Pak J Sci Ind Res 1999 42 (1) 34-38

COMPARISION OF INFILTRATION MEASUREMENT TECHNIQUES IN BORDER IRRIGATION

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(Received 25 June 1996; accepted 7 October 1997)

Volume balance and cylinder infiltrometer method of infiltration measurements were carried out at Bangladesh Agricultural University farms to determine the infiltration characteristics in Border irrigation for better irrigation management. First, second and third irrigation trials were conducted in non-vegetative border and fourth trial was conducted in vegetative border (Maize crop). The rate of application of water in first, second, third and fourth trial were 12.42, 2.21, 5.19 and 5.19 l s^{-1}, respectively. A general equation of infiltration rate was developed for the study area and comparison was made between Volume balance method and Cylinder infiltrometer method. It was observed that for all the trials cumulative infiltration and infiltration rate by Volume balance method was higher than that of cumulative infiltration and infiltration rate by Cylinder infiltrometer method. It was also observed that the values of infiltration characteristic constants a and b by Volume balance method were higher than those of the values of a and b by Cylinder infiltrometer method.

Key words: Infiltration, Infiltrometers, Border irrigation.

Introduction

The infiltration process plays a conspicuous role in irrigation management and management of water resources for agricultural purposes. Infiltration is also considered to be the basic criterion in the design and improving the efficiencies of surface irrigation.

The entry of water into the soil surface is called infiltration. It is a physical property of soil of great importance to irrigators and soil scientists. The major factors affecting the infiltration of water into the soil are type of soil and condition of the soil surface, slope of the field, initial soil moisture content, rate of water application, hydraulic conductivity, porosity, organic matter, vegetal cover, land use, entrapped air and depth of the ground water table.

Many attempts by various workers have been made to measure infiltration rate under field conditions. Single or double cylinder infiltrometers are mostly used for measuring infiltration rate of soils. Since cylinder infiltrometer represents the ponded condition, it does not simulate the flow conditions as actually occur in the field. The volume balance method which is based on the law of conservation of mass, helps to determine the infiltration characteristics of soil under actual flow conditions during irrigation application.

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Burgy and Luthin (1956) compared the infiltration rate obtained by single ring infiltrometer with that of double ring infiltrometer and found no significant difference in the results (on a uniform soil having no stratification). Herman and Dovnir (1960) presented a solution of volume balance equation by graphical means. They pointed out that the time infiltration curve obtained by volume balance method is more representative of average condition of the field than that made by ring infiltrometer. Ram(1972) compared infiltration constants from volume balance and infiltrometer methods of measurement. He suggested that the volume balance method be used for determining the infiltration constants in surface irrigation systems.

It is known that border method of irrigation is suited for close growing crops like wheat, barley, fodder crops, legumes and oil-seeds, etc. In border irrigation, infiltration is the most important factor. But so far, there has been no study in Bangladesh to determine infiltration characteristics by comparing double-ring infiltrometer method and volume balance method in border irrigation. It is possible to determine the infiltration characteristics in border irrigation in all soils and for all crops of Bangladesh. Hence, the present work was undertaken as a pilot one to evaluate characteristics of border irrigation using two methods of infiltration under non-vegetative and vegetative condition in a silty loam soil of Bangladesh Agricultural University farm.

Materials and Methods

Experimental investigations were carried out at Bangladesh Agricultural University farm area, Mymensingh. The study area lies approximately between 24° 36', to 24° 54', N latitude and between 90° 15', to 90° 30', E longitude. Two plot were selected for the experiment. Border width of each plot was 8 m and border length was 40 m. Two border-strips were prepared keeping 1 m gap between the adjacent levees. Levees were roughly 30 cm wide and 20 cm high. The slope of the experimental plots and elevation at different points were determined by dumpy level. To avoid outward seepage polythene sheets were vertically placed at 20 cm depth below the surface along the side of the levees of the two plots. The bed of the earthen canal from cutthroat flume to the delivery point at the head-end of the plots was completely covered with a piece of polythene sheet ensuring no loss of water in between. Maize crop was used as a vegetative cover. Line to line distance of maize crop was 30 cm and plant to plant distance was about 15 cm. During water supply to the plots three openings were made for each plot at the upstream side. The openings were 2 m apart with a dimension of 10cm X 10cm.

Soil samples from depths of (0-10) and (10-20) cm were collected by auger from each of the experimental plots. Textural analysis of the soils was carried out by hydrometer method. Core sampler method was used to determine the bulk density of the soils. Gravimetric method was used to determine the soil moisture of the experimental plots. Bulk density and soil moisture were determined before each irrigation trial.

Infiltration was measured using cylinder infiltrometer method and volume balance method. In cylinder infiltrometer method, the cylinders were 25 cm deep and were made from 2 mm thick steel. Diameter of the inner and outer cylinder were 30 cm and 60 cm, respectively. Before each irrigation trial, infiltration behavior of the soil was studied at two places, one at approximately middle point of the upper half and the other at the middle point of lower half of the plots. The infiltration characteristic for the whole irrigated area was obtained by averaging the two mathematically fitted curve for a particular trial.

The volume balance method infiltration was measured per unit width of border at every instant of time. Different advance time, advance length and average depth of flow are needed to measure infiltration in this method. For measuring depth of flow on the border length, meter scales were used. The least count of meter scale was 0.1 cm. These meter scales were tied with bamboo sticks in such a way that zero marking of the scale was levelled with the field surface. The depth of flow was measured at three points (2 m apart) across the border by meter scales after every 5 m interval from the upstream end of the border. In this method infiltration was measured by subtracting volume of water applied to the volume of water stored at different times for different lengths of the border.

In plotting infiltration curves for both the methods, the elapsed time is plotted on the X-axis and the cumulative infiltration on the Y-axis. Cumulative infiltration data were fitted to the well known equation (Kostiakov 1932) of the form

$$I_c = at^b \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Infiltration characteristic constants a and b were find out by using an optimization techniques (Rosenbrock 1960). Then curves were drawn using developed equations. R^2 values between observed and calculated infiltration measurements are given in Table 1.

Table 1

Infiltration characteristic constants a and b obtained by cylinder infiltrometer and volume balance method

Irrigation Trials		Slope	Method					
			Cylinder infiltrometer			Volume balance		
		%	a	b	R^2	a	b	R^2
Non vegetative border	First	0.256	0.453	0.429	0.989	0.626	0.631	0.940
		0.218	0.450	0.461	0.987	0.677	0.565	0.980
	Second	0.256	0.233	0.393	0.992	0.151	0.324	0.930
		0.218	0.212	0.462	0.989	0.292	0.448	0.860
	Third	0.270	0.304	0.397	0.990	0.241	0.560	0.990
		0.230	0.297	0.443	0.978	0.326	0.476	0.970
Vegetative border	Fourth	0.250	0.480	0.570	0.948	0.564	0.548	1.000
		0.210	0.480	0.560	0.953	0.602	0.540	0.970

Before each irrigation trial, discharge was measured by cut-throat flume.

For different size of flume, the flume length coefficient and flow exponent for submerged and free flow conditions are determined using graphs presented by Skogerboe *et al* (1973).

Results and Discussion

The soil texture in the experimental plot was found to be silt loam (USDA classification system). Average bulk densities at topsoil and subsoil were 1.30 gm cc^{-1} and 1.49 gm cc^{-1}, respectively. Average moisture content at topsoil and subsoil were 25.89% and 30.12%, respectively. Bulk densities were found to increase or decrease with the increase or decrease of moisture content.

Figure 1(a-h) represents the variation of the cumulative depth of infiltration against elapsed time by cylinder infiltrometer and volume balance method for different irrigation trials. In all the cases it was observed that cumulative infiltration by volume balance method is higher than cumulative infiltration by cylinder infiltrometer method. Also in all the cases infiltration rate by volume balance method is higher than infiltration rate by cylinder infiltrometer method which are shown in Fig. 1(a) to 1(h). Moreover, for all the trials in cylinder infiltrometer and volume balance method constant infiltration rate attained between 80 to 90 minutes. The values of infiltration characteristic constants a and b [as shown in Equation (1)] are given in Table 1 for different irrigation trials. The values of a and b by volume balance method are higher than those of the values of a and b by cylinder infiltrometer method. Michael (1978) stated that the values of a and b ranged between 0 to 1 which are similar to the findings in Table 1.

During the time of experiment it was observed that on upstream side of the border, water front advance is sufficiently high (i.e. velocity of flow of water is high) as compared to the downstream side. In case of cylinder infiltrometer there is no surface flow hence the rate of infiltration is low compared to that by volume balance method. In case of volume balance

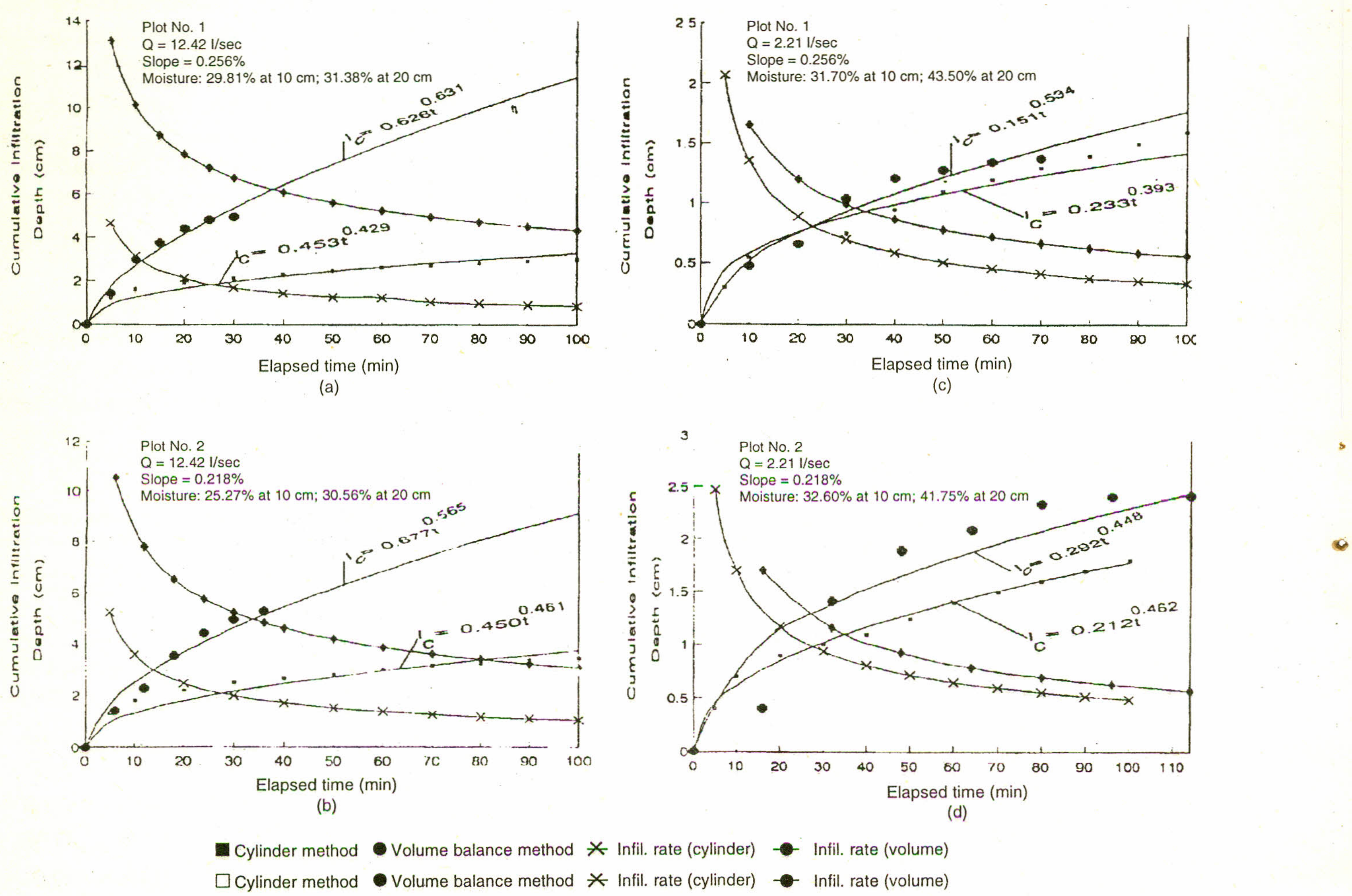

Fig 1(a,b,c,d). Plot of cumulative infiltration depth and rate versus elapse time.

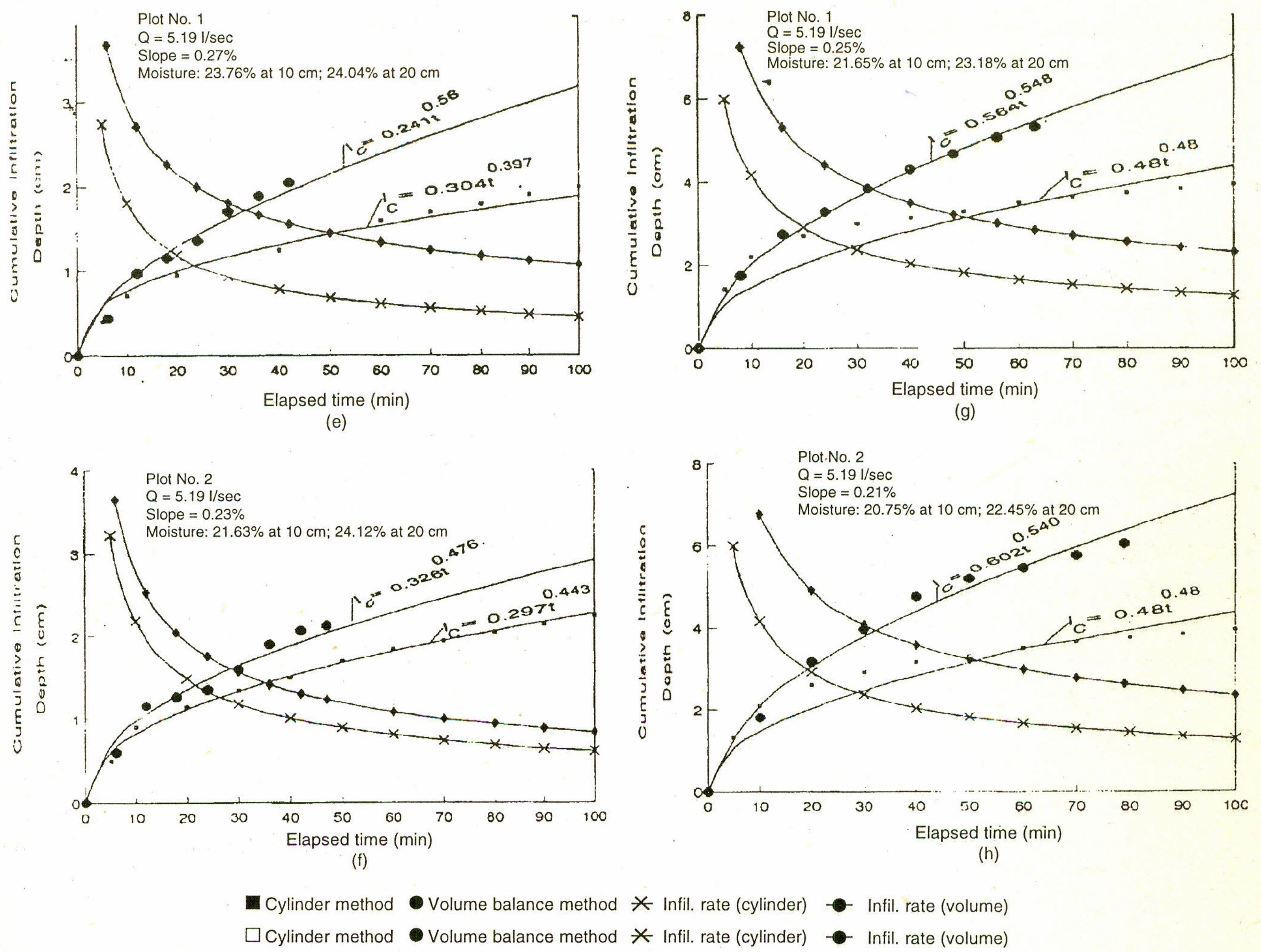

Fig. 1(e,f,g,h). Plot of cumulative infiltration depth and rate versus elapse time.

method recharge area is large but in case of cylinder infiltrometer method recharge area is small. Thus the cumulative infiltration is more by volume balance method than that of cylinder infiltrometer method. The later one does not give the true picture of the overall infiltration characteristics of the soil while water is flowing in the border unless a large number of infiltrometers are used for finding out the infiltration characteristics of the soil. On the other hand volume balance method considers all the variations within the area under consideration. The use of volume balance method for determining infiltration constants eliminates the extra work involved in measuring infiltration by cylinder infiltrometer method. Owing to the aforesaid reasons Ram (1972) recommended that use of volume balance method is preferred for determining infiltration characteristics of the soil.

To find out the representative infiltration equation for the experimental plot, analysis of variance was done to check that there was no significant difference in the values of infiltration characteristic constants. Table 3 shows that there is no significant difference between the values of 'a' in cylinder infiltrometer method and volume balance method at 1% and 5% level. Similarly, variance test (Table 4) showed insignificant difference between the values of 'b' in cylinder infiltrometer method and volume balance method at 1% and 5% level. Considering the arithmetic mean of all a and b values respectively, the average infiltration equation becomes

$$I_c = 0.399\ t^{0.502} \quad \text{.................... (2)}$$

where I_c = cumulative infiltration, cm and t = elapsed time, minutes.

Conclusion

After extensive analysis the following conclusions were drawn from this study:

(i) For cylinder infiltrometer method the average initial and final infiltration rates were 3.46 cm h^{-1} and 0.73 cm h^{-1}, respectively. While in volume balance method, the rates were 5.25

$cm^{-1}h$ and 1.98 cm h^{-1}, respectively. Thus, it was observed that cumulative infiltration and infiltration rate by volume balance method were higher than that of the values obtained by cylinder infiltrometer method for all the trials.

(ii) Constant infiltration rate was attained between 80 to 90 minutes for all the trial in both the methods.

(iii) The values of infiltration characteristic constants a and b by volume balance method were higher than those of the values of a and b by cylinder infiltrometer method. The average values of a and b by cylinder infiltrometer method were 0.364 and 0.453, respectively and for the volume balance method these values were 0.435 and 0.55, respectively.

(iv) The values of infiltration constants a and b were found in the range of 0 to 1 for both the methods.

References

Burgy R H, Luthin J N 1956 A test of single and double ring type infiltrometers. *Transaction American Geophysics Union,* **37,** 189-192.

Herman J F, Dovnir 1960 Determining infiltration rates in irrigation borders. *J Geophysical Research* **65** 2125-2131.

Kostiakov A N 1932 On the dynamics of the coefficient of water percolation in soil and on the necessity of studying it from a dynamic point of view for purposes of amelioration. *Transaction VI comm. Int. Soc. Soil Science* (Russian Part A) 17-21.

Michael A M 1978 *Irrigation Theory and Practices.* Vikos Publishing House Pvt. Ltd., New Delhi, India, pp 592.

Ram R S 1972 Comparison of infiltration measurement techniques. *Journal of Agricultural Engineering (ISAE)* **9** 67-75.

Rosenbrock H H 1960 Automatic method for finding the greatest or least value of a function. *The Computer Journal* **3** 175-184.

Skogerboe G V, Bennet R S, Walker W R 1973 *Selection and Installation of Cutthroat Flumes for Measuring Irrigation and Drainage Water.* Publication, Colorado State University Expt, Stn, USA.