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Determination of Infiltration Characteristics of Heavy Black Soils

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ABSTRACT

In all types of soil and water engineering computations where soil is a medium to work with knowledge about infiltration characteristics is extremely essential. Infiltration was measured in double ring infiltrometer and check basins. Check basin method was found to be better infiltration measurement technique in black soils. Cumulative infiltration measured in 2m × 2m check basins in black soils at Navsari was represented by equation. $IC = 35670\ M^{-2.653}\ t^{0.640}$ where 'IC' is cumulative infiltration in mm, 'M' is antecedent moisture content in percentage and 't' is elapsed time in minute

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INTRODUCTION

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 systems, rainfall run-off modeling and drainage systems design.

Many attempts by various workers (Kostia kov 1932, Burgy and Luthin 1956, Bouer 1957, Herman and Dovnir 1960, Erie 1962, Christiansen *et al* 1966, Ram and Lal 1970) have been made to measure infiltration in field condition. Single or double ring infiltrometers are mostly used for measuring infiltration rate of soils. Heavy black soils develop cracks on drying and swell when wet. Therefore, these soils create a special problem in infiltration measurement. Infiltration-time function predicted by infiltrometer technique is point function and, therefore, more likely to be affected by developing craks during drying in these type of soils.

Infiltration was measured with a view to compare double ring infiltrometer and check besin methods, study the effect of antecedent moisture and thereby, suggest a mathematical model for prediction of infiltration characteristics of black soils.

METHODS AND MATERIALS

The experiment was laid out at Agricultural College farm, Navsari. Twenty plots of size 2m × 2m were prepared leaving a buffer area of 2m on all the four sides of each plot. All plots were irrigated by applying 5 cm depth of water to bring homogenous initial moisture conditions before starting the infiltration measurements. Infiltration was mesured by double ring infiltrometer

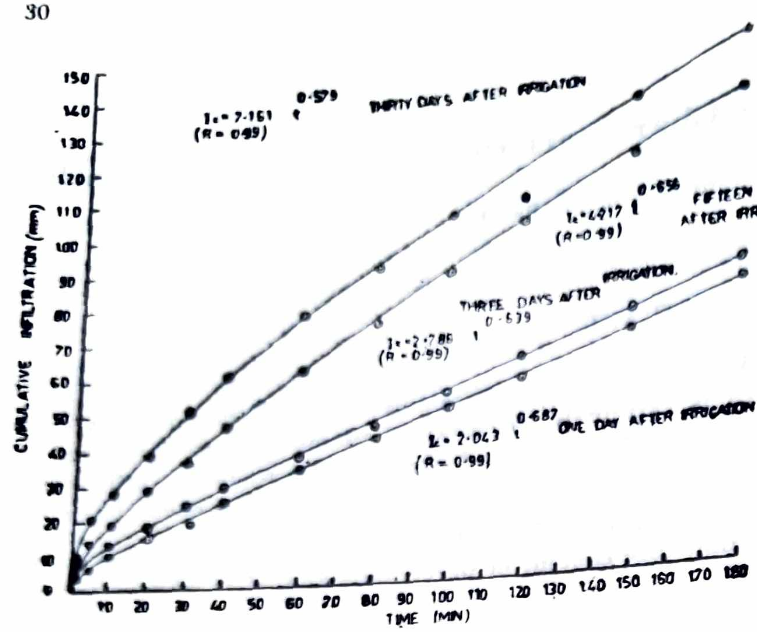

Fig. 1 Relationship between time and cumulative infiltration in checkbasin.

and check basin method on 1, 3, 7, 15 and 30 days after irrigation. Each treatment was replicated twice.

In infiltrometer method, two iron rings of 48·3 and 30·5 cm diameter and 40 cm height were used. Both rings were driven concentrically to a depth of 20 cm in soil. During experiment a constant depth of 5 cm water was maintained in both the rings with the help of hook gauge. Infiltration depth was measured (volume of water divided by cross sectional area of inner ring of infiltrometer) after 2, 5, 10, 20, 30, 40, 60, 80, 100, 120, 150 and 180 minutes.

In check basin method, experiments were started by applying a depth of 5 cm of water. This depth was maintained with the help of hook guage throughout the experimental period. The infiltration was measured at the same time interval as in case of infiltrometer method.

Soil samples were taken before each infiltration test from the depths of 0-15, 15-30, 30-45, 45-60, 60-75, 75-90, 90-105, 105-120, 120-135 and 135-150 cm by auger. These samples were oven dried and per cent moisture content was determined.

The observations on cumulative infiltration with respect to time, as detailed above were noted and analysed.

RESULTS AND DISCUSSION

Data on cumulative infiltration in check basin against time was plotted on a simple arithmetic scale (Fig. 1) and was fitted in Kostia-Kov infiltration equation as follows.

$$Ic = at^b$$

Where

Ic = cumulative infiltration,

t = time, and

a,b = Constants which depend on moisture and soil physical characteristics.

Infiltration equations for different days were as follows

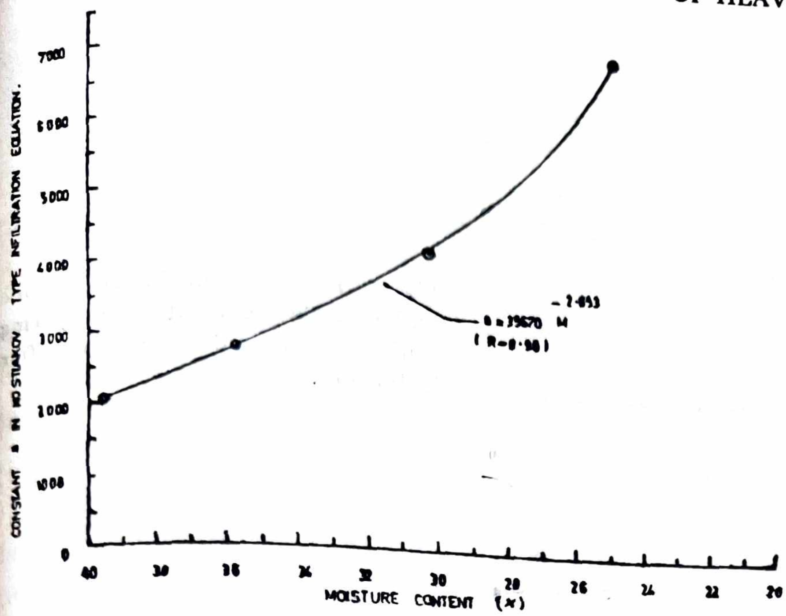

Fig. 2 Relationship between moisture content and constant a in kistiakov type infiltration equation.

Infiltration equation after 24 hours of irrigation:

$Ic = 2{\cdot}043\ t^{0{\cdot}687}$— — — — — —

(M.C. = 39·45% in 0-15 cm layer)...1

Infiltration equation after 3 days of irrigation:

$Ic = 2{\cdot}786\ t^{0{\cdot}639}$— — — — — —

(M.C. 35·65% in 0-15 cm layer)....2.

Infiltration equation after 7 days of irrigation:

$Ic = 4{\cdot}217\ t^{0{\cdot}656}$— — — — — —

(M.C. 30·11% in 0-15 cm layer).....3.

Infiltration equation after 30 days of irrigation:

$Ic = 7{\cdot}161\ t^{0{\cdot}579}$— — — — — —

(M.C. 24·71% in 0-15 cm layer)....4.

In the above four equations 'Ic' is cumulative infiltration in mm, 't' is time in minute and 'M.C.' is per cent moisture content.

Infiltration constants 'a' in above equations were plotted against moisture content in 0-15 cm soil layer as shown in Fig. 2. It fitted in the power equation as follows

$a = 35670\ M^{-2{\cdot}653}$ ....(5)

Where a = infiltration constant

M = Moisture content %

To test the goodness of fit, 'R' for each equation was calculated and was found 0·99 in each case, indicating very good fit. Combining equations (1), (2), (3), (4) and (5) it was found that

$Ic = 35670\ M^{-2{\cdot}653}\ t^{0{\cdot}640}$ ....(6)

The goodness of fit, 'R' for the equation (6) was worked out and found to be 0·904 indicating a very good fit. Thus, a mathematical model of the form $Ic = aM^{b}\ t^{c}$ where a, b, and c are the constants depending upon soil and moisture characteristics, could be used for defining infiltration — time — moisture content relationship.

Equation (6) indicates that as the moisture content decreases, cumulative infiltration for the same elapsed time increases while for the same moisture content, cumulative infiltration increases with a decreasing rate. It means

GAU. RES. J. 1979. 4 (2)

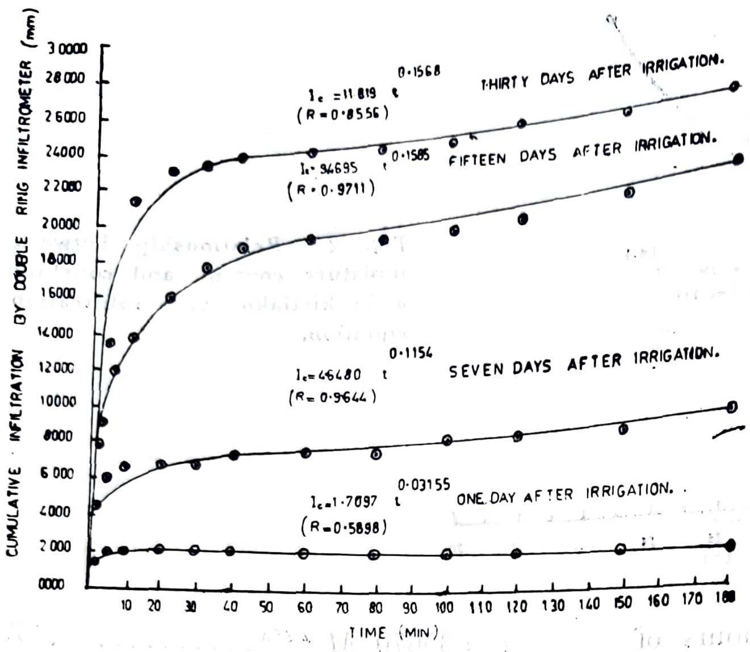

Fig. 3 Relationship between time and cumulative infiltration by ring infiltrometer on different days after irrigation.

that as the time increases infiltration rate decreases.

Similarly, data on cumulative infiltration measured by double ring infiltrometer against time was fitted in Kostia-Kov infiltration equation. Infiltration equations for 1st, 3rd, 15th and 30th day after irrigation are as follows and are graphically represented in Fig. 3.

$Ic = 1{\cdot}7097\ t^{0{\cdot}03155}$ ....(7)

$Ic = 4{\cdot}6480\ t^{0{\cdot}1154}$ ....(8)

$Ic = 9{\cdot}4695\ t^{0{\cdot}1585}$ ....(9)

$Ic = 11{\cdot}8190\ t^{0{\cdot}1568}$ ....(10)

Constants 'a' in equation (7), (8), (9) and (10) when plotted against moisture content, gave a relationship as follows:

$a = 4084000\ M^{-3{\cdot}9034}$ ....(11)

Value of 'R' for equation (11) was found to be 0·8473. But when average value of 'b' in equations (7), (8), (9) and (10) was used, value of 'R' was very low and hence it was concluded that an average value of 'b' can not be used for predicting infiltration at various moisture contents. Very low value of 'a' in equation (7), (8), (9) and (10) further indicated that infiltration rate dropped drastically with time and became almost zero after 30 to 40 minutes.

The result of experiments during 1971-72 and 1974-75 at Agricultural College Navsari Farm, indicated that infiltration rate varied from 0·25 to 0·65 cm/hr (Annonymous, 1975). However, the experimental methodology is not indicated anywhere. Infiltration is a function of antecedent moisture content and time and is essentially a process of water flow in unsaturated condition. It is, therefore, not clear whether the reported results (Annonymous, 1975) are the findings of experiments in laboratory condition or the field condition. It is further not clear, how a constant value of infiltration rate has been arrived at, when infiltration rate is a function of time and moisture content.

Comparision of infiltration measurements by check basin and double ring methods:

Equation (1), (2), (3) and (4) indicate that cumulative infiltration for same elapsed time and at same moisture content was many times more in case of check-basin method as compared to double ring method. At the end of three hours of test on 1st, 7th and 30th day after irrigation, cumulative infiltration by check basin method was 75·7, 128·7 and 144·3 mm and by double ring infiltrometer the same were 1·982, 21·835 and 25·765 mm, respectively. Check basin method of infiltration measurement in black soil can be favoured because of the following.

1. Check basin method of infiltration measurement being more near infiltration in natural condition, it can be directly applied for irrigation or drainage computations.
2. Black soils, once became dry it is extremely difficult to drive infiltrometer.
3. Infiltration curves for equations (7), (8), (9) and (10) show that infiltration rate is almost zero after 30 to 40 minutes. It is not true in actual condition.

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