GAU Res. J. 1992. 17 (2) : 37-44

Hydraulic Properties of Loamy Sand Soil of Agrustalf

C. L. Patel, S. B. Patel and B. K. Patel

B. T. R. S., Gujarat Agricultural University, Anand Campus, Anand and Water and Land Management Institute, Anand

ABSTRACT

The flow equation describing the movement of water out of a soil sample in the pressure plate apparatus has been used to calculate capillary conductivity. Infiltration was measured by double ring infiltrometer at various initial soil moisture content. Considering bulk density of 1.6 g cm^{-3} uniformly for 100 cm soil depth, loamy sand soils can supply 29 cm water in available form in soil water potential of -0.3 to -15.0 bar range. The capillary conductivity (K) recorded at 0.3 and 1.0 bar pressure was 11.5 x 10^{-3} and 0.37 x 10^{-3} cm day^{-1}, respectively. It rapidly decreased to 0.004 x 10^{-3} cm day^{-1} at 16 bar. K values decreased extremely rapidly with declining water content upto 27 per cent and the reduction was gradual with further decrease in moisture content. The cumulative infiltration of 300 minutes increase from 0.8 to 5.9 cm with reduction in soil moisture content from 28.6 to 5.9 per cent. The infiltration rate declined with time, the rate of decrease was more pronounced with low soil moisture content. As the soil moisture content decreased, cumulative infiltration for the same elapsed time intensified while for the same moisture content, cumulative infiltration enhanced with a decreasing rate.

(Received on 10th Sept., 1990)

INTRODUCTION

Variation in intensity of rainfall causes most areas to experience differential water supply which has significant role on the growth of plants. Retention of water by soils and movement of water in soils are, therefore accounted as two major hydraulic properties important for soil and water management. The study of the infiltration time relationship as a function of antecedent moisture content is a vital element, not only in hydrologic cycle but it is also important in design of surface irrigation system, rainfall run-off modelling and drainage systems design. An attempt was made to study the hydraulic properties of loamy sand soil of middle Gujarat.

MATERIALS AND METHODS

The experimental procedures and apparatus were essentially the same as those normally used to make moisture tension versus moisture content measurements (Richards, 1949). Fragmented soil passing a 2 mm sieve was packed into a cylinder 20 cm in diameter and 5 to 10 cm in height directly on the plate. The soil was thoroughly wetted and allowed to stand overnight. An initial pressure of 100 to 150 millibars was applied to the chambers and the sample was allowed to come to equilibrium. The outflow was collected into a burette with the end of the outflow tube level with the centre of the soil sample so that the effect of the gravitational field would be a minimum. Data taken during this first pressure increment were

not used to calculate capillary conductivity, K. When equilibrium was attained at 200 millibars, the pressure in the chamber was increased by approximately 100 millibars and the outflow recorded as a function of time. When outflow ceased, the pressure was again increased and the process repeated. The soil water potential versus moisture content measurements were plotted. The capillary conductivity was calculated as per following mathematical treatment (Gardner, 1956).

The pressure chamber outflow in one dimension is described by

$$\frac{\partial \theta}{\partial t} = \frac{l}{pg} \frac{\partial}{\partial z} (K(Q) \frac{\partial p}{\delta z} \quad \text{.....(1)}$$

In general, this equation is non-linear and difficult to solve analytically. Under certain exerpimental conditions, assumptions may be made which linearise the equation and make possible its solution. First, we assume that ΔP is chosen sufficiently small that K is approximately constant during flow process. Secondly, we assume that, over this small range of water content, θ is linear function of the suction S. Noting that, for this case P = (Pf - S), where Pf is the final gauge pressure and S is that soil water suction corresponding to the water content θ q, we can write

$$\theta (P) = a + bp \quad \text{.....(2)}$$

where a and b are constants substituting (2) in (1) gives

$$\frac{\partial p}{\partial t} = \frac{D\partial^2 P}{\partial z^2} \quad \text{..... (3)}$$

Solving the equation by assuming certain boundary conditions, rearranging the terms and taking natural logarithms it lead to the equation

$$\ln (Q_O - Q) = \ln \frac{(8QO)}{\pi^2} - \alpha^2 Dt \quad \text{... (4}$$

This equation can be used to determine the diffusivity D from experimental data. If experimentally determined value of (Q_O-Q) are plotted against t on semi-log paper, a straight line with a slope equal to $\alpha^2 D$ and intercept $8Q_O/\pi^2$ should be obtained. If the slope of the line is denoted by B, then $D = B/\alpha^2$ and, since $K = gBb/\alpha^2$ we obtain the result

$$K = \frac{BQ_O\, gp}{V\, D\, P\, \alpha^2} \quad \text{.....(5)}$$

If Q_O is in ml, B in day^{-1}, ΔP in dynes cm^{-2} and α^2 in cm^{-2} K will be in cm day^{-1}. The capillary conductivity at any suction S may be determined by selecting a pressure interval $Pi < P < Pf$, corresponding to a suction interval $Si < S < Sf$ remembering that at equilibrium P is numerically equal to S.

For infiltration study, a plot was irrigated by applying 20 cm depth of water to bring homogenous intitial moisture conditions before starting infiltration measurements. Infiltration was measured by double ring infiltrometer on 1, 3, 7, 13 and 20 days after irrigation. In infiltrometer methods (Burgy and Luthin, 1956) two iron rings of 50 and 30 cm diameter and 4 cm height were used. Both rings were driven concentrically to a depth of 15 cm in soil. During experiment a constant depth of 5 cm water was maintained in both the rings. Infiltration depth was measured after 5, 10, 20, 40, 60, 90, 120, 180, 240 and 300 minutes. Soil samples were taken before each infiltration test from the depths of 0 - 15 and 15 - 30 cm by auger. These samples were oven dried and per cent moisture content was determined.

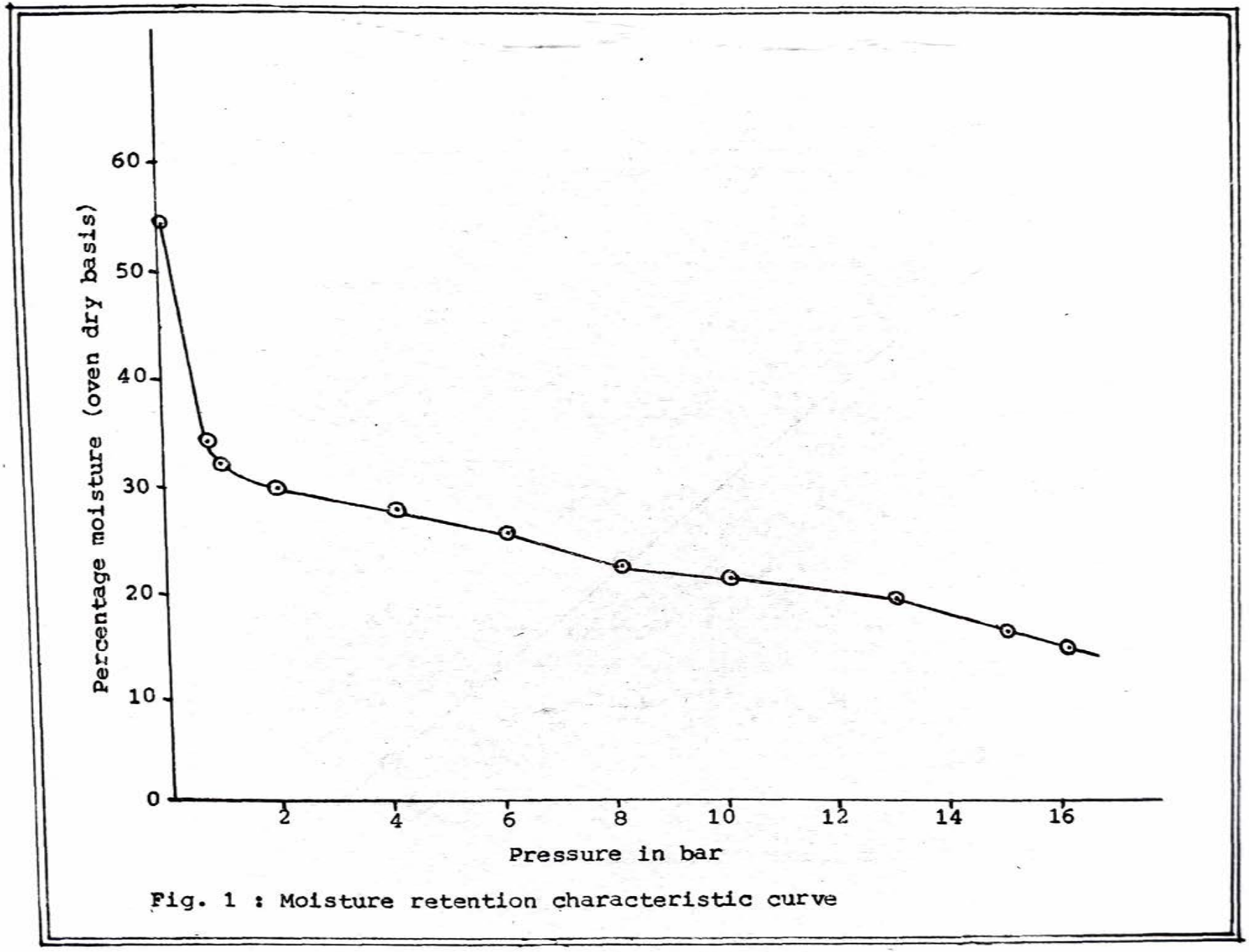


Fig. 1 : Moisture retention characteristic curve

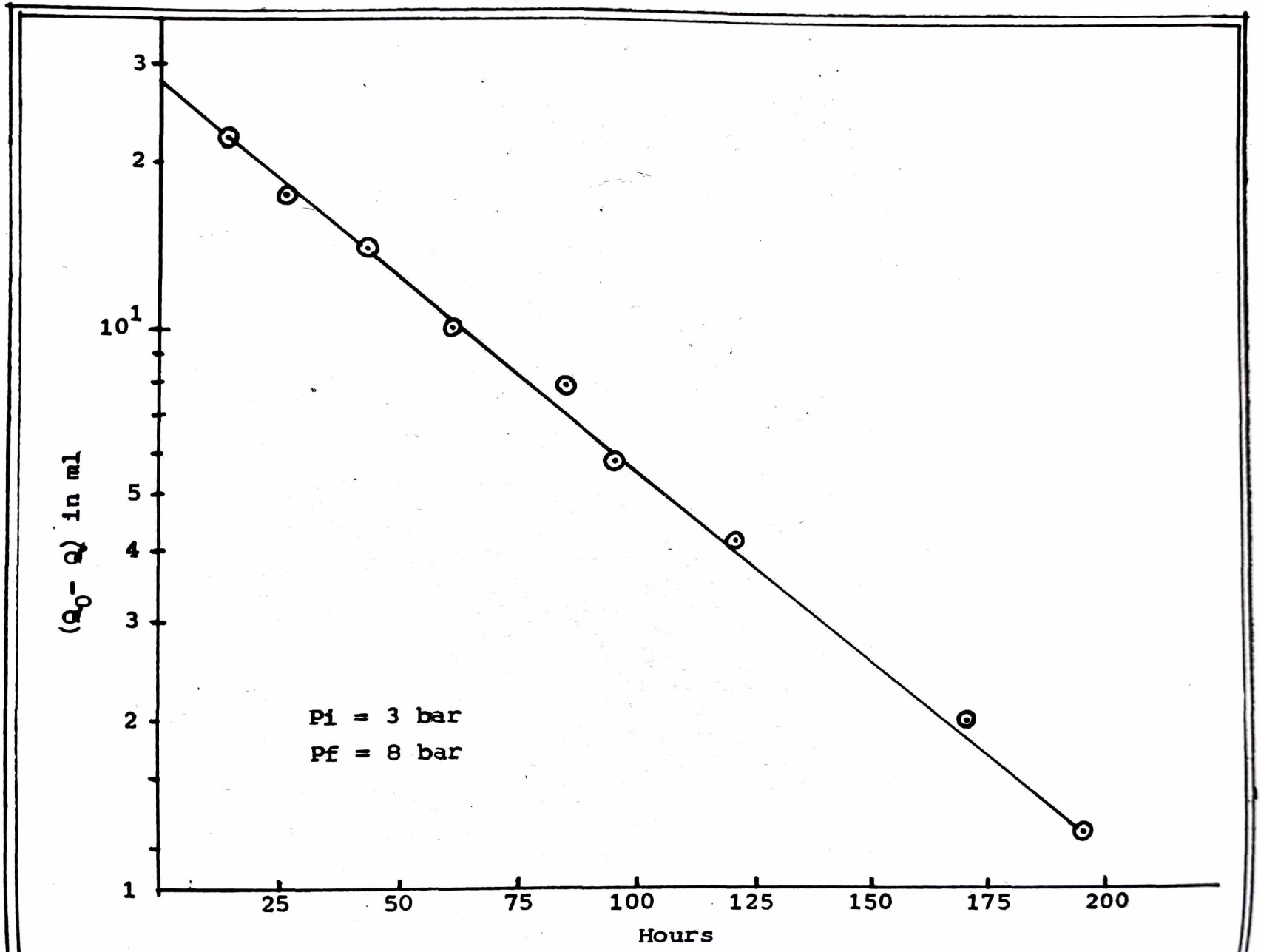


Fig. 2: Semi-log plot of outflow as a function of time

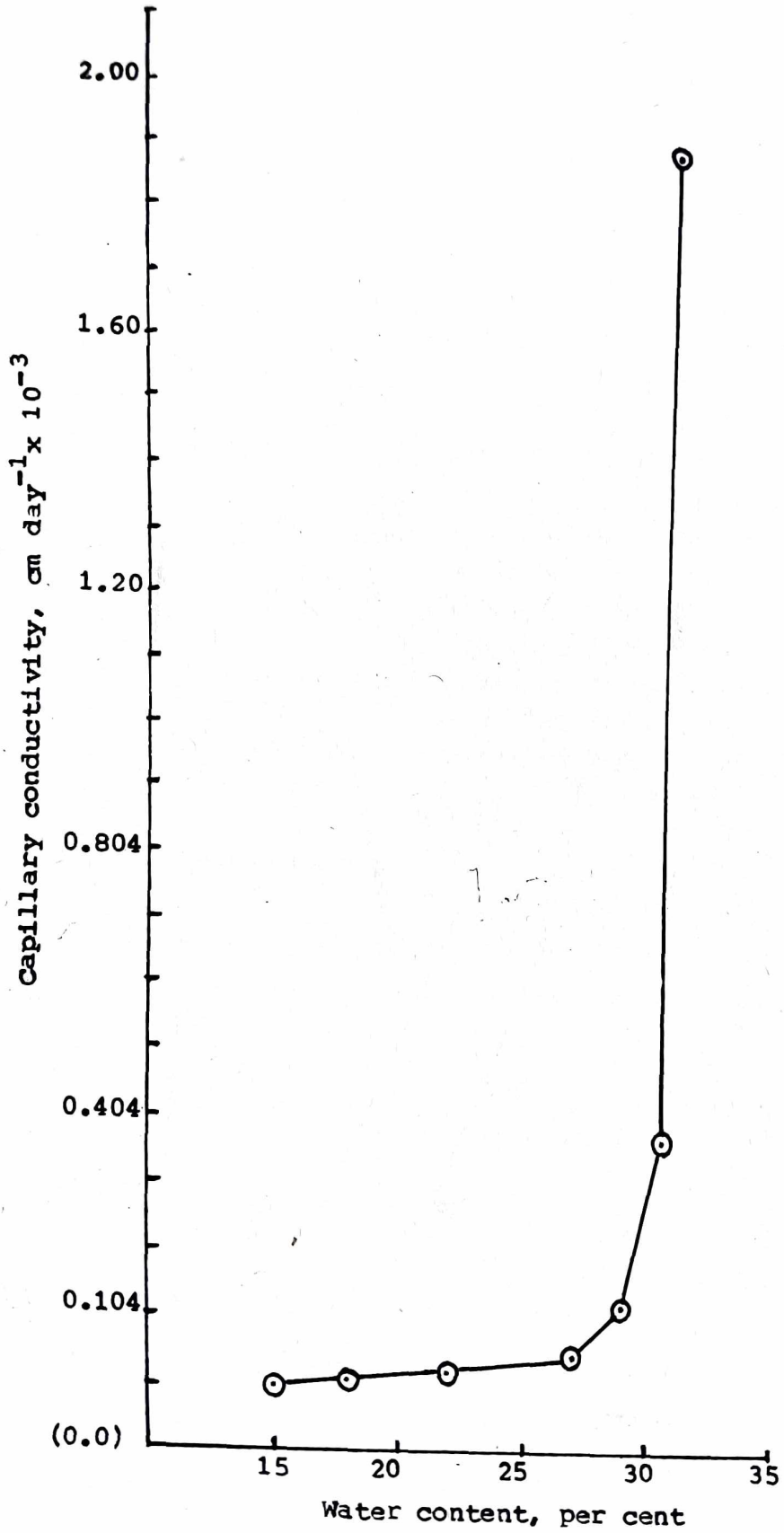
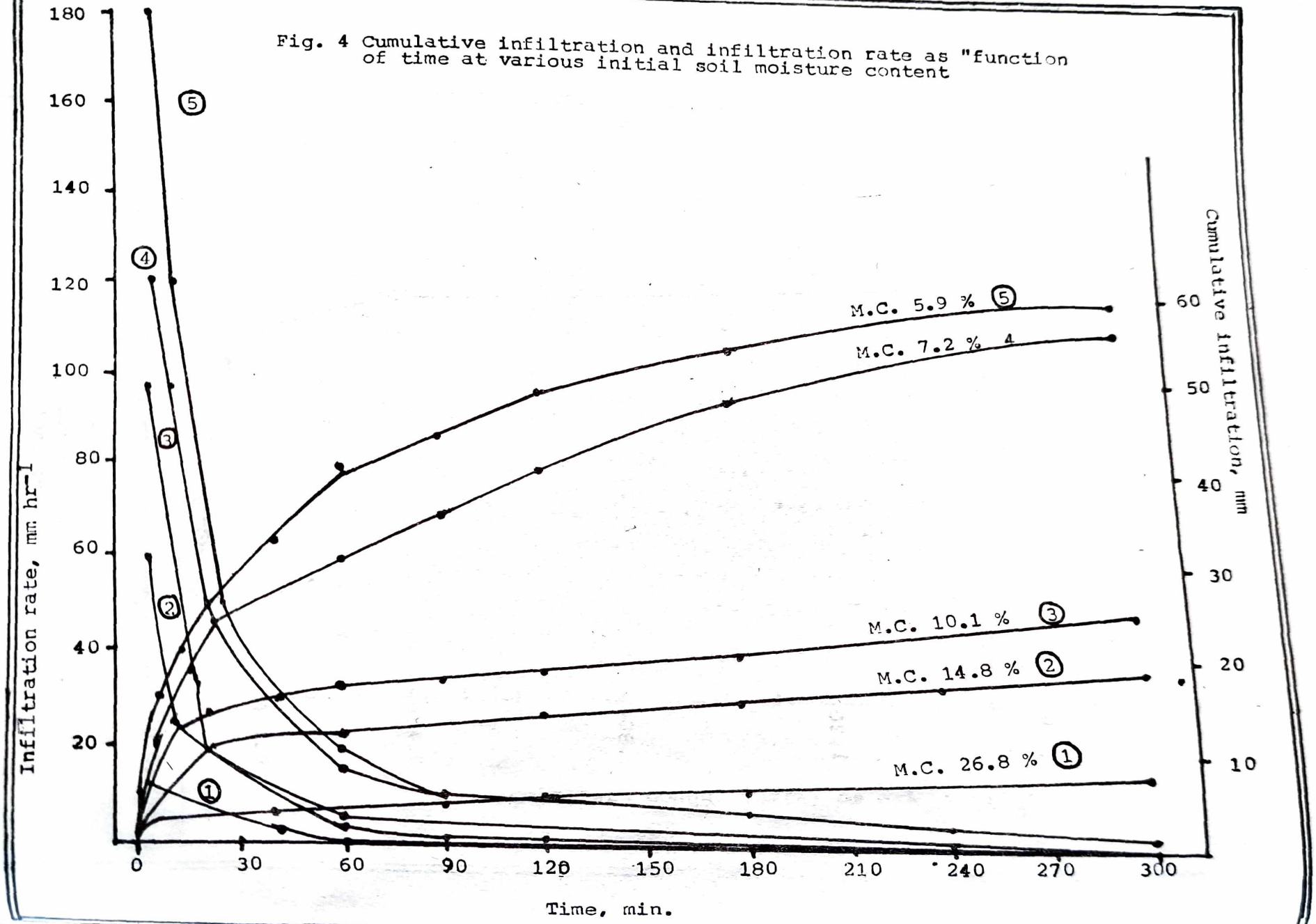


Fig. 3: Capillary conductivity as a function of water content

Fig. 4 Cumulative infiltration and infiltration rate as "function of time at various initial soil moisture content



RESULTS AND DISCUSSION

The soil moisture retention as a function of pressure is depicted in Fig. 1. As the pressure increased from 0.0 to 0.3 bar, the moisture content decreased rapidly from 54.0 to 34.4 per cent. With further increased in pressure to 15 bar, the moisture retention was 16.1 per cent. Thus, from field capacity to permanent wilting point, the loamy sand soil of Anand retained 18.3 per cent moisture. Though bulk density varies with depth of soil but for practical purpose considering the bulk density of 1.6 g cm^{-3} uniformly for 100 cm depth of soil, these soils can supply 29 cm water in available form i.e. in the soil water potential of -0.3 to -0.15 bar range.

The capillary conductivity (K) was calculated as per the procedure described. The outflow data as a function of time are plotted in Fig.2. The straight line is fitted to the experimental points by eye. The expected deviation from the straight line in the vicinity of t = 0 appears. In some cases there was a tendency for the experimental points to deviate from a straight line near the end of a run. The calculated K values for the soil are given in Table-1 for each initial and final pressure. The capillary conductivity recorded at 0.3 and 1.0 bar Pf were 11.5×10^{-3} and 0.37×10^{-3} cm day^{-1}, respectively. It was more rapidly decreased to 0.004×10^{-3} cm day^{-1} at 16 bar Pf as pressure increase from zero owing to large pore spaces that permit high rate of flow under conditions of near saturation at low matric suction. The K values are plotted as a function of water content in Fig.3. While the actual water content range included is small, it represents a major portion of available water range. It is obvious that the conductivity decreased extremely rapidly with declining water content

TABLE 1

Capillary conductivity of loamy sand soil.

Pressure, bars		
Pi	*Pf*	*K, Cm day^{-1}*
0.2	0.3	11.5×10^{-3}
0.3	0.4	4.8×10^{-3}
0.4	0.5	1.9×10^{-3}
0.5	0.6	8.7×10^{-4}
0.6	0.8	6.3×10^{-4}
0.8	1.0	3.7×10^{-4}
1.0	2.0	1.2×10^{-4}
2.0	4.0	0.49×10^{-4}
4.0	8.0	1.6×10^{-5}
8.0	14.0	0.47×10^{-5}
14.0	16.0	0.38×10^{-5}

upto 27 per cent. It reduced gradually with further decreasing in moisture content. Thus, as the matric suction is increased from zero or moisture content decreased from saturation, air enters first the largest and then progressively smaller pores. The proportion of total cross-sectional area effective in conducting water is thereby decreased; and the movement is confined to films and small pores, in which the rate of movement is low according to the capillary-tube principle (Gardner, 1960). At the sametime, the flow is impeded by a decrease in continuity of water films among particles and an increase in tortuosity of the path.

The cumulative infiltration and infiltration rate as a function of time at various initial soil moisture content is plotted in Fig.4. The final infiltration rate at initial soil moisture contents of 26.8 and 14.8 per cent was 0.1 cm hr^{-1}. It was 0.5 cm hr^{-1} at 7.2 and 5.9 per cent of initial soil moisture contents. The initial infiltration rate at higher initial soil moisture content was very low in comparison to that of at lower soil moisture content. This causes to surface ponding during monsoon in case high rainfall is followed by drizzling rainfall. The cumulative infiltration of 300 minutes increased from 0.8 to 5.9 cm with reduction in soil moisture content from 28.8 to 5.9 per cent. The infiltration rate declined with time, the rate of decrease was more pronounced with low soil moisture content during an infiltration process owing to decrease in matric potential gradient that is associated with the ever deeper penetration of wetting front (Philip, 1954). As the soil moisture content decreased, cummulative infiltration for the same elapsed time intensified while for the same moisture content, cumulative infiltration enhanced with a decreasing rate.

Thus, in the soil moisture range of 27 per cent to saturation, large quantities of water is supplied to crop roots in shorter time owing to very high rate of hydraulic conductivity. Secondly, infiltrability of this soil is low at high moisture content due to higher bulk density at 15 - 30 cm depth of soil. This results more accumulation of water in rhizosphere and when it couples with high temperature during late September causes oxygen deficiency to crop roots and especially scalding damage to tobacco crop. The crop is likely to experience moisture deficiency below 27 per cent of soil moisture content as water supply to root surface reduces owing to low hydraulic conductivity rate.

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