International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 2772-2776

Received: 17-09-2019
Accepted: 22-10-2019

Hirapara Paraskumar S
PG Scholar, Department Soil and Water Conservation Engineering, College of Agricultural, Engineering and Technology, Godhra, Anand Agricultural University, Gujarat, India

Kathiriya Gaurav R
PG Scholar, Department Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Gujarat, India

Ashish Sonawane
Assistant Professor, Department Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, Dediapada Navsari Agricultural University, Gujarat, India

Corresponding Author:
Hirapara Paraskumar S
PG Scholar, Department Soil and Water Conservation Engineering, College of Agricultural, Engineering and Technology, Godhra, Anand Agricultural University, Gujarat, India

Impact of various tillage treatments on physical properties and infiltration characteristics of the soil

Hirapara Paraskumar S, Kathiriya Gaurav R and Ashish Sonawane

Abstract
Tillage is one of the most important operations in agriculture. Tillage not only helps to provide favorable soil conditions for plant growth but also improves the physical condition of the soil. It also affects the moisture holding capacity of the soil. An experiment was conducted to study the effect of various tillage operations on the physical properties of the soil and on the infiltration characteristics. It was observed that moisture content was 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 highest in M. B. plough (2.35 gm/cc) while it was lowest in M. B. ploughed and rotavator tilled soil (1.39 gm/cc) and bulk density in rotavator tilled soil was 1.91 gm/cc. When the infiltration rate was measured for all the treatments it was revealed that the infiltration rate was least in the undisturbed soil (0.01 cm/min) and was highest in the soil tilled by M. B. plough (0.1 cm/min). It was also observed that the infiltration rate was higher in the case of M.B. ploughed and rotavator tilled soil (0.09 cm/min) as that of only tilled by rotavator (0.03 cm/min). It can be thus concluded that there could be a sort of compaction of the soil surface during the tillage operation using a rotavator. Seed germination percentage was observed in the M. B. ploughed and rotavator tillege soil was highest (90%) while lowest in only rotavator tille soil which was around 85%. In the overall scenario, it was revealed that the 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 concluded that the rotavator compact the soil and may form a hard layer in the subsoil layer. In rotavator tilled land infiltration rate and germination percentage was also found to 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 for infiltration. When compared the observed and predicted values of the infiltration rate, the R^2 value was found to be approaching unity for Horton's model in all the tillage treatments under study.

Keywords: Tillage, infiltration, accumulated infiltration, horton's model, kostiakov's model

Introduction

The total geographical area of the state is about 196 lakh hectares. Out of the total geographical area, 99.66 lakh hectares are under the net cultivable area which is 50% of the total geographical area. The total gross cropped area is about 122.11 lakh hectares in the state. The total gross irrigated area is 56.14 lakhs ha which is accounted for 45.97% of total crop area (Anonymous, 2015) [3]. The average per capita land holding capacity of the farmers in Gujarat is 2.33 ha. Total operational land 2 holders in the state are 48.86 lakhs, who possess the cultivable land with an average of 2.03 ha. per landholders. Out of total landholders, 37.16% marginal farmers, 29.25% small farmers, 22.10% Semi-medium farmers, 10.49% medium farmers & 1.00% large farmers. (Anonymous, 2015) [3]. Agricultural preparation of soil with tools and implements for obtaining ideal conditions for better seed germination, seedling establishment, and growth of plants is called tillage. Tillage is one of the most important soil management practices in agricultural land and is the fundamental agro-technical operations because of its influence on soil properties, environment, and crop production. Tillage can have both favorable and unfavorable 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 the 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 allows good root growth in crops. There are various tillage operations that have been carried out by farmers before cultivation.

Tillage can affect 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) [14]. Infiltration is the process by which water on the ground surface enters into the soil. The 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 the 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) [20], the most important factor determining whether water will soak in or runoff 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 maneuvering of the soil due to disturbance that is generated by farm implement. Soil moisture acts as a modular between the land surface and atmosphere, thereby influencing climate and weather (Entekhai and Brubakar, 1995). It influences various processes related to plant growth and hence ecological patterns (Redriguez-I turbe, 2000) and agricultural production (Western *et al*., 2002) [18] as well as a range of soil processes (White, 1997) [19]. Meek *et al*. (1989) [9] measured a 17% increase in infiltration rate in the field when the soil was packed lightly before the first flood irrigation compared with no packing. Patel and Singh (1981) [12] 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 in the infiltration rate of four times when traffic compacted soil from a bulk density of 1.7 to 1.89 Mg/m.

The study was conducted with the objective to study the effect of various tillage practices, which are generally followed by farmers of the study area, on the infiltration rate of the soil.

Materials and Methods

Experimental Site

Location

Dediapada is a taluka 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 km². The terrain of the region is rugged and hilly with an altitude ranging from 400 to 600 m.

Site description

Field experiments have been carried out on small plots, divided into 5×10 m subplots, situated within the experimental area of the College of Agricultural Engineering & Technology - Dediapada.

Treatments

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

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.

Bulk density of soil

Bulk density of the soil is one of the most important soil physical properties. The bulk density of the soil was determined before and after the tillage operation so that a change in bulk density could be estimated. The core cutter method was used to estimate the bulk density of the soil. The following formulation was used to calculate bulk density by the core cutter method.

Dry bulk density = mass of soil / volume of cylinder = M_S / V_C……………… (1)

Wet bulk density = (mass of soil + mass of liquids) / volume of cylinder

= (M_S + M_L) / V_C………………... (2)

Moisture content

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

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

Where,

W = Moisture content in %,

W1 = Wt. of can in gm,

W2 = Wt. of can + Wt. of wet soil sample in gm,

W3 = Wt. of can + Wt. of dry soil sample in gm.

Infiltration rate

Infiltration was measured using a double-ring infiltrometer. 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 the infiltration rate. For each treatment infiltration rate and accumulated (cumulative) was determined by observing the dynamics of water level in the infiltrometer. The test was conducted till the constant rate of infiltration rate (basic infiltration rate) was achieved.

Fig 1: Double ring infiltrometer

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. The details of the modeling study are as follows:

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 the 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 $iç$. The infiltration rate is given by:

$i = ic + (i_o - ic)\, e{-}kt$ …………... (4)

Where,
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 Eq. 1, Taking ic to left-hand side:
$i - i_c = (i_o - i_c)\, e^{-kt}$
Dividing by i_o – ic, gives:
$[i - i_c / i_0 - i_c] = e^{-kt}$
Taking the Logarithm of both sides gives:
$\ln [i - i_c / i_0 - i_c] = - kt$
$Y = [i - i_c / i_0 - i_c]$
$\ln y = -kt$
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 that assumes that at time t = 0, the infiltration rate is infinite and at time t, the rate approaches zero. The equation is given by:

$I = Ct\alpha$ …………... (5)

Where,
t is the time elapsed for the experiment.
I is the Cumulative infiltration.
α, and C are empirical constants that depend on soil conditions.
To determine the parameters α and C, the logs of both sides of (2) were taken.

$\log I = \log C + \alpha \log t$ …………... (6)

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 the following equation:

$y = at^{\alpha}$ …………... (7)
$y = at^{\alpha} + b$ …………... (8)

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 a favorable environment for seed germination. To determine the germination percentage for gram seeds were sown in the 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 the germination percentage was calculated.

Results and Discussion

The experiment was conducted to determine the infiltration rate of the soil as affected by different tillage operations. There were four treatments including control treatment.

It was observed in all the treatments 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 figure 2 that the difference in moisture content before and after the treatment was in rotavator tilled land. This can be due to the good churning of soil layers by rotavator operation. Least change was found in M.B. plough tilled land.

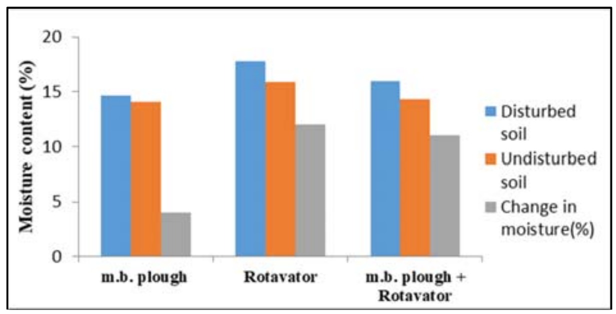

Fig 2: Moisture content for different treatments

Bulk density of the soil tilled by in M.B. plough was found to be 2.35 gm/cc which was 2.52 gm/cc before tillage. In rotavator tilled soil 1.91 gm/cc while it was 2.10 gm/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 gm/cc and 1.48 gm/cc respectively. This underlined the fact that after the tillage operation the bulk density of soil reduces to some extent which was due to the breaking of the consolidated hardpan of the soil.

In the infiltration study, it was observed that the initial infiltration rate of non-tillage or control plot was 0.12 cm/min and a 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. The initial and basic infiltration rate in M.B. plough tilled soil was 0.36 to 0.08 cm/min respectively. Figure 3 shows the variation in the infiltration rate for various treatments. It is clearly visible that the infiltration rate for M. B. plough tilled soil was highest and it was obliviously lowest for control or soil with no tillage.

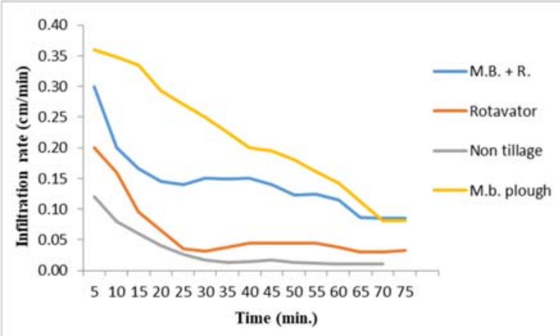

Fig 3: Infiltration rate for different tillage treatments

It was also observed that the rotavator may compact the soil structure which reduces the infiltration rate of the soil. It could be concluded that when a combination of M.B. Plough and Rotavator used the effect of compaction has minimized.

Similar results were observed when accumulated infiltration was studied for different treatments and the results are shown in figure 4.

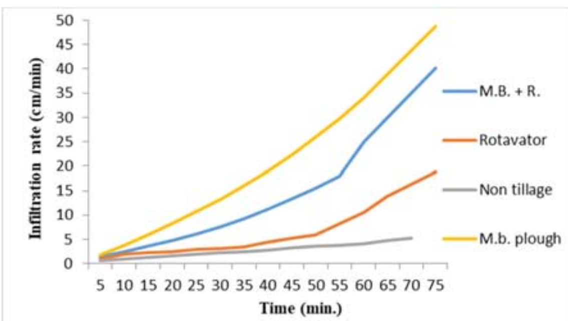

Fig 4: Accumulated Infiltration for different tillage treatments

Accumulated infiltration values for control plot, rotavator tilled plot, combine tilled plot (M. B. Plough + Rotavator) and M.B. plough tilled plot was 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 the 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 a higher value of R^2 than that of Kostiakov's model. The R^2 value for Horton's model and Kostiakov's model for different treatments have shown in Figures 4 and 5. This can be revealed that Horton's model has a high predictability to estimate the infiltration rate compared to Kostiakov's model.

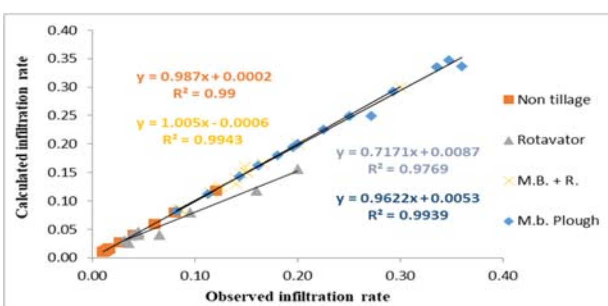

Fig 5: Horton's Model Comparison

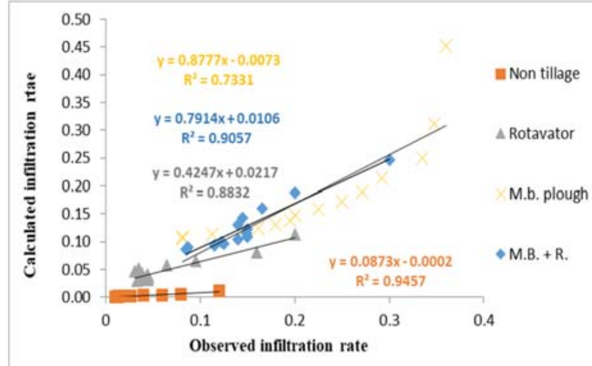

Fig 6: Kostiakov's Model Comparison

The study of germination of seeds in different tillage operations revealed that a control plot where no tillage operation was carried out, germination percentages were found to be 60%. Maximum percentage of seed germination i.e. 90% was found to be in a treatment that 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% and 75% respectively.

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 the infiltration rate as compared to Kostiakov's Model.

Conclusion

It was observed that a higher amount of moisture content into an m. b. plough tillage land 17.75%. Whereas moisture content into a combine tillage land (T_3) and rotavator tillage land was 15.95%, 14.68% respectively. The bulk density of a non-tillage land was higher than other tillage lands. It was observed that bulk density in non-tillage land was 2.50 gm/cc. Bulk density measured in M.B. plough tillage land for undisturbed soil was 2.52 gm/cc, and whereas tillage land 2.35 gm/cc. It was recorded that a lower amount of bulk density into combine tillage land (T3) for undisturbed soil 1.48 gm/cc, and tillage land 1.39 gm/cc. In rotavator tillage land (T2) bulk density in undisturbed soil was 2.10 gm/cc, and tillage land bulk density 1.91 gm/cc.

The infiltration rate in non-tillage land (T4) measured 0.12 cm/min and the accumulated infiltration rate was 5.32 cm. The calculated infiltration rate form Kostiakov's model was 0.012 cm/min and Horton's model 0.12 cm/min. It observed that the infiltration rate in rotavator tillage land (T2) was 0.2 cm/min and accumulated infiltration rate 18.80 cm. Calculated infiltration rate form Kostiakov's and Horton's model was 0.11 cm/min and 0.16 cm/min respectively. The infiltration rate in combine tillage land (T3) was 0.3 cm/min and whereas accumulated infiltration rate 40.10 cm. Calculated infiltration rate form Kostiakov's was 0.25 cm/min whereas, Horton's model 0.30 cm/min. It measured that the infiltration rate in M.B. plough tillage land (T1) was 0.36 cm/min, whereas accumulated infiltration rate 48.7 cm. The calculated infiltration rate form Kostiakov's was 0.45 cm/min and Horton's model was 0.34 cm/min.

Germination percentage in non-tillage land, rotavator tillage land, combine tillage land and M.B. plough tillage land were 60%, 85%, 90%, and 75% respectively.

On the basis of the observations, we found that rotavator tillage operation bulk density was lower compare to combine tillage land. Lower bulk density means a lower amount of water hold by the soil and moisture content of the soil also decrease. Rotavator tillage operation compact the soil at a certain depth and restricted root development of the plant.

In combine tillage operation moisture holding capacity of the soil was moderate and germination percentages were high compared to other tillage soil. So, combine tillage operation must be used for seed sowing or preparation of the field.

References

1. Abu-Hamdeh NH. The Effect of Tillage Treatments On Soil Water Holding Capacity and On Soil Physical Properties International Soil Conservation Organisation Conference – Brisbane, 2004.
2. Ajayi AS, Brai MA, Eriakha EC, Ehiomogue P. Evaluation of Methods for Estimating the Decay Constant (K) of Horton's Infiltration Model. International Journal of Interdisciplinary Research and Innovations. 2016; 4(2):13-18.
3. Anonymous. Report On Task Force to Derive Suggestions to Increase Agriculture Development in Gujarat. Department of Agriculture & Cooperation Government of Gujarat Gandhinagar, 2015, 1-2.
4. Christopher O Akinbile, Olanipo A Famuyiwa, Fidelis O Ajibade, Toju E Babalola. Impacts of Varying Tillage Operations on Infiltration Capacity of Agricultural Soil International Journal Soil Science. 2016; 11(2):29-35.
5. Entekhabi D, Brubaker KL. An analytic approach to modeling land-atmosphere interaction: Stochastic extension. Water Resources Research. 1995; 31(3):633-644.
6. Gregory Justin H, Michael D Dukes, Grady L Miller, Pierce H Jones. Analysis of Double-Ring Infiltration Techniques and Development of a Simple Automatic Water Delivery System. Applied Turfgrass Science, 2005. DOI: 10.1094/ATS-2005-0531-01-MG.
7. Kováč J Macák M, Švančárková M. The effect of soil conservation tillage on soil moisture dynamics under single cropping and crop rotation. Plant Soil Environ. 2005; (3):124-130.
8. Matula S. The influence of tillage treatments on water infiltration into soil profile. Plant Soil Environ. 2003; 49(7):298-306.
9. Meek BD, EA Rechel, LM Carter, WR DeTar. Changes in infiltration under alfalfa as influenced by time and wheel traffic. Soil Science Society American Journal. 1989; 53:238-241.
10. Miriti JM, G Kironchi, AO Esilaba, CKK Gachene, LK Heng, DM Mwangi. The effects of tillage systems on soil physical properties and water conservation in a sandy loam soil in Eastern Kenya J Soil Science Environment Management. 2013; 4(7):146-154.
11. Mohammad Zakwan, Mohammad Muzzammil, Javed Alam. Application of spreadsheet to estimate infiltration parameters. Perspectives in Science. 2016; 8:702-704.
12. Patel MS, Singh NT. Changes in bulk density and water intake rate of a coarse textured soil in relation to different levels of compaction. Journal of Indian Society of Soil Science. 1981; 29:110-112.
13. Rameshwar S Kanwar. Effect of Tillage Systems on the Variability of Soil Water Tensions and Soil-Water Content American Society of Agricultural Engineers, 1989, 32(2).
14. Rashidi M, F Keshavarzpour. Effect of different tillage methods on soil physical properties and crop yield of melon (Cucumis melo). ARPN Journal of Agricultural and Biological Science. 2008; 3(2):41-46.
15. Rodriguez-Iturbe I. Ecohydrology: A hydrologic perspective of climate-soil-vegetation dynamics. Water Resources Research. 2000; 36(1):3-10.
16. Touma J, Alberge J. Determining soil hydrologic properties from rain simulator or double ring infiltrometer experiments: a comparison. Journal of Hydrology. 1992; 135:73-86.
17. Uloma Adindu Ruth, Akoma Chigozie Samuel, Igbokwe Kelechi Kingsley. Estimation of Kostiakov's Infiltration Model Parameters of Some Sandy Loam Soils of Ikwuano-Umuahia, Nigeria. Department of Physics/ Electronics, 2014, 1(1).
18. Western AW, RB Grayson, GB Oschl. Scaling of soil moisture: A hydrologic perspective. Annual Rev. Earth Planet Science. 2002; 30:149-180.
19. White RE. Principles and practice of soil science. The soil as a Natural resource. Oxford, UK: Blackwell Science, 1997, 348.
20. Wuest S, J Williams, T Johlke. Effects of tillage on water infiltration - Project Summary. Natural Resource Conservation Service, United States Department of Agriculture, 2006.