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Evaluation of infiltration equation at IGKV Raipur farm

Abhishek Ranjan and Ishika Singh

Abstract
Infiltration is one of the important variables in the hydraulics of irrigation. The design of an irrigation system depends to a large extent upon the infiltration characteristics of soil. Since the inception of research activities in the field of irrigation, scientists have been confronted with the problem of determining infiltration characteristics of the soil due to its temporal variation. The major factor affecting the infiltration rate of soil water are the initial moisture content, condition of soil surface, hydraulic conductivity of the soil profile, texture, porosity etc. Infiltration rate are also affected by the porosity of the soil which is changed by cultivation or compaction. It is observed that infiltration rate and accumulated infiltration for papaya grown field more than that for paddy harvested upland field. The average infiltration rate in paddy harvested field was found to be lesson, (4.09 cm/hr) than (6.35 cm/hr) in papaya grown filed. The average value of basic infiltration rate and the time to reach basic infiltration rate for papaya grown field were found to be (0.76 cm/hr) and (188 min) respectively. However it was observed to be (0.73 cm/hr) and (183 min) respectively for paddy harvested upland field. It was concluded that the Kostiakov equation yielded the lower value (4.36), RMSE (3.39) and MBE (2.20) for papaya grown and the lowest value of (3.82), RMSE (2.74) and MBE (2.13) paddy harvested field. Hence, the Kostiakov infiltration equation was found to be best suited for the area under study.

Keywords: infiltration, RMSE, MBE, bulk density, soil moisture, soil texture

Introduction

In India about 75.32 percent of its population is mainly dependent on agriculture and its allied activities. As far as agriculture is concerned, water is one of the most important inputs for the crop. Due to inadequate and uneven distribution of rainfall during the growth period of crop it becomes necessary to apply additional water to the soil in the form of irrigation for plant use. Yield and quality of crop suffer due to improper scheduling of irrigation. The knowledge of infiltration rate is an important practical consideration to improving water use efficiency in irrigated agriculture. Infiltration is one of the important variables in the hydraulics of irrigation. The design of an irrigation system depends to a large extent upon the infiltration characteristics of soil. Three phases of the hydrologic cycle of particular interest to agricultural engineers are infiltration, evaporation and transpiration. The infiltration can be defined as the passage of water into the soil surface and distinguishes from percolation, which is the movement of water through the soil profile. It is derived from rainfall or artificial irrigation and related to the transpiration of plants and the evaporation of soil surface. It is influenced by the properties of soil, fluid and hydraulic gradient. Infiltration may be considered as three step sequence surface entry, transmission through the soil and depletion of storage capacity in soil. These are important factors affecting infiltration, in addition to the characteristics of the permeable medium and percolating field. It is well known that when water is applied to the surface of the soil, a part of it seeps into the soil. This movement of water through the soil surface is known as infiltration and plays a very significant role in the runoff process by affecting the timing, distribution and magnitude of the surface runoff. Further infiltration is the primary step in the natural ground water recharge. The major factor affecting the infiltration rate of soil water are the initial moisture content, condition of soil surface, hydraulic conductivity of the soil profile, texture, porosity etc. Infiltration rate are also affected by the porosity of the soil which is changed by cultivation or compaction. Cultivation influences the infiltration rate by increasing the porosity of the surface soil and breaking up the surface seal.
Keeping the views of above, the present study was undertaken with the following objectives:

1. To determine parameters of various infiltration equation conducting infiltration test in the field.
2. To select of infiltration model describing the best infiltration characteristics of the soil.
3. To observe the effect of moisture content and bulk density of the on infiltration characteristics.

Materials and Methods

Experimental site

The field experiments were conducted in the plot of Papaya grown and paddy harvested field adjoining to Indira Gandhi Krishi Vishwavidyalaya farm during mid November, 2017. The field has an approximate uniform topography with deep and well drained sandy loam soil.

Geograpical and cilmatic condition

It is situated at 21.23°North latitude, 81.70°East longitudes and at an altitude of about 52.00 meter above the mean sea level. The climate of the area concerned is humid sub tropical climate and receives fairly good amount of south west monsoon rainfall. The average annual rainfall in the area is 1489 mm. out of which nearly 1348 mm (90%) occurs in the monsoon months. The average minimum and maximum temperatures during the hottest months of May to June rises from 3 to 4 ^{0}C and 44 to 46 ^{0}C respectively. The minimum temperature during Rabi season falls down from 8 to 10 ^{0}C in January while the maximum temperature rise upto 42 ^{0}C during the harvest time in the month of April.

Equipments and Instruments

Hydrometer

Hydrometer is an instrument used to measure the relative density of the soil or liquid that is the ratio of density of the soil particle to the density of water. It is based on Archimedes principle. It determines the percentage content of sand, silts, and clays (Fig. 1). Hydrometer consist a beaker of capacity 500 ml, filtration apparatus of 1000 ml, sedimentation cylinder of 0.20 mm sieve and plunger. Hydrometer was used to measure the soil texture.

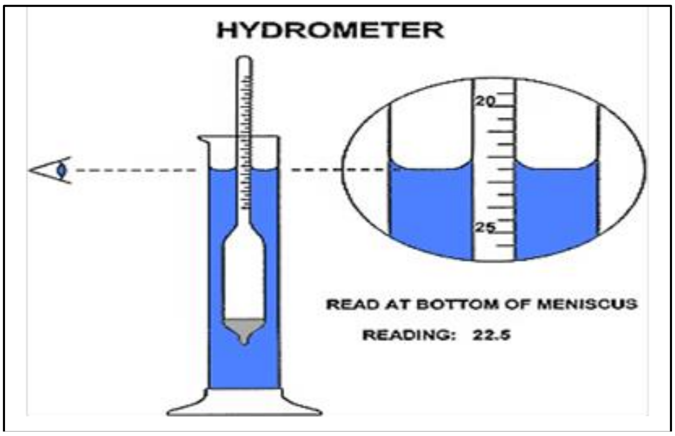


Fig 1: Schematic view of Hydrometer in a action

Soil moisture box

Soil moisture box is a small cylindrical box which is made up of aluminum. The height and inner diameter of the box were 5 cm and 2.5 cm respectively. The boxes were used to collect the soil samples in the field in order to determine the moisture content of the field.

Core cutter soil sampler

Core cutter soil sample was used to determine the bulk density of the soil at various layers below the soil surface of the area under study. The core cutter has an outer cylinder which is made of iron metal and inner cylinder which is made of bronze metal. The inner cylinder has the inner diameter of 54 mm and the length of 60 mm. The different component of core cutter soil sample has been shown in Fig. 2.

Fig 2: Core cutter soil sample

Double ring infiltrometer

Double ring infiltrometer (Fig. 3) were used to measure the accumulated infiltration in the papaya grown and paddy harvested upland fields. The size of outer ring and inner ring were 60 cm and 30 cm respectively, and the height of the rings was 45 cm. Cylinder were installed 10 cm deep in the soil. Water level in the inner cylinder was measured with the help of measuring scale. After the initial setting, measurement was made at different time intervals to determine the amount of water that had infiltration during that time. Water was added time to time in the space between outer and inner ring so that the level of water in inner ring and in spacing between inner and outer ring be equal.

Fig 3: Double ring infiltrometer

Methodology

Soil physical properties

Texture

Soil texture was determined by hydrometric method. Soil samples for the area under study where taken and solution of soils samples were made by adding water 100 ml of calgon solution was added to solution of soils samples and was shaken for 10 to 20 min in a beaker. 1 liter of distilled water was added to fill the sedimentation cylinder and reading on plunger scale was taken. Thus the percentage of sand, silt and clay were obtained diving by the plunger reading of sand, silt and clay by total weight of soil sample in aggregate.

Soil moisture

Soil samples were collected from selected points and at different depths (0 to 5 cm, 20 to 25 cm, 40 to 45 cm and 60 to 65 cm) with the help of soil augers at papaya grown upland field and paddy harvested upland field. The soil samples were immediately kept in the moisture boxes and their lid were closed to stop loss of moisture through evaporation. The boxes were accurately weighted and after opening their lids they were kept in thermostatic oven. They were dried at a temperature of 105^{0}C for a period of 24 hrs to drive away all the moisture. The moisture of soil was determined with the help of the formula given below.

$$M.C. = \frac{W_w - W_o}{W_o} \times 100$$

Where,
w_w = weight of wet soil sample (gm)
W_o = weight of oven dry soil sample (gm)

Bulk density
To determine the bulk density, the soil samples at various depths (0 to 6 cm, 30 to 36 cm and 60 to 66 cm) from top surface of soil in papaya grown and paddy harvested upland fields were taken with core cutter soil sampler. Core sampler was commonly used to take undisturbed soil samples. The cylinder of the core sampler, which has its cutting edge, is driven into the soil and an un-compacted core of soil obtained. The samples were carefully trimmed at both ends of core cylinders. They were dried in an oven at105 ^{0}C for about 24 hrs until all the moisture is driven off and the sample weighed again. The volume of core cylinder was measured to be 126.73 cm^3. The bulk density of soil at different depths of papaya grown and paddy harvested upland field were determined with the help of core cutter soil sampler using the following formula given below.

$$B.D = \frac{W_o - W_b}{V_c}$$

Where,
W_o = Weight of oven dry soil sample (gm)
W_b = weight of empty box (gm)
V_c = volume of core cylinder (126.73 cm^3)

Determination of model parameters
An attempt was made to select the best infiltration equation representing the infiltration process in situ condition. Parameter of the following infiltration equations was determined.

Kostiakov equation
Different empirical and analytical approaches have been made to estimate the infiltration rate. Kostiakov (1931) first suggested an equation of following form.

$$I = K t^n$$

Where,
I = Infiltration Rate, (cm/hr)
t = Time Elapsed, (min.)
K & n = Constants

Modified Kostiakov Equation
To overcome the Kostiakov new equation was proposed as given below.

$$I = K t^n + C$$

Where,
I = Infiltration rate, (cm/ hr)
t = Time elapsed, (min.)
K & n = Constants
C = Basic infiltration rate, (cm / hr)

S C S equation
Soil conservation service of USDA proposed following equation for accumulated infiltration and infiltration rate. This equation has the form

$$Z = K t^n + F$$

Where,
Z = Accumulated depth, (cm)
t = Time elapsed, (min)
K & n = Constants Parameters
F = Constants
F is also a parameter and calculated by using the following relation.

$$F = \frac{Z_1 Z_2 - Z_3^2}{Z_1 + Z_2 - 2Z_3}$$

Here, Z_1, Z_2, Z_3 are the corresponding cumulative infiltration values at elapsed time t_1, t_2 and t_3 respectively.

$$t_3 = \sqrt{t_1 t_2}$$

The value of t_1 and t_2 were taken to be 1 minute and 287 minutes respectively.

$$t = \sqrt{287} = 16.94 \text{ Min}$$

The value of cumulative infiltration Z corresponding to time t, was calculated by linear interpolation between elapsed time 16 minutes and 26 minutes.

Philip equation
Philip (1957). Proposed an equation for computing the cumulative infiltration rate, which is as follows.

$$z = st^{\frac{1}{2}} + At$$

Where,
Z = Accumulated depth, (cm)
t = Elapsed time, (min)
A = Constant
S = soil property

For small period of time the term (At) vanishes. So, the equation gats the form

$$z = st^{\frac{1}{2}}$$

Hence the value of parameter S is calculated as

$$s = \frac{z}{t^{\frac{1}{2}}}$$

For estimation of the 1st parameter S, Sharma *et al*. (1979) have suggested that the value of time t, should be less than 4minutes. In this work time t, has been taken as 1 minute.
For the estimation of the second parameter A, Ghosh and Sasmal (1980) have found A = 1/3 K_S, in which K_S is the

saturated hydraulic conductivity of the soil. They found this to be good approximations.

Horton equation

Horton (1940) worked on infiltration using single ring infillrometer and the develop and equation as given below.

$$f = f_C + (f_0 - f_C)\, e^{-rt}$$

Where,
F = Infiltration rate at any time (t)
F_C = Constant infiltration rate at or basic infiltration rate
f_0 = Initial infiltration rate
t = Time from beginning of the storm
r = Constant depending upon the soil characteristics and vegetation cover.

Statistical Analysis

Statistical analysis such as Chi–square, Root Mean Square Error (RMSE) and Mean Bias Error (MBE) where made in order to selected best infiltration equation.

Chi-square (χ^2) test.

The Chi–square test statistics between observed data and estimated data were calculated by following equation.

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_{li} - E_{li})^2}{E_{li}}$$

Root Mean Square Error (RMSE)

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_{li} - E_{li})^2}$$

Mean Bias Error (MBE)

$$\text{MBE} = \frac{1}{N}\sum_{i=1}^{N}(O_{li} - E_{li})$$

Where,
O_{li}= observed infiltration rate (cm/hr)
E_{li} = estimated infiltration rate (cm/hr)

Result and Discussion

Determination of soil texture

The soil texture of the selected fields was determined using hydrometer method. The percentage of soil particles e.g. Sand, silt and clay in soil aggregate were obtained to be 56.87%, 26.94% and 13.67%, respectively in papaya grown upland field. However, the percentage of soil particles in paddy harvested upland field obtained were eg. 14% sand, 26.73% silt and 14.13% clay. Based on percentage contribution of sand, silt and clay, the papaya grown and paddy harvested fields were classified as sandy loam soil.

Calculation of moisture content or bulk density

The moisture content and bulk density of the steady area were determined at each point were the infiltration experiment conducted. The soil samples adjacent to each infiltrometer and at different depths such as top surface 20 cm, 40 cm and 60 cm below the soil surface were collected with the help of moisture box. Every moisture boxes were weighted after and before oven dry at 105^0 c for 24 hr duration. Thus obtained moisture content at different depth for the steady area was represented in Table 1. The downward variation of moisture content for the steady area were shown in Fig. 4 and 4.2 graphically the maximum value of moisture content at top surface (soil layer of 5 cm depth) for both the fields were obtained. Whereas the minimum value of moisture content at depth of 60 cm (soil layer of 60 to 65 cm depth) were observed. The average moisture content at the top surface 20 cm, 40 cm and 60 cm depth below soil surface for the steady area were 14.12, 15.41, 19.55 and 19.64% respectively for papaya grown field and 15.10, 17.30, 19.57 and 20.39% respectively for paddy harvested field were observed (Table 4. Hence from the Fig. and Table, it can be conducted that the moisture content decreases as the depth below top surface of soil increases. Similarly, the bulk density at top soil surface, 30 cm and 60 cm below the soil surface were determined. The compact soil samples adjacent to each infiltrometer were collected for different depth with the help of core cutter soil sampler. The values of bulk density for top soil surface 30 cm and 60 cm below the soil surface for the steady area were determined and presented in Table 1. The downward variation of bulk density for the steady area was presented in Fig. 5 and 6 graphically. Both the Fig. and Table indicate the minimum value of bulk density at top soil surface and maximum value of bottom soil layer for the steady area. The average values of bulk density at top soil surface. 30 cm 60 cm below the soil surface were found to be 1.54, 1.37, 1.27 and 1.34 gm/cm^3 respectively for papaya grown upland field and 1.27, 1.28, 1.36 and 1.46 gm/cm^3 for paddy harvested field. Both the Fig. and Table inter that the bulk density increases as the depth below soil surface increases. The higher values of bulk density and the lower values of moisture content in papaya grown field and the lower values of bulk density and the higher values of moisture content in paddy harvested field also observed (Table 1).

Table 1: Soil physical properties at different points in papaya grown upland and paddy harvested upland fields.

Fields	Points	Moisture content (%) at various depth				Bulk density (gm/cm^3) at various depth			
		Top surface	40 cm	60 cm	Ave.	Top surface	30 cm	60 cm	Ave.
Papaya grown upland	1	7.10	17.10	22.40	14.12	1.40	1.53	1.70	1.54
	2	10.07	17.14	20.30	15.41	1.10	1.41	1.60	1.37
	3	14.29	21.10	25.70	19.55	1.10	1.30	1.51	1.27
	4	13.10	22.70	26.87	19.64	1.23	1.31	1.47	1.34
Paddy harvested upland	1	9.80	16.14	22.17	15.10	1.10	1.30	1.42	1.27
	2	11.10	19.30	23.10	17.30	1.00	1.30	1.37	1.23
	3	14.10 15.32	21.10 19.30 22.60	22.90 24.32	19.57 20.39	1.30 1.00	1.37 1.20	1.41 1.30	1.36 1.16

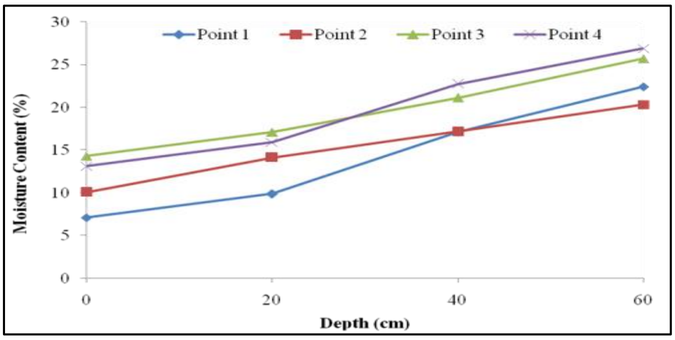


Fig 4: Moisture content at different depths below Soil surface in papaya grown upland field.

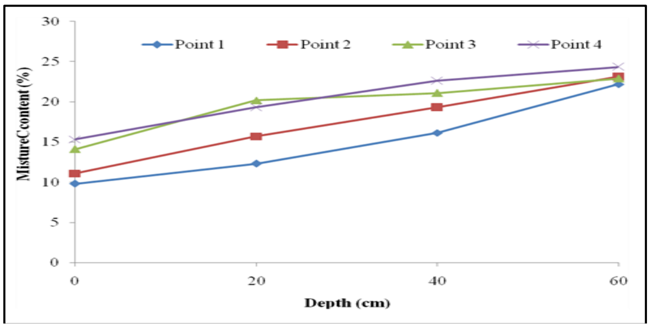


Fig 5: Moisture content at different depths below Soil surface in paddy harvested upland field.

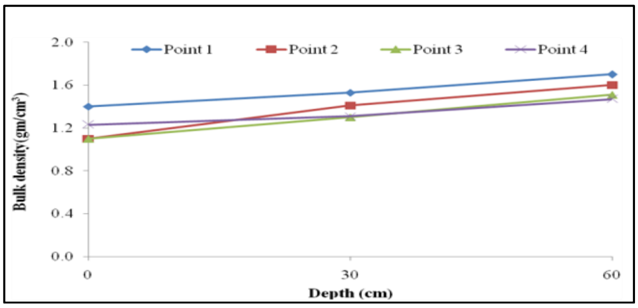


Fig 6: Bulk density at different depths below Soil surface in paddy harvested upland field.

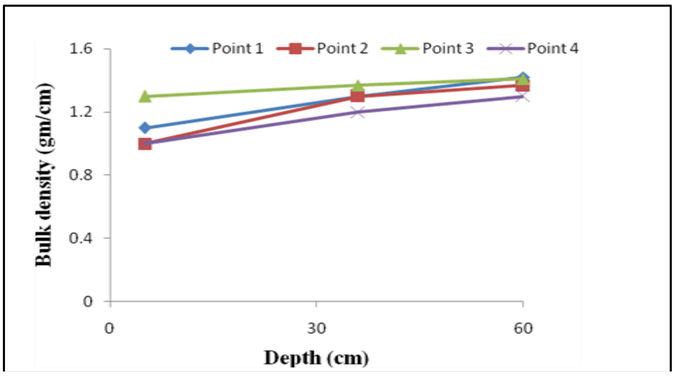


Fig 7: Bulk density at different depths below Soil surface in paddy harvested upland field.

Calculation of time to reach basic infiltration rate

Infiltration experiments were conducted for study of infiltration characteristics for the steady area. Double ring infiltrometer were installed at square grid points of 10 m × 10 m on grid in the field. The infiltration characteristics such as average infiltration rate and time to reach basic infiltration rate for different point of the steady area were present in Table 2. The average infiltration rate were found to be in range of 6.09 to 7.11 cm/hr With average value of 6.35 cm/hr in papaya grown field, however it observed to be in the range of 2.84 to 5.24 cm/hr with average value of 4.09 cm/hr in the paddy harvested field. The average infiltration rate in paddy harvested field was found to be lesser (4.09 cm/hr) then that (6.35 cm/hr) in papaya grown field. Table 2 reveals the time to reach the basic infiltration rate that range from 136 to 256 minutes with a mean value of 188 minutes and basic infiltration rate lies between 0.45 and 1.10 cm/hr for papaya grown upland field whereas the time to reach the basic infiltration rate range from 136 to 220 minutes with mean value of 183 minutes and basic infiltration rate is found to be between 0.60 and 0.90 cm/hr for paddy harvested upland field.

Table 2: Infiltration characteristics at different points in papaya grown upland and paddy harvested upland fields.

Fields	Points	Average infiltration rate (cm/hr)	Basic infiltration rate (cm/hr)	Time to reach basic infiltration rate (Min)
Papaya grown	1	5.86	1.10	256
	2	6.33	0.67	170
	3	7.11	0.80	136
	4	6.09	0.45	190
Paddy harvested	1	5.24	0.85	220
	2	4.64	0.67	200
	3	2.84	0.90	196
	4	3.65	0.60	136

Infiltration parameters

Papaya grown field, the values of constant parameters K and n in Kostiakov equation ranges from 0.26 to 0.45 and -0.74 to -0.41 respectively. For S.C.S. equation, the values of constant parameters K, n and F ranges from 0.37 to 0.53, -0.33 to -0.47 and -0.96 to -0.83 respectively. For Modified Kostiakov equation, the values of constant parameters K, n and C ranges from 0.22 to 0.87, 0.32 to 0.57 and 0.005 to 0.083 respectively. For Philip equation, the values of constant parameters S and A ranges from 0.10 to 0.50 and 0.0011 to 0.0060. For Horton equation, the values of constant parameter range from 3.24 to 6.27.

The average value of constant parameters K and n in Kostiakov equation was 0.41 and -0.59 respectively. For S.C.S. equation, the average value of parameters K, n, and F obtained is 0.43, -0.40 and -0.89 respectively. For Modified Kostiakov equation, the average value of parameters K, n and C obtained is 0.59, -0.41 and 0.0126. For Philip equation, average value of parameters S and A obtained is 0.27 and 0.0027 respectively and for Horton equation, the average value of parameter r is 3.6.

For paddy harvested upland field, the value of constant parameters K and n in Kostiakov equation ranges from 0.27 to 0.37 and -0.60 to -0.47 respectively. For S.C.S. equation, the values of constant parameters K, n and F ranges from 0.28 to 0.51, -0.31 to -0.53 and -0.87 to -0.35 respectively. For Modified Kostiakov equation, the values of constant parameters K, n and C range from 0.28 to 0.61, - 0.21 to- 0.62 and 0.005 to 0.021 respectively. For Philip equation, the values of constant parameters S and A ranges from 0.10 to 0.40 and 0.0020 to 0.0030 respectively. For Horton equation, the values of constant parameter r range from 1.20 to 1.43.

The average value of constant parameters K and n in Kostiakov equation are 0.32 and 0.53 respectively. For S.C.S. equation, the average value of parameters K, n, and F obtained is 0.41, -0.39 and -0.53. For Modified Kostiakov equation, the average value of parameters K, n and C obtained is 0.44, -0.37 and 0.011 respectively. For Philip equation, average value of parameters S and A obtained is 0.25 and 0.0024 respectively and for Horton equation, the average value of parameter r is 1.32.

These values shows that the average value of constant parameters in all equations for Papaya grown field is greater than that of Paddy harvested field. The reason behind this is the value of constant parameters decreases with the increase in moisture content and moisture content of paddy harvested upland is more than that of Papaya grown field.

After comparing the values of constant parameter K and n in all equations for both the field it is found that minimum value of K and maximum value of n is obtained in Kostiakov equation.

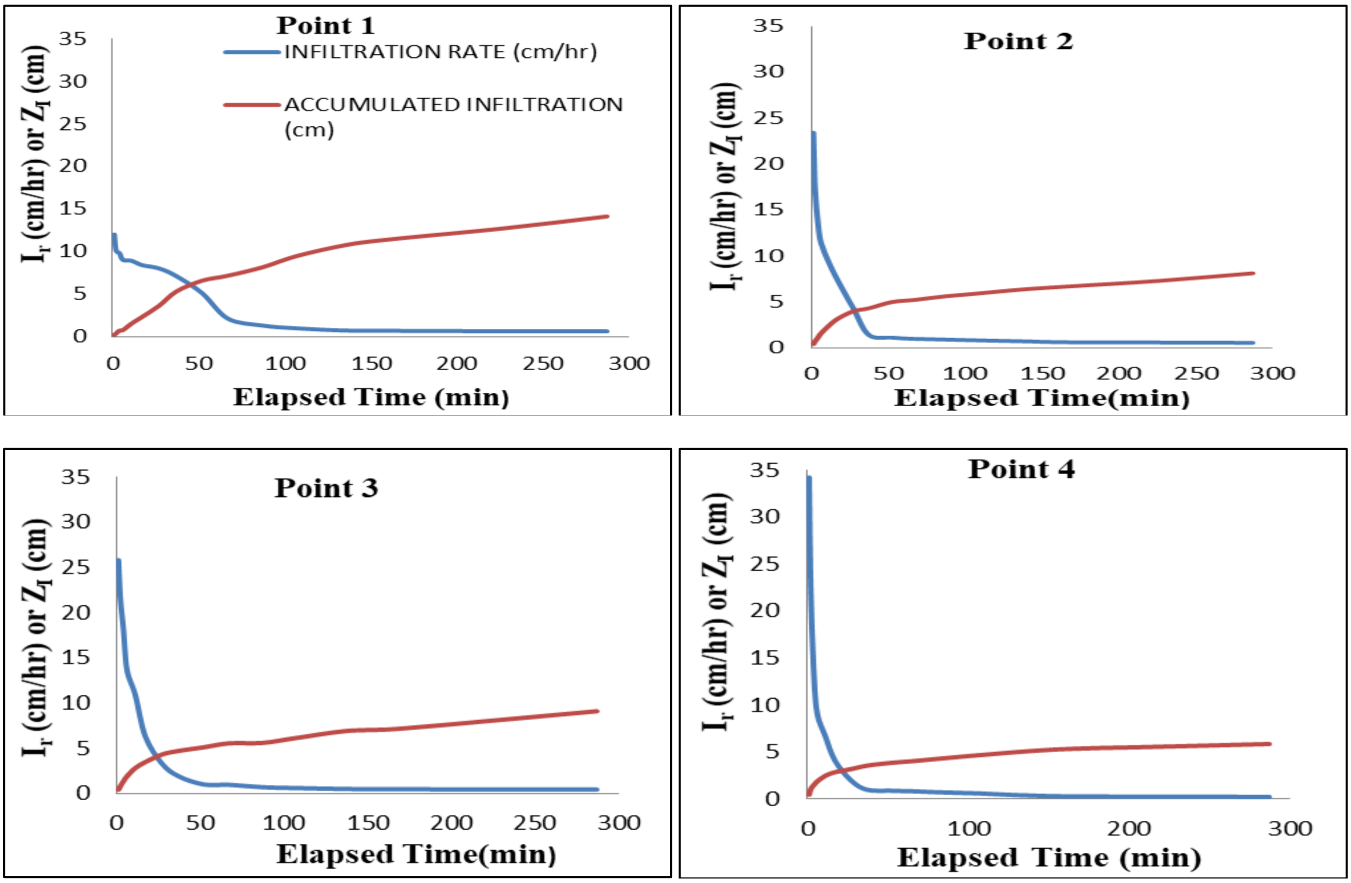
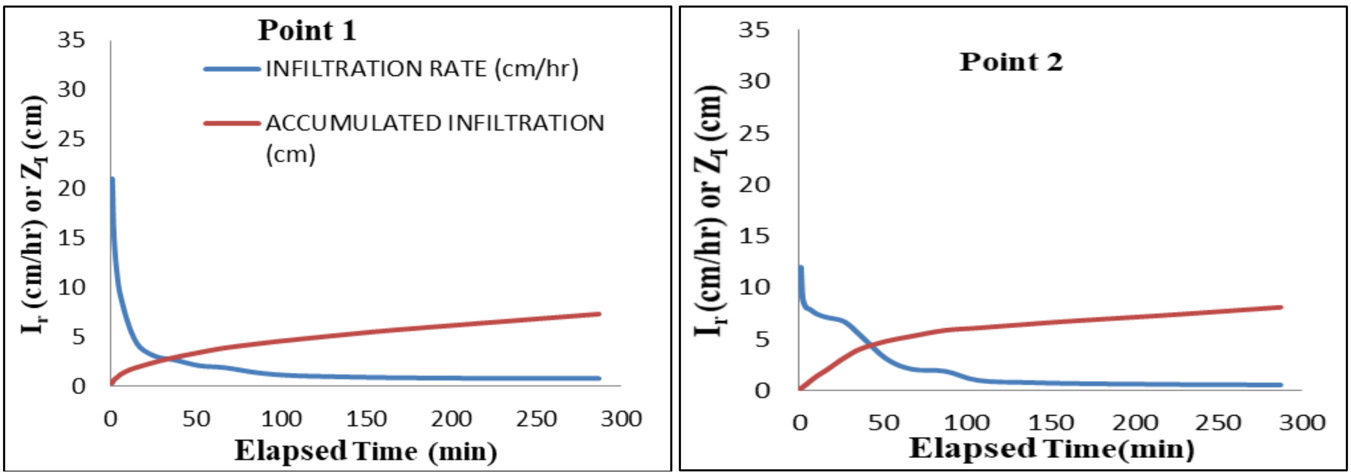
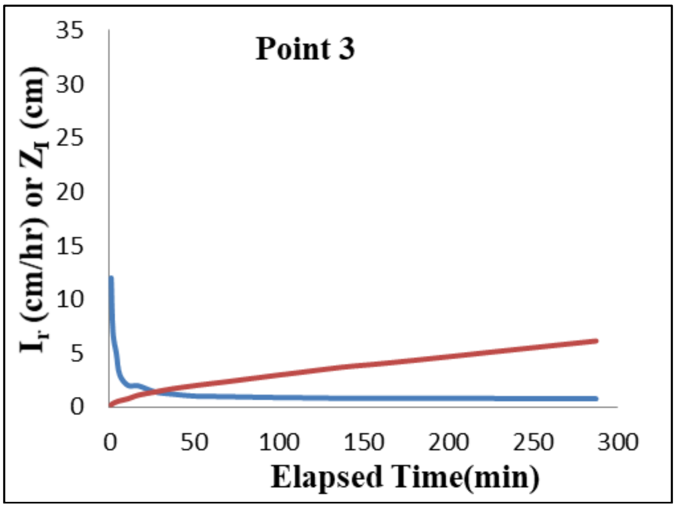


Fig 8: Infiltration characteristics in papaya grown upland field





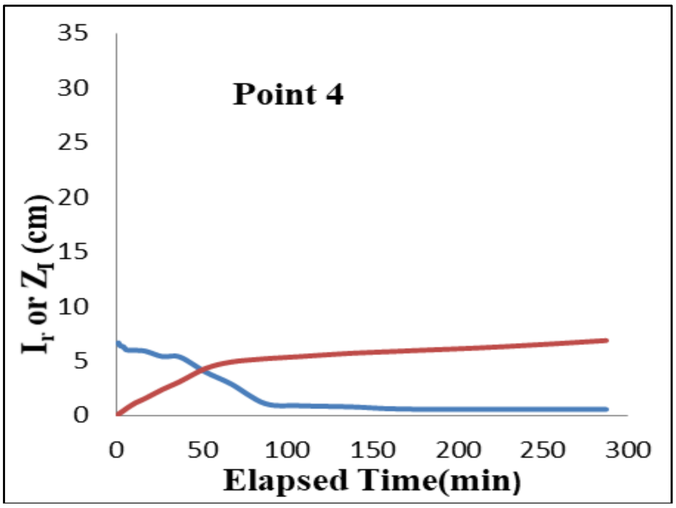


Fig 9: Infiltration characteristics in paddy harvested upland field

Selection of the best infiltration equation

For this purpose such statistical measures as chi-square, RMSE and MBE for each of the 4 point have been used in papaya grown upland field and rice harvested upland field. In order to judge the performance of model on overall basis chi-square, RMSE and MBE have been calculated and given in the table 3 and table 4.

The table 3 shows that Kostiakov equation has lowest chi-square, RMSE and MBE value (4.36, 3.93, and 2.20 respectively) for papaya grown upland field and chi-square, RMSE and MBE value (3.82, 2.74, and 2.12 respectively) for paddy harvested upland field in table 4. Hence Kostiakov equation is considered best for sandy loam soil of Raipur.

Table 3 and table 4 also reveals that S.C.S equation has second lowest chi-square, RMSE and MBE value (4.40, 4.16, and 2.42) for papaya grown upland field, and hence it is considered as second best equation suited for sandy loam soil of Raipur.

Although, S.C.S equation has second lowest values of chi-square, RMSE and MBE but this equation, three parameters are to be determined leading to increased complexity. But in case of Kostiakov equation only two parameters are to be determined. Hence, Kostiakov equation can also be used for the estimation of infiltration characteristics.

Based on the analysis, five different equations used in this study have been Kostiakov equation was best in Raipur region. But in 1995 the study of infiltration rate given that S.C.S equation was best in Raipur region.

Table 3: Infiltration parameters at different points in papaya grown upland fields

Fields	Points	Kostiakov		S.C.S equation			Modified Kostiakov			Philip		Horton
		K	n	K	n	F	K	n	C	S	A	r
Papaya grown upland	1	0.26	-0.74	0.37	-0.39	-0.96	0.80	-0.39	0.016	0.10	0.0017	4.47
	2	0.42	-0.54	0.39	-0.40	-0.91	0.47	-0.32	0.006	0.50	0.0060	6.27
	3	0.50	-0.67	0.44	-0.47	-0.83	0.87	-0.57	0.023	0.10	0.0011	4.32
	4	0.45	-0.41	0.53	-0.33	-0.85	0.22	-0.35	0.005	0.40	0.0020	3.24
Average		0.40	-0.59	0.43	-0.39	-0.88	0.59	-0.40	0.013	0.27	0.0027	4.60

Table 4: Infiltration parameters at different points in paddy harvested upland fields

Fields	Points	Kostiakov		S.C.S equation			Modified Kostiakov			Philip		Horton
		K	n	K	n	F	K	n	C	S	A	r
Paddy harvested upland	1	0.36	-0.60	0.28	-0.43	-0.49	0.28	-0.31	0.023	0.10	0.0020	1.28
	2	0.27	-0.51	0.41	-0.32	-0.35	0.33	-0.21	0.013	0.40	0.0070	1.20
	3	0.30	-0.53	0.51	-0.53	-0.87	0.57	-0.62	0.005	0.20	0.0030	1.34
	4	0.37	-0.47	0.41	-0.31	-0.41	0.61	-0.31	0.003	0.30	0.0020	1.43
Average		0.32	-0.52	0.40	-0.39	-0.53	0.44	-0.36	0.011	0.25	0.0025	1.31

Comparison between observed infiltration rate (I_o) and estimated infiltration rate (I_E) by using Kostiakov infiltration equation

An attempt has been made to test between observed infiltration rate (I_o) and estimated infiltration rate (I_E) by Kostiakov infiltration equation. The chi-square test, MBE, and RMSE value in Table 5. We obtained the Kostiakov equation is best estimated infiltration rate (I_E) in Raipur farm, minimum deviation between the observed infiltration rate and estimated infiltration rate for different point by Kostiakov equation.

Table 5: Test statistics between observed and estimated infiltration data for the area under study

Infiltration Equation	Chi square					RMSE					MBE				
	1	2	3	4	Average	1	2	3	4	Average	1	2	3	4	Average
	Papaya grown upland filed														
Kostiakov Euation	3.30	4.47	6.37	3.21	4.36	2.24	3.67	2.60	7.20	3.93	1.34	2.43	2.36	2.67	2.20
S.C.S equation	5.67	4.21	4.67	3.45	4.40	3.34	4.30	4.70	4.21	4.16	1.45	2.34	2.30	3.60	2.42

Modified. Kostiakov	4.23	4.30	5.67	4.21	4.60	3.14	3.10	4.20	6.50	4.23	1.67	2.54	4.20	3.10	2.87
Phylip Equation	4.12	3.13	5.67	7.80	5.18	4.67	3.60	3.54	5.23	4.26	1.34	2.37	3.67	4.30	2.94
Horton Equation	7.90	8.90	6.80	5.90	7.37	5.40	6.40	4.32	9.20	6.90	3.50	3.40	4.60	7.40	4.73

Table 6: Test statistics between observed and estimated infiltration data for paddy harvested field

Infiltration Equation	Chi square					RMSE					MBE				
	1	2	3	4	Average	1	2	3	4	Average	1	2	3	4	Average
Kostiakov Euation	3.02	5.23	3.56	3.51	3.82	3.20	2.34	3.12	2.30	2.74	1.45	2.56	2.40	2.10	2.13
S.C.S equation	4.23	2.67	3.78	4.70	3.84	4.21	3.76	3.20	3.10	3.56	1.20	1.50	4.20	2.70	2.40
Modified. Kostiakov	5.30	4.20	4.10	3.10	4.17	3.70	4.12	3.56	3.78	3.79	3.78	2.50	2.70	2.32	2.82
Phylip Equation	4.76	3.67	4.80	5.70	4.73	4.40	3.67	4.90	3.50	4.14	3.20	2.70	3.90	2.80	3.15
Horton Equation	7.90	8.50	7.40	6.70	7.62	6.80	5.30	7.40	8.40	6.97	6.10	4.20	5.20	5.70	5.30

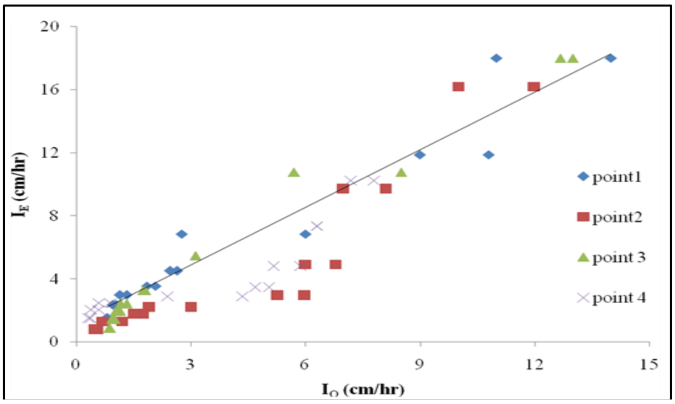


Fig 10: Comparison between observed and estimated infiltration rate using Kostiakov infiltration equation for papaya grown upland field.

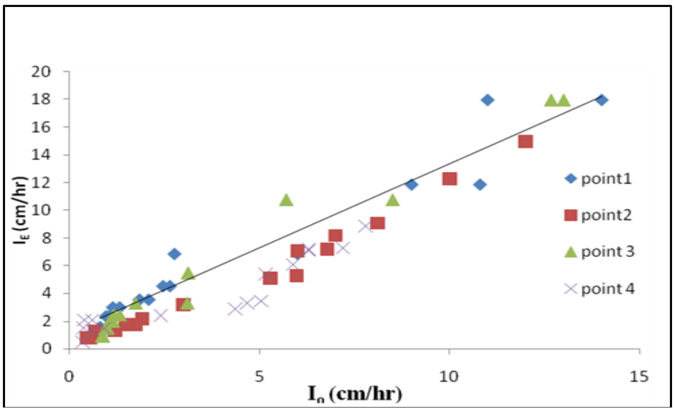


Fig 11: Comparison between observed and estimated Infiltration rate using Kostiakov infiltration equation for paddy harvested upland field.

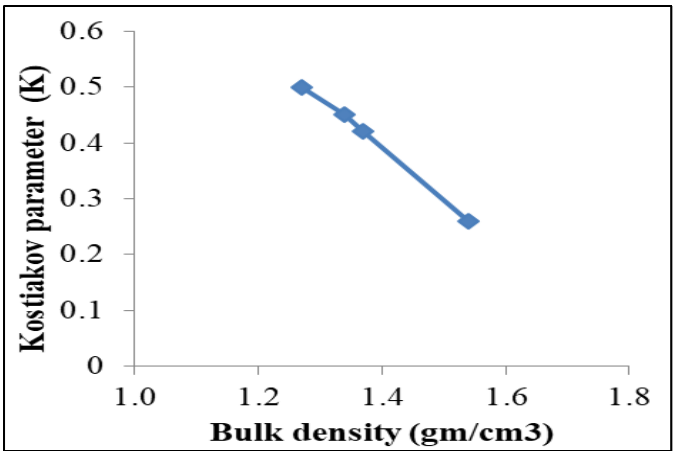


Fig 12: Effect of bulk density on Kostiakov on parameter (K) for papaya grown upland field

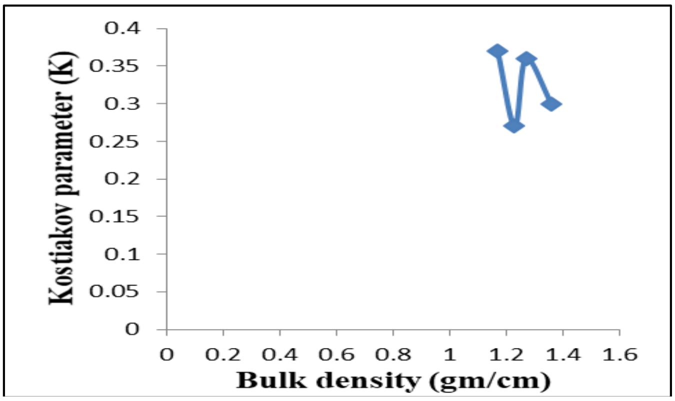


Fig 13: Effect of soil moisture on Kostiakov Parameter (K) for paddy harvested upland field

Conclusions

- The papaya grown and paddy harvested fields were classified as sandy loam soil. The bulk density and moisture content were directly to proportional to the depth below soil surface in papaya grown and paddy harvested field. The higher value of bulk density and the lower value moisture content were observed in papaya grown field and the lower value of bulk density and higher values of moisture content were observed in paddy harvested field.
- It is observed that infiltration rate and accumulated infiltration for papaya grown field more than that for paddy harvested upland field. The average infiltration rate in paddy harvested field was found to be lesson. (4.09 cm/hr) than (6.35 cm/hr) in papaya grown filed.
- The average value of basic infiltration rate and the time to reach basic infiltration rate for papaya grown field were found to be (0.76 cm/hr) and (188 min) respectively. However it was observed to be (0.73 cm/hr) and (183 min) respectively for paddy harvested upland field.
- It was concluded that the Kostiakov equation yielded the lower value (4.36), RMSE (3.39) and MBE (2.20) for papaya grown and the lowest value of (3.82), RMSE (2.74) and MBE (2.13) paddy harvested field. Hence, the Kostiakov infiltration equation was found to be best suited for the area under study.
- The inverse relationship was observed between the parameter (K) of Kostiakov infiltration equation and bulk density of soil in papaya grown and paddy harvested fields.

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