 1. —Capillary conductivity versus soil water content for Humatas clay.

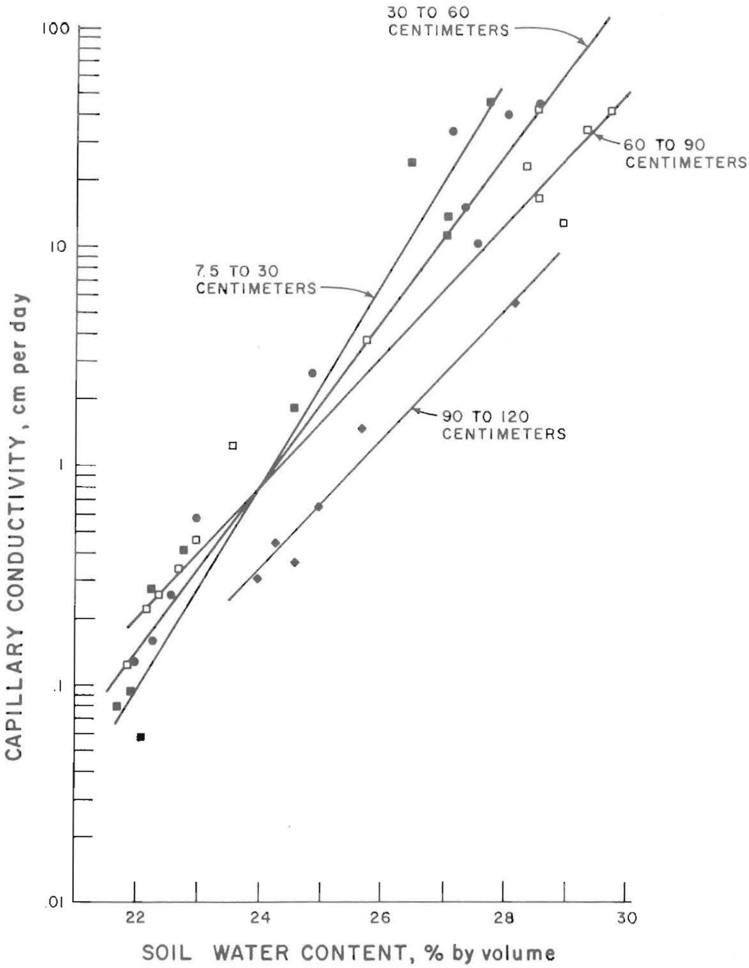

FIG. 2. —Capillary conductivity versus soil water content for Bayamón sand.

in a greater than tenfold decrease in capillary conductivity. This is an example of the great dependence of capillary conductivity upon water content. Soil water tension changes under the plastic covering were small, giving a narrow range of water content for the 0- to 60-cm zone. Graphed on a linear vertical axis, apparent scatter at these depths is suppressed.

Figure 1 also shows that the soil at the lower depths drained most readily and that soil from 0- to 60-cm depth restricted water movement most. For the Humatas soil, the 30- to 60-cm depth has been correlated with clay accumulation.

Capillary conductivity values for Bayamón soil are given in figure 2.

Relative to Humatas soil, capillary conductivities are much greater. Capillary conductivity values for all depths are similar in accordance with the visual uniformity of the soil.

Capillary conductivity is highly water content dependent. In general, a 2% decrease in water content will result in a tenfold decrease in capillary conductivity. This relationship is somewhat less steeply sloping for Bayamón than for Humatas soil over the range of water contents observed.

Use of capillary conductivity values in conjunction with tensiometer data can provide estimates of water flux at any depth in the profile. Such information is particularly useful when data are required on the magnitude of water loss beneath the root zone due to deep percolation in irrigation efficiency studies. A specific application of the data is in estimating the magnitude of upward movement of water from a water table to supply a crop. If the top 60 cm of the Humatas profile were dewatered to a tension of 3/4 bar (water content = 46.6% (4)) by a crop which rooted only to 60 cm, soil water tensions below 60 cm of about 1/10 bar might be expected (water content = 46.7% (4)). In such a situation capillary conductivity would be on the order of 0.003 cm/day. Calculations reveal that upward flux of water might then be 0.06 cm/day. Thus, 10% of the water for evapotranspiration might be supplied from the profile below the root zone. The data can also provide estimates of nutrient loss by deep percolation once salt concentrations of the leachate are known. Unfortunately, the curves of figures 1 and 2 cannot be extrapolated with confidence to provide good estimates of capillary conductivity versus water content in drier soils.

RESUMEN

Se calcularon los valores de conductividad capilar para los suelos Humatas y Bayamón. Se encontró que estos valores dependen en alto grado del contenido de agua del suelo. Usando los valores de conductividad capilar se estimó que el 10% del agua requerida para la evapotranspiración puede ser suministrada por el movimiento ascendente del agua de aquella parte del perfil del suelo fuera de la zona de raíces de las plantas.

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