STUDY OF EFFECT ON INFILTRATION CHARACTERISTICS AND PHYSICAL PROPERTIES OF THE SOIL IN RESPONSE TO VARIOUS TILLAGE OPERATIONS

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ABSTRACT

Tillage is one of the most important operations in the agriculture. Tillage not only helps to provide favourable soil condition for plant growth but also improves physical condition of the soil. It also affects the moisture holding capacity of the soil. An experiment was conducted to study effect of various tillage operations on physical properties of the soil and on the infiltration characteristics. It was observed that moisture content was found the highest in rotavator tilled soil (17.75 %), while least in the soil tilled by M.B. plough (14.68 %). Bulk density was found to be the highest in M. B. plough (2.35 g/cc), while it was the lowest in M. B. ploughed and rotavator tilled soil (1.39 g/cc). Bulk density in rotavator tilled soil was 1.91 g/cc. Infiltration rate was recorded least in the undisturbed soil (0.01 cm/min) and was highest in the soil tilled by M. B. plough (0.1 cm/min). Thus, it can be concluded that, there could be sort of compaction of the soil surface during the tillage operation using rotavator. Considering the seed germination percentage, it was observed that in the M. B. ploughed and rotavator tilled soil, the seed germination was highest (90%), while lowest in only rotavator tilled soil which was around 85 per cent. In overall scenario, combination of M.B. plough and rotavator could be the best combination as compared to other treatments considered for the study. It can be also be concluded that rotavator compact the soil and may form hard layer in the sub soil layer. In rotavator tilled land infiltration rate and germination percentage was also found lower compared to other treatments under study. It was also revealed that Horton's model was better in estimating infiltration rate as compared to the Kostiakov's model. When compared the observed and predicted values of infiltration rate, the R^2 value was found to be approaching unity for Horton's model in all the tillage treatments under study.

KEY WORDS: Germination, Horton's model, Infiltration rate, Kostiakov's model, Tillage

INTRODUCTION

Total geographical area of the state is about 196 lakhs hectares. Out of total geographical area, 99.66 lakhs hectares are under net cultivable area which is 50 per cent of total geographical area. Total gross cropped area is about 122.11 lakhs hectares in the state. Total gross irrigated area is 56.14 lakhs ha which is accounted for 45.97 per cent of total crop area (Anonymous, 2015). Average per capita land holding capacity of the farmers in Gujarat is 2.33 ha. Total operational land holders in the state are 48.86 lakhs, who possess the cultivable land with an average of 2.03 ha. per land holders. Out of total land holders, 37.16 per cent marginal farmers, 29.25 per cent small farmers, 22.10 per cent semimedium farmers, 10.49 per cent medium farmers and 1.00 per cent large farmers (Anonymous, 2015). Physical manipulation of soil with tools and implements for obtaining conditions ideal for better seed germination, seedling establishment and growth of plants is called tillage. Tillage is one of the key soil management practices in agricultural land use and is one of the fundamental agro-technical operations because of its influence on soil properties, environment and crop production. Tillage can have both favourable and unfavourable effects on different physical properties of treated topsoil. Tillage affects the soil water status as well as the capacity of plants to utilize it, while it also increases detention of surface water and its entry into the soil. It has been shown that tillage can increase hydraulic conductivity and improve water use. Moreover, after tillage, surface area of soil is increased that allow good root growth in crops. There are various tillage operations which have been carried out by farmers before cultivation. Tillage affects the soil physical properties that are important for plant growth improvements of root penetration, water infiltration and soil moisture storage, weed control, and supply of nutrients from rapid decomposition of organic matter are considered the most beneficial contributions of tillage to crop production (Rashidi and Keshavarzpour, 2008). Infiltration is the process by which water on the ground surface enters into the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour (L^1T^{-1}). Infiltration or the downward entry of water into soil is one of the important processes in the soil phase of the hydrological cycle. The water entry into the soil is caused by metric as well as gravitational forces, this entry may occur in the lateral and upward directions as well as downward. Infiltration is caused by two forces namely gravity and capillary action. According to Wuest *et al.* (2006), the most important factor determining whether water will soak in or run off is the ability of the soil surface to resist slacking and reconsolidation or crushing of the soil surface – slaking which occurs when soil aggregates (cluster or clumps of soil) break apart in water into separate soil particles. This thus makes soil aggregation a very important property of most soil as it controls water infiltration to a greater extent than the amount of sand, silt and clay and is a function of the surface manoeuvring of the soil due to disturbance that be generated by farm implement. Soil moisture acts as a modular between the land surface and atmosphere, thereby influencing climate and weather (Entekhabi. and Brubaker, 1995). It influences various processes related to plant growth and hence ecological patterns (Rodriguez-Iturbe, 2000) and agricultural production (Western *et al.*, 2002) as well as a range of soil processes (White, 1997). Meek *et al.* (1989) measured a 17 per cent increase in infiltration rate in the field when soil was packed lightly before the first flood irrigation compared with no packing. Patel and Singh (1981) reported that if the bulk density in a coarse textured soil was increased from 1.7 to 1.9 Mg m^{-3}, hydraulic conductivity decrease by a factor of 260. Meek et al. (1992) using the same soil also measured a decrease on infiltration rate of four times when traffic compacted soil from a bulk density of 1.7 to 1.89 Mg/m^{-3}. Looking to these, the experiment was conducted to study effect of various tillage practices, which are generally followed by farmers of the study area, on the infiltration rate of soil.

MATERIALS AND METHODS

Experimental Site

Location

Dediapada is a taluka place located

in the Narmada district of south Gujarat. The latitude and longitude of Dediapada are 23.3° N & 72.63° E, respectively, and the total geographical area is around 1023.9 km^2. The terrain of the region is rugged and hilly with an altitude ranging from 400 to 600 m.

Site description

Field experiments was carried out on small plots, divided into 5 × 10 m sub-plots, situated within the experimental area of the College of Agricultural Engineering, Dediapada.

Treatments

There were four treatments were laid down for the experiment. The detail of the treatments is given in Table 1.

Bulk density of soil

Bulk density of the soil was determined before and after the tillage operation so that change in bulk density could be estimated. Core cutter method was used to estimate bulk density of the soil. Following formulation was used to calculate bulk density by core cutter method.

Dry bulk density = mass of soil / volume of cylinder = M_S / V_C

Wet bulk density = (mass of soil + mass of liquids) / volume of cylinder = $(M_S + M_L) / V_C$

Moisture content

Moisture content is the quantity of water contained in a material. Standard gravimetric method was followed to estimate soil moisture content before and after the test. Moisture content was determined using following formula.

$$W\ (\%) = \frac{W2-W3}{W3-W1} \quad (3)$$

Where,

W = Moisture content in %,

W1 = Wt. of can in g,

W2 = Wt. of can+Wt. of wet soil sample (g)

W3 = Wt.of can+Wt. of dry soil sample (g)

Infiltration rate

Infiltration was measured using double-ring infiltrometer (Plate 1). There were two concentric cylinders in the double ring infiltrometer of 30 cm and 60 cm diameter which were driven into the ground for estimating infiltration rate. For each treatment infiltration rate and accumulated (cumulative) infiltration rate were determined by observing dynamics of water level in the infiltrometer. The test was conducted till the constant rate of infiltration rate (basic infiltration rate) was achieved.

Modeling infiltration

To model the infiltration rate for each treatment, two widely acclaimed models i.e. Horton's model and Kostiakov's model were selected and their performance was compared.

Horton's model

Infiltration is the process by which water seeps into the ground through the surface of the earth. Horton's equation is the most popular for determining the infiltration rate of soil. The equation named after Robert E. Horton (1940), is a semi- empirical formula that says that infiltration starts at a constant rate i_0 and is decreasing exponentially with time t. After some time when the soil saturation level reaches a certain value, the rate of infiltration will level off to the rate $i_ç$. The infiltration rate is given by:

$$i = i_C + (i_o - i_C)\, e^{-kt}$$

Where,

i is the cumulative infiltration,

i is the infiltration rate at time t;

i_o is the initial infiltration rate,

i_c is the constant or equilibrium infiltration rate after the soil has been saturated,

k is the decay constant specific to the soil.

Solution of the model for practical application

From equation $i = i_C + (i_o - i_C)\, e^{-kt}$,

Taking i_C to left hand side:

$i - i_c = (i_o - i_c)\, e^{-kt}$

Dividing by i_o – ic, gives : $\frac{i - ic}{i_o - ic} = e^{-kt}$

Taking the logarithm of both sides gives:

$$\ln\left[\frac{i - ic}{i_o - ic}\right] = -k \times t$$

$$Y = \frac{i - ic}{i_o - ic}$$

$$\ln y = -kt$$

The plot of ln y versus the elapsed time (t) was obtained on a linear graph gives the value of k which is the third parameter of the equation.

Kostiakov's model

Kostiakov's infiltration models are derived using the data observed either in the field. This model suggested a formula which assumes that at time t = 0, the infiltration rate is infinite and at time t, the rate approaches zero. The equation is given by:

$I = Ct^{\alpha}$

Where,

t is the time elapsed for the experiment.

I is the Cumulative infiltration.

α, and C are empirical constants that are depend on soil conditions.

To determine the parameters α and C, the logs of both sides of (2) were taken.

$$\log I = \log C + \alpha \log t$$

A plot of log I against log t gives a straight line whose slope gives the value of α, while log C gives the intercept. The value of C was determined by anti-log c.

Accumulated infiltration

Accumulated infiltration also called cumulative infiltration. Relationship between accumulated infiltration and elapsed time are usually expressed by following equation:

$$y = at^{\alpha}$$

$$y = at^{\alpha} + b$$

Where,

y = accumulated infiltration in time t, cm

t = elapsed time or infiltration opportunity time, min.

a, b, α are characteristics constants.

Germination percentage

Germination is the process of seeds development into new plants. Tillage helps to provide favourable environment for seed germination. To determine germination percentage for gram seeds were sown in field with all treatment (T_1, T_2, T_3 and T_4) after the ploughing operation and also control plot. The seed germination in each plot was counted and germination percentage was calculated.

RESULTS AND DISCUSSION

It was observed that moisture content of soil gradually decreased after the tillage operation. In non tillage land moisture content of soil was higher than tilled land. It was clearly evident from the Figure 1 that difference in moisture content before and after the treatment was in rotavator tilled land. This can be due to well churning of soil layers by rotavator operation. Least change was found in M.B. plough tilled land.

Bulk density of the soil tilled by in M.B. plough was found to be 2.35 g/cc which was 2.52 g/cc before tillage. In rotavator tilled soil 1.91 g/cc while it was 2.10 g/cc earlier. In the M.B. plough + rotavator tilled land, the values for bulk density before and after the tillage was found to be 1.39 g/cc and 1.48 g/cc respectively. This underlined the fact that after the tillage operation the bulk density of soil reduces to some extent which was due to breaking of consolidated hard pan of the soil.

In the infiltration study, it was observed that initial infiltration rate of non-tillage or control plot was 0.12 cm/min and basic infiltration rate was observed to be 0.01 cm/min. For rotavator tilled land initial and basic rate of was 0.2 to 0.03 cm/min, respectively. Similarly, the respective values of infiltration rates for M.B. plough and rotavator (Combine) tilled soil was 0.30 to 0.09 cm/min. Initial and basic infiltration rate in M.B. plough tilled soil were 0.36 to 0.08 cm/min, respectively. The Figure 2 shows that variation in the infiltration rate for various treatments. It is clearly visible that infiltration rate for M. B. plough tilled soil was the highest and it was obliviously the lowest for control or soil with no tillage. It was also observed that rotavator may compact the soil structure which reduce the infiltration rate of soil. It could be concluded that when combination of M.B. Plough and Rotavator was used, the effect of compaction due to only use of rotavator could be minimized.

Similar results were observed when accumulated infiltration rate was studied for different treatments and the results are shown in Figure 3. Accumulated infiltration values for control plot, rotavator tilled plot, combine tilled plot (M. B. Plough + Rotavator) and M.B. plough tilled plot were observed to be 5.32 cm, 18.80 cm, 40.10 cm, and 48.70 cm. respectively.

Horton's infiltration model and Kostiakov's infiltration model were tested and compared for their efficiency to predict infiltration rate for the treatments under study. It was observed that Horton's model had a high predictability as compared to Kostiakov's model. When observed and predicted values of infiltration were compared, Horton's model gave higher value of R^2 than that of Kostiakov's model. The R^2 value for Horton's model and Kositakov's model for different treatment has shown in the Figure 4 and 5. This can be revealed that Horton's model have high predictability to estimate infiltration rate compared to Kostiakov's model.

Study of germination of seeds in different tillage operation revealed that control plot where no tillage operation was carried out, germination percentages was found to be 60 per cent. Maximum percentage of seed germination i.e. 90 per cent was found to be in a treatment which had combine tillage of M.B. plough + Rotavator. The value of germination percentage in rotavator tilled land and M.B. plough tilled land was found to be 85 per cent and 75 per cent, respectively.

The results obtained in the experiment are supported by the findings of Patel, and Singh (1981). Abu-Hamdeh (2004), Miriti *et al*. (2013), Ajayi *et al*. (2016) and Christopher *et al*. (2016)

CONCLUSION

It was concluded from the study that, treatment in which soil manipulation was carried out by M. B. plough followed by rotavator was the best of all the other treatments in terms of infiltration rate. It was also concluded that Horton's infiltration model was better in estimating infiltration rate as compared to Kostiakov's Model.

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Table 1: Detail of treatments

Treatment	Description
T_1 (MB Plough)	Tillage carried out only by tractor drawn MB Plough
T_2 (Rotavator)	Tillage carried out only by tractor drawn Rotavator
T_3 (MB Plough + Rotavator)	Tillage carried out by first MB Plough followed by Rotavator
T_4 (No tillage)	Control plot without any tillage operation.

Plate 1: Double ring infiltrometer

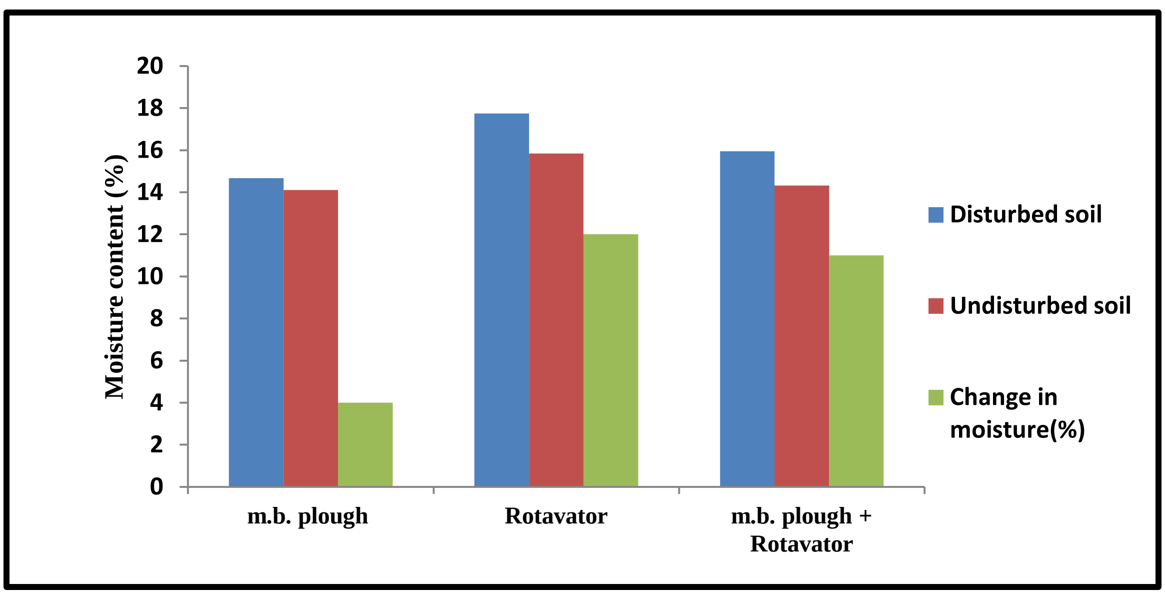

Fig. 1: Moisture content for different treatments

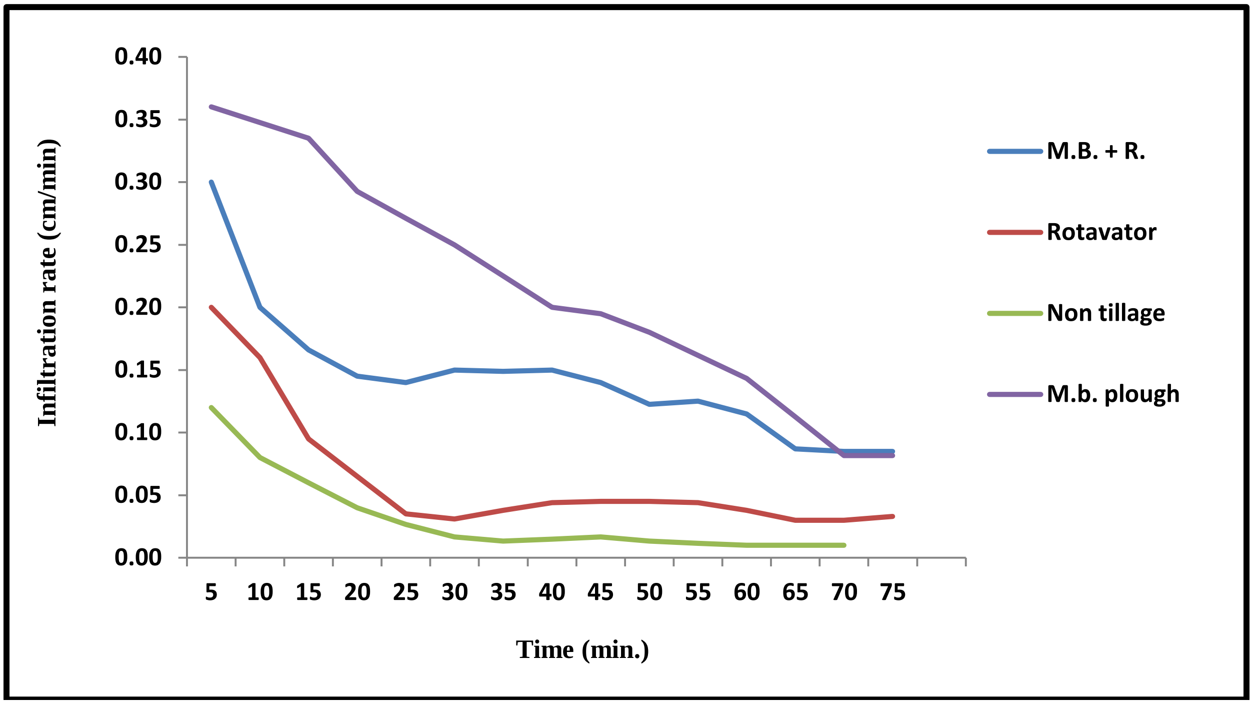

Fig. 2: Infiltration rate for different tillage treatments

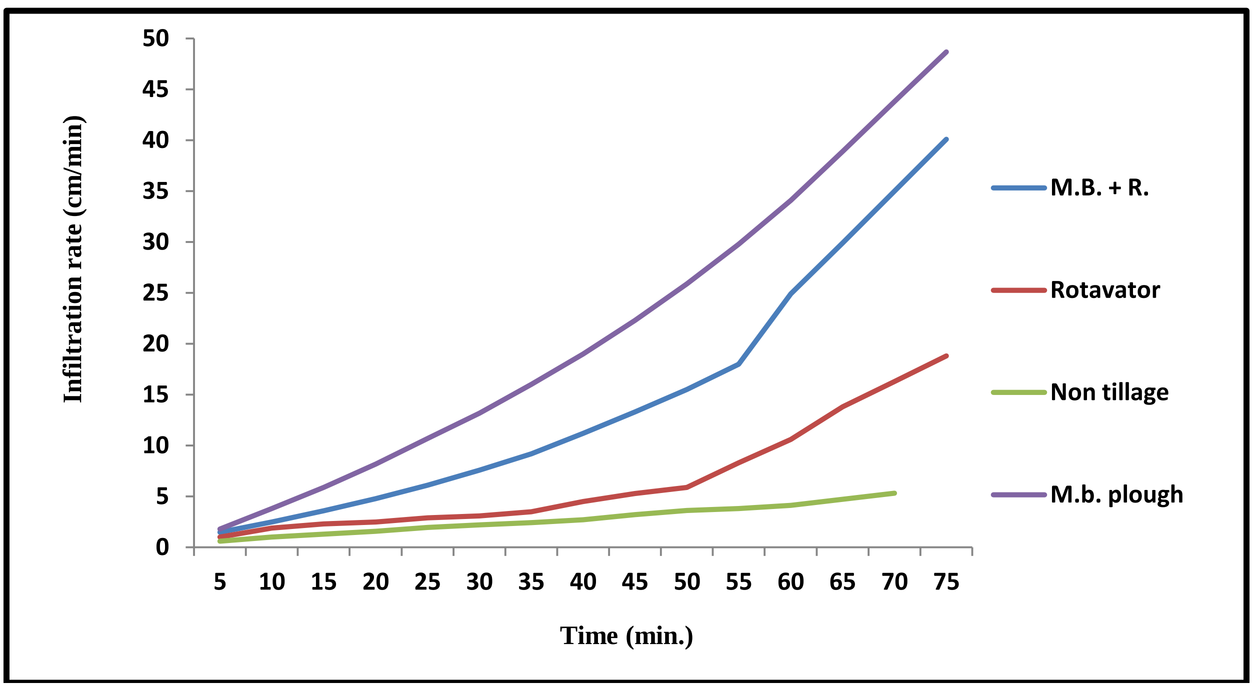

Fig. 3: Accumulated infiltration for different tillage treatments

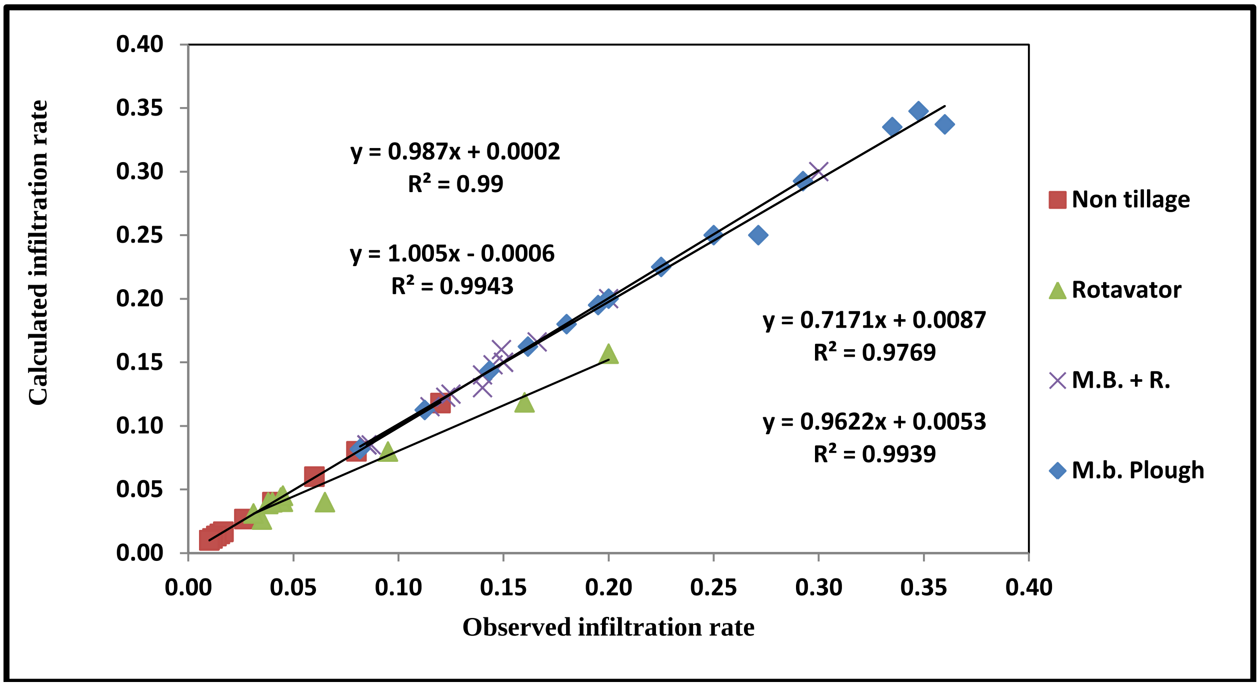

Fig. 4: Horton's model comparison

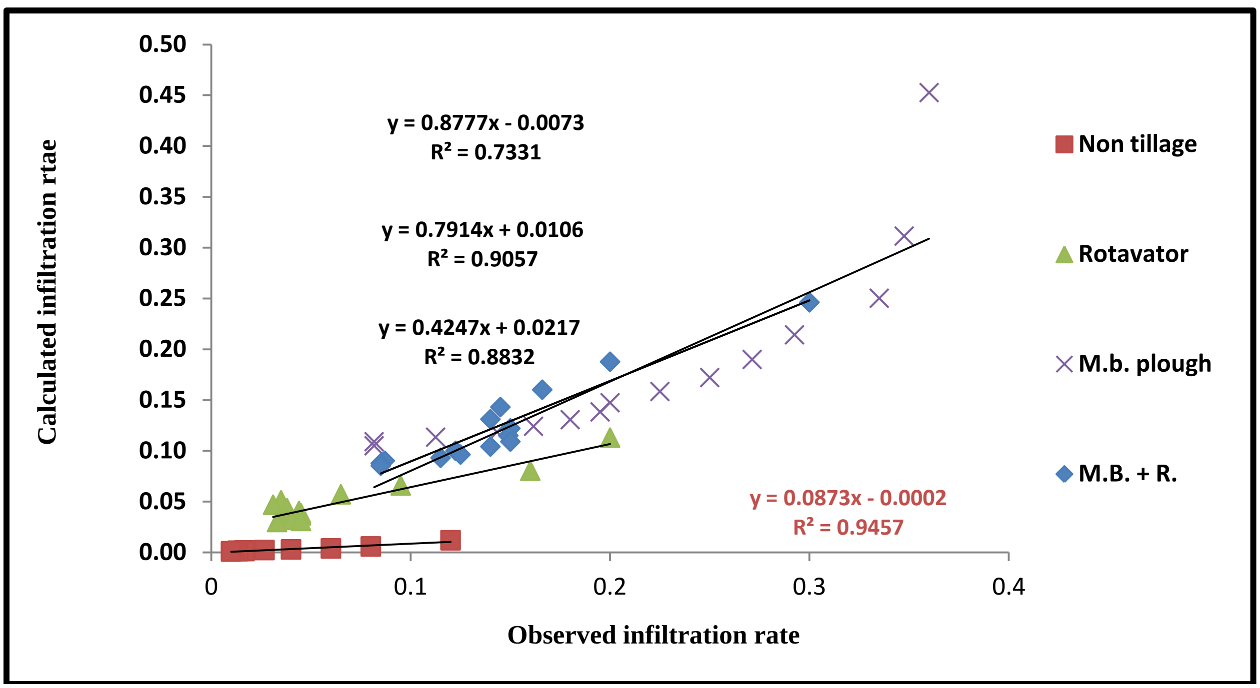

Fig. 5: Kostiakov's model comparison

[MS received : October 16 , 2019] *[MS accepted : November 28, 2019]*