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RESEARCH PAPER

EFFECTS OF TILLAGE METHODS ON SOIL INFILTRATION RATE IN UYO, NIGERIA

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ABSTRACT
This study evaluated the effect of tillage methods on the infiltration rate of a sandy loam soil in Uyo, Nigeria. Tillage treatments adopted include zero –tillage, crude tillage, plough alone and plough harrow tillage. The result of the study revealed that the basic infiltration rates under zero crude, plough and plough harrow tillage in a sandy loam soil in Uyo were 18mm/hr, 20mm/hr, 21mm/hr and 24mm/hr respectively. A 2-way analysis of variance (ANOVA) was used to test the significance difference between the average infiltration rates under the different tillage treatments. The study showed that there is a significant effect of tillage method on soil infiltration rate and soil infiltration rate under different tillage treatment followed the order plough + harrow > Plough alone > Crude tillage > Zero tillage. The study recommends that farmers in Uyo should endeavour to till their farm before planting at least with crude tillage implement as it will help to pulverize the soil surface and make it easier for irrigation and root penetration as well as root development.

KEY WORDS: Tillage, Soil, Infiltration, Plough, Variance.

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INTRODUCTION
The yield of crops on a particular farmland depends majorly on the soil – plant - water relationship. Good soil manipulation enhances better penetration of water into the plant root zone, enabling root absorption of soil moisture for better plant growth and development. Proper soil management world over has resulted in increased yield of crops, fibers and wood leading to food sufficiency and wealth creation. However where the soil is mismanaged vast areas of land has been eroded away leading to food scarcity, hunger and poverty. Maltreatment of the soil in various parts of the world has led to soil erosion on a vast scale.

The damaging aspect of soil erosion which is the physical removal of the upper layer of the topsoil leads to the loss of vital nutrient. Loss of soil nutrient through erosion is a global phenomenon which can be eliminated by proper soil conservation methods.

In the early stages of the development of crop culture, vegetation that competed with plants that provide food was removed by hands. Food production was generally limited under these conditions. Adewoyin and Ajav (2011); Ajav and Adewoyin (2012) stated that soil tillage is considered to be one of the biggest farm operations as it requires more energy on the farm. Besides, it is usually used to reduce the effects of erosive force of the wind and water on the farm land. The practice of tillage include ploughing, harrowing, ridging is adopted for controlling erosion and conservation of moisture in the root zone. This in turn produces cloddy soil surface, reduces wind velocity and change the status of the moisture content and other soil properties. Ogban *et al.* (2008) reported increase of organic matter as a result of tillage practice. This act of soil manipulation is majorly aimed at presenting the crop root zone

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of the soil for proper absorption for crop germination, growth and maturity. As the soil becomes wet, the water is held in pores and the capillary potential is increased (Beven, 2010). Proper tillage practices can be used to improve soil related constraints while improper tillage operation may cause a range of undesirable processes such as destruction of soil structure, accelerated erosion, depletion of organic matter, disruption of water cycle, organic and plant nutrient. Tillage practice which is majorly divided into two, namely primary and secondary tillage ultimately influences the soil physical properties for better aeration, moisture penetration and plants performance.

Kamemickova *et al.* (2012) stated that the treatment of the top layer of the soil plays a key role in the changes of the hydro-physical properties, mainly saturated hydraulic conductivity of the surface layer, soil perforation through tillage enhances soil water catchment and increases the infiltration of water into the soil surface, raising the hydraulic conductivity sorptivity values (Abrisqueta *et al*., 2006).

There are about seven methods of tillage practices as important as they are, all of them cannot be practiced on the same kind of soil, under the same environmental condition to give the same desired positive result. Ahaneku and Dada (2013) observed that desirable tillage methods are those that positively impact soil physical properties and result in good till.

This enhances soil aeration, infiltration rate and water holding capacity of the soil. It also encourages root penetration, nutrient uptake and vigorous growth of crops through reduced penetration resistance of the soil to plant root and farm implement (Ahaneku and Dada, 2013).

The application of conservation tillage has the advantage of cultivating the leaves of the previous year's crop residue on field before and after planting the next crop to reduce soil erosion and run-off. Conservation tillage methods include no – till, strip-till, ridge-till and mulch-till. Each methods requires different types of specialized or modified equipment and adaptation in management and has been found to reduce erosion by up to 60%- 90%.The depth of tillage may turn out to be of disadvantages to the exercise. Conventional tillage practice including mouldboard ploughing to a 150 mm depth and other tillage operations could lead to loss of 50% of the soil organic matter and about the same amount of organic Nutrient. After rainfall, tillage may be necessary to reduce evaporation loss and maintain adequate water in the root zone. Though excessive tillage could lead to loss of organic matter but if the number of tillage operation is minimized and timed primarily to maximize water conservation the advance effect on organic matter can be minimized.

The soil is essential for the survival of the human race on the earth as it provides most of the food required, fibers for clothing and wood for building materials. But in many parts of the world the soil has been so mismanaged that it will never be able to produce at least not in the near future. The soil serve as the foundation upon which plant stand and equally serve as a major water catchment and retention trough for the crops thereby making water readily available for the plant roots for increase yield. The physical properties of the soil and their various interactions are influenced largely by soil structure (as characterized by the size, shape and strength of aggregates or the size, shape and stability of pores) and crop residues or organic amendments (placement, quantity and type of organic materials). The performances of crops are equally affected by the physical properties of the soil including water retention capacity, strength, porosity, aeration and temperature. The soil water characteristics play a leading role in determining the nature and extent of variations in the other Soil physical properties. Tillage generally affects the structural properties of a soil by breaking down clods and thus altering the pour size distributions, and hence the stability of the pores is very dependent on soil organic matter bonds. Therefore the basic of all good management is to encourage the development of a good stable soil structure with very active root development and organic activity.

Water enters the soil surface due to combined influence of gravity and capillary forces. Both forces act in the vertical direction to cause percolation. This process of infiltration involves both transmission and storage of soil moisture. 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

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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 be 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) as well as a range of soil processes (White,1997). The means of conserving moisture falls into three categories namely increasing infiltration, reducing evaporation and preventing unnecessary plant growth. Water infiltrates easily on sandy soils thus reducing water retention. However on heavy soils in most environments, water retention is high, residue levels could delay planting resulting in poor early seedling vigor. In many localities, infiltration is limited by surface crushing rather than by properties of the deeper soil. Improvement of infiltration reduces run off and thus increase available soil water. The main methods use to increase infiltration are the use of soil amendment, soil management by tillage and conservation farming. These methods may be used separately or together. Deep ploughing enhances weed control and the loosing of compacted soil layers. Deep ploughing distorts farmland surfaces increase infiltration and water retention in the land holes and depressions. Climatic factors like the rainfall makes soil moisture level rise, balances water loss through evapo-transpiration drainage and percolation to the ground water zone – loss of soil moisture is usually higher during the dry season of the year leading to higher evapo-transpiration rate. The moisture status of the soil is expressed in volumetric moisture content and the capillary potential of the water held in the soil pores. As the soil becomes wet, the water is held in large pores and the capillary potential increase (Beven, 2010). Rainfall leads in increasing the soil moisture, the rate of infiltration depends on the intensity of the input and the initial moisture condition of the surface soil layer and hydraulic characteristics of the soil. Small-scale effects such as the presence of a surface seal of low permeability (due to the management of surface soil particles by rain splash) or the presence of large channels and cracks in the surface soil may be important in controlling infiltration rates.

If rainfall intensity is greater than the infiltration rate, water will accumulate on the surface and run off will begin (Pidwikny, 2006). Movement of water into the soil is controlled by gravity capillary action and soil porosity. Of these factors, soil porosity is most important. Soil porosity is controlled by its texture, structure, and organic content. Coarse textured soils have larger pores and fissures than fine-grained soils and therefore allows for more water flow. Pores and fissures found in soils can be made larger through a number of factors that enhance internal soil structure. The burrowing of worms and other organisms and penetration of plants roots can increase the size and number of macro and micro-channels within the soil. The amount of decayed organic matter found at the soil surface can also enhance infiltration. Organic matters are generally more porous than mineral soil particles and can hold much greater quantities of water (Pidwirny, 2006).

Suresh (2008) views infiltration as the movement of water into the immediate soil surface. It is an important component in watershed modeling for the prediction of surface run off. In a study carried out at Oregon State University (Machado *et al*., 2005) identified soil organic matter as a soil factor that can affect the aggregation of soil particles and infiltration. The result also showed that a small increase in soil organic matter can have a substantial effect on soil aggregation and a very important effect on water infiltration even in a highly filled cropping system, where increased organic matter levels are very difficult to achieve or maintained near the soil surface. Meek *et al*. (1992) evaluated factors that affect soil water infiltration to include traffic, tillage between crops and the formation of channels by roots of perennial crops. According to Kooistra *et al*. (1984), the infiltration rate will be increased when sandy loam soil is filled because of the lower bulk density, infiltration rate will also decrease because large-pore continuity will be disrupted, and the importance of these two factors will depend on the level of compaction of the soil. The proper use of tillage, control and timing of traffic and selection of crops will allow a grower to maintain adequate infiltration levels so that adequate irrigation water can be applied.

Tillage may increase or decrease the infiltration rate depending on the degree of soil compaction. Unsaturated hydraulic conductivity (k) values that were increased at least four fold by chiseling 0.43 m deep compared with an untilled check. Infiltration of simulated rain when the level of tillage disturbance was reduces and suggested that the increase may have been caused by changes in the surface seal. Lai (1978) measured infiltration rates of a field where

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maize (*Zea mays* L) was cultivated for five years to be 480 mm/hr for no-till and 150mm/hr for the ploughed treatment. It was revealed that surface residue prevented surface seal in the no- till treatment.

Meek *et al*. (1989) measured a 17% 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 1.89Mg/m^3.

Tillage disturbs natural channels that have formed in soil the increase in porosity when soil is tilled may not result in an increase in filtration rate because of disruption of the vertical continuity of the pores (Kooistra *et al.*, 1984). Plant roots are important in forming new channels. Root growing initially may decrease infiltration rates, but later decomposition of roots leaves channels that result in increased infiltration rates.

The objective of this study is to determine the effects of tillage methods on Soil infiltration rate in a selected area of Uyo Metropolis, Nigeria. The different tillage methods adopted in the Study area who's Soil is generally classified as Sandy loam are: Zero Tillage, Crude Tillage, Plough + Harrow Tillage and Plough Tillage alone.

MATERIALS AND METHODS

Site Location and Selection

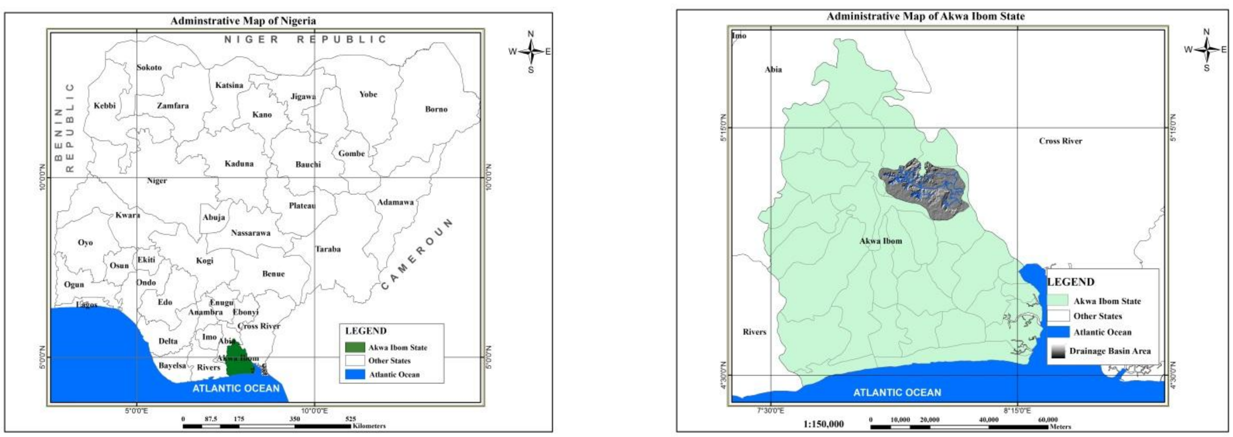

Figure 1: (a) Map of Nigeria showing Akwa Ibom State (b) Map of Akwa Ibom State showing Uyo

The experiment was carried out in Uyo, Akwa Ibom State, Nigeria (Figure 1) Uyo geographically lies in the Niger – Delta and is a key member of the South-South Zone, which account for more than 90% of Nigeria wealth. Rich in oil and Natural gas with fertile land mass measuring 8,412sqm. It has a coastline of 129km suitable for investment and tourism. Lying between latitude $4^0$33' North longitude $7^0$36 and $8^0$25 East. Uyo falls within the tropical rainforest of Nigeria with dominant vegetation of green foliage of Trees, shrubs the state has two distinct seasons – the rainy season lasts from April to October while the dry season is from November to March. In the coastal region rainfall is almost all the year round. The rainfall varies from 3,000mm along the coast to 2000mm in land; the mean temperature varies between 25 and 28^0C. With a population of about 2,385,756 people whose major occupations include farming, fishing and petty trading.

Method

Soil samples were collected at the experimental sites using Hand soil auger at a staggered distance from each other. The soil samples were collected at three different depths of 0 – 25cm, 25 – 50cm and 50 – 75cm respectively and stored in rubber container and preliminary test and measurement of soil properties were made before the

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commencement of tillage operations. The tested properties include moisture content, bulk density, particle size distribution and soil class.

Materials

The materials used for the tillage and infiltration experiment included shovel, hammer, spirit level, stop watch, 200 liters plastic drum, timber 75mm x 100mm x 400mm, 600 liters of water, swarag Tractor, 3 disc plough, Tandem Harrow and machete. Determination of soil moisture content were done using moisture can (crucible) hot and oven dried and desiccators. Core cylinders, weighing balance, oven, desiccators, hammer, rubber band spade, spatula among others were used to determine the bulk density of the soil sample. Hydrometer method was used to determine the particle size distribution of the six soil samples, mechanical stirrers, stirrer's cups soil hydrometer, thermometer, 1000ml measuring cylinder and weighing balance was the apparatus use while the dispersing reagent was sodium hexametaphosphate.

The study considered four tillage treatment base on the type and combination of tillage implements used Viz zero tillage, crude tillage, plough tillage and plough + Harrow tillage. Tillage depth was maintained at 16-18cm for all treatments except zero tillage and crude tillage.

The soil porosity, bulk density, organic matter content and moisture content were determined using standard laboratory procedures (ASTM, 2002a and ASTM 2002b).

At the commencement of the experiment immediately following the tillage operations tillage depth was measured at 18cm randomly on the ploughed plot. A steel rude was inserted down into the tillage soil until a characteristic hard pan was encountered. The tillage depth was measured from the corresponding reading on the steel rule under the zero tillage, the soil was not tilled.

The soil was left bare for infiltration measurement to be taken. Under the crude tillage treatment, the soil was tilled using a steel spade. The tilling was made manually by the researcher. However, the foot-press method was adopted in order to maintain a uniform tillage depth. The plough tillage involved the use of a disc plough of diameter 50cm and effective plough width 0.8m. The plough was hinged on the tractor for the tillage operation. Tillage was done at a single run. The average speed of the tillage operation was 200mph and uniform tillage depth range of 16 to 18cm.

The plough +harrow method was obtained by a combined use of plough and harrow each for a single run operation. The plough was used first and followed by the harrow to break the tillage lump.
The plough was hinged to the tractor for the tillage operation. Tillage was done at a single run. The average speed of the operation was 200mph and a uniform tillage depth of 16 to 18cm.

The infiltration rates and basic infiltration rates were determined using a double ring cylinder infiltrometer with each ring being 3mm thick, with diameter 60cm for outer ring and 30cm for inner ring, both were 30cm high. The concentric rings were driven with a mallet into the ground uniformly without till and unduly disturbing the soil to at least 15cm, the side of the rings were kept vertically and the measuring rod was driven into the soil so that approximately 12cm is left above the ground. Spirit level was then used to achieve uniform level. Ponding depth method was used and the test began by pouring water into the rings until the depth were approximately 100mm. The level of water in the inner ring was recorded at the beginning of the test and the water level was also noted after 2 minutes; the drop in water level in the inner ring was recorded using the graduated measuring rod and the water was added immediately to level back to approximately the original level at the start of the test. The tests were continued until the drop in water level is the same over the same time interval. Readings were made at intervals of 2,3,5,10,20, and 20 minutes thereby giving a cumulative time of 80 minutes. Thus infiltration rates were computed using equation (1) below for each tillage method.

$$\text{Infiltration rate} = \frac{\text{depth infiltrated in time interval}}{\text{Time interval}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

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The cumulative infiltration rate was plotted against cumulative time for the four different tests under different soil tillage treatment. A 2-way analysis of variance (ANOVA) was used to test the significance difference between the average infiltration rates under the different tillage treatments.

RESULTS AND DISCUSSION

Some engineering properties of the soil other than infiltration carried out at the commencement of the tillage operations included moisture content, bulk density, particle size distribution and soil classification.

The initial soil moisture content of the soil had values ranging from 8.09% to 8.75%. Soil moisture content was averaged at 8.32% with a mean deviation of 0.372. The initial bulk density of the soil had values ranging from 0.611kg/m^3 to 0.613kg/m^3. Soil moisture content was averaged at 0.612km^3 with a mean deviation of 0.372. The particles size distribution of the soil particles namely: Sand, Silt and Clay were measured. The Mean percentages of Sand, Silt, Clay and organic matter from the analyzed soil sample were 74.43%, 13.64% and 1669% respectively. These mean values of the soil particles size were used in the reading of the textural class of the soil samples from the textural triangle gives a Sandy Loam soil classification.

Observation and measurements obtained from the measurement of soil infiltration for the plot under zero tillage are presented in table1. Infiltration measurements were taken at 1 day and 2 days after tillage respectively.

The average cumulative infiltration (mm) under the different tillage treatment was computed as presented in Tables 3 & 4.

These average values were used to plot infiltration rate curves for the tillage treatments as shown in figures 2, 3 and 4 respectively. This shows that infiltration rate under the different soil tillage treatments increased in the order plough +Harrow > Plough > Crude > Zero.

This is evidenced in the curves as the infiltration curve for plough +harrow is posited above other curve. The infiltration curve for zero tillage was positioned below other curves. This implies that the rate of infiltration increased with the advancement of tillage method. To further verify the result, a 2-way analysis of variance (ANOVA) was used to test the significance different between the average infiltration rates (Table 3) under the different tillage treatment. The ANOVA result computed is shown in Table 5 and the test of significance of Table 6 show that there is a significant difference between infiltration rates under different tillage treatment (F cal = 15.25; F crit = 9.28. N =4 p = <0.05). However, there was no significant difference between the infiltration rates at different stages of till (F cal = 3.99; F crit = 10.13 N = 2, P < 0.05) this implies that tillage method affects the infiltration rate of the soil.

CONCLUSION

The study evaluated the effect of tillage methods on the infiltration rate of the sandy loam soil of Uyo, Akwa Ibom State, Nigeria shows that under zero tillage infiltration rates were 18mmhr, crude tillage 20mmht while that under plough alone and plough + Harrow tillage was 21mmht and 24mmht respectively. There is a significant effect of tillage method on the infiltration rate and the soil infiltration rate under different tillage treatment followed the order Plough +Harrow > plough alone> crude tillage >zero tillage.

Base on the result of the study, it is recommended that farmers in Uyo should endeavour to till their farms land before planting as it help to pulverize the soil surface and make it easier for irrigation and easy root penetration as well as root development.

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Table 1: Computations of Infiltration Rate for Plough Tillage

S/N	Time	Infiltration (1-d Tilth)	Infiltration (2-d Tilth)	Infiltration rate (1-d Tilth)	Infiltration rate (2-d Tilth)
	minutes	mm	(mm)	mm/minute	mm/minute
1	2	11	9	5.5	4.5
2	3	9	10	3	3.33
3	5	12	12	2.4	2.4
4	10	15	13	1.5	1.3
5	10	14	10	1.4	1
6	10	9	9	0.9	0.9
7	20	7	6	0.35	0.3
8	20	7	6	0.35	0.3
Total	80	84	75		
		Average**		1.05	0.94

**Average infiltration rate = (Total Infiltration/Total Time)
1-D Tilth = one day after tillage; 2-D Tilth = two days after tillage **Basic infiltration rate = 21mm/hr.

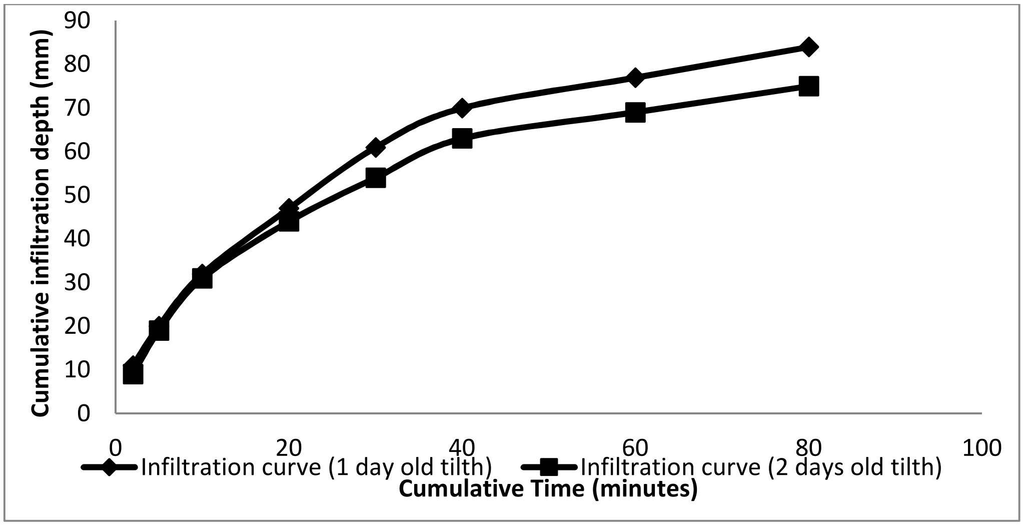

Figure 2: Infiltration Curves for Plough Tillage

Table 2: Computations of Infiltration Rate for Plough + Harrow Tillage

S/N	Time	Infiltration (1-d Tilth)	Infiltration (2-d Tilth)	Infiltration rate (1-d Tilth)	Infiltration rate (2-d Tilth)
	minutes	mm	(mm)	mm/minute	mm/minute
1	2	12	9	6	6
2	3	11	6	3.66	3.67
3	5	13	9	2.6	2.6
4	10	16	14	1.6	1.4
5	10	14	12	1.4	1.2
6	10	9	7	0.9	0.8
7	20	8	6	0.4	0.35
8	20	8	6	0.4	0.35
Total	80	91	84		
		Average**		1.14	1.05

**Average infiltration rate = (Total Infiltration/Total Time)
1-D Tilth = one day after tillage; 2-D Tilth = two days after tillage **Basic infiltration rate = 24mm/hr.

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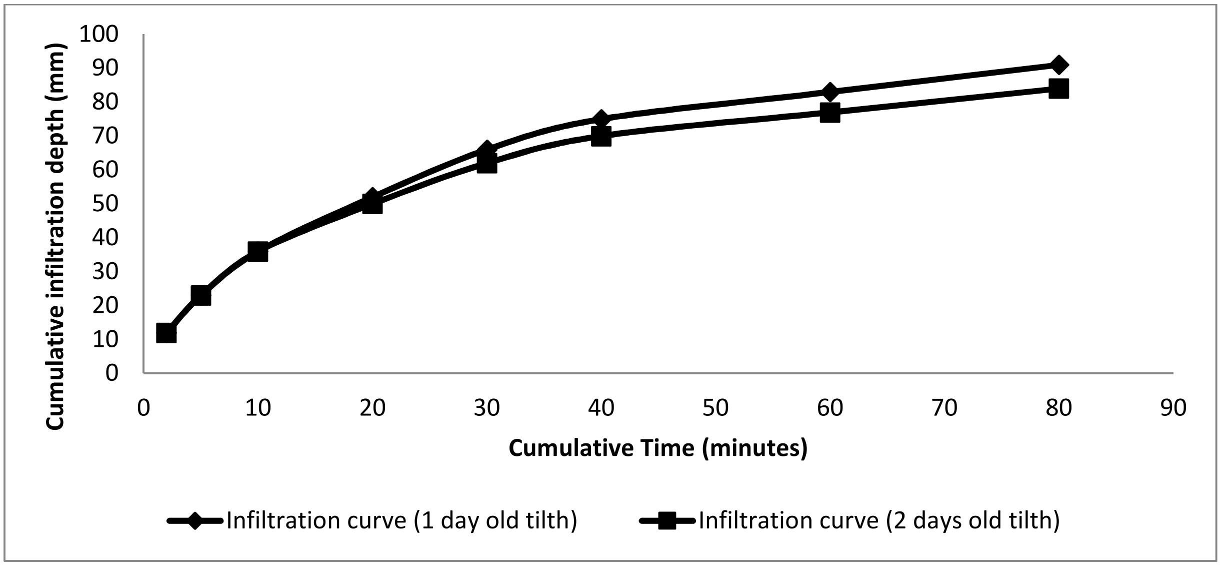

Figure 3: Infiltration Curve for Plough + Harrow Tillage

Table 3: Average Infiltration Depths under Different Tillage Treatments

Cumulative Time (minutes)	Average infiltration depth (mm)			
	Zero-Tillage	Crude Tillage	Plough Tillage	Plough + Harrow Tillage
2	8.5	8	10	12
5	15	16	19.5	23
10	24.5	26.5	31.5	36
20	38	39.5	45.5	51
30	49.5	49.5	57.5	64
40	56.5	57.5	66.5	72.5
60	62.5	64.5	73	80
80	68.5	71.5	79.5	87.5

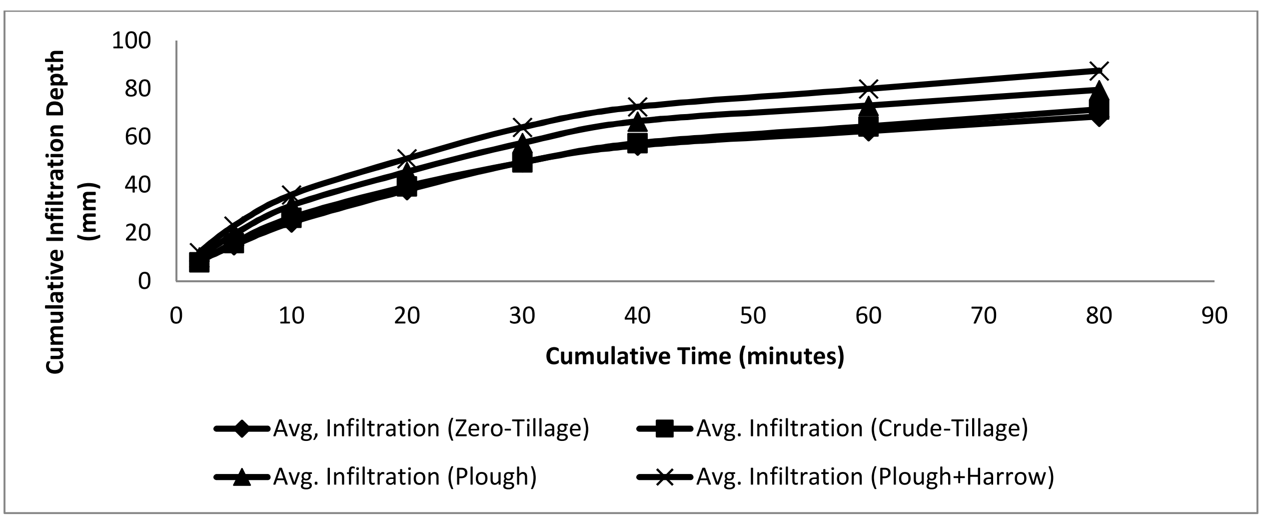

Figure 4: Comparative Infiltration Curves for Different Tillage Treatments

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Table 4: Average Infiltration Rate under Different Tillage Treatments

Tillage Method	1 day old Tilth	3 days old Tilth	Average
Zero Tillage	0.85	0.86	0.855
Crude Tillage	0.91	0.88	0.895
Plough Tillage	1.05	0.94	0.995
Plough + Harrow Tillage	1.14	1.05	1.095

Table 5: Analysis of Variance (2-Way classification) Summary

Summary	Observations	Sum	Average	Variance
Zero Tillage	2	1.71	0.855	5E-05
Crude Tillage	2	1.79	0.895	0.00045
Plough Tillage	2	1.99	0.995	0.00605
Plough + Harrow Tillage	2	2.19	1.095	0.00405
1 day old Tilth	4	3.95	0.9875	0.017358
2 days old Tilth	4	3.73	0.9325	0.007292

Table 6: ANOVA Test of Significance

Source of Variation	SS	Df	MS	F	P-value	F crit
Rows	0.0694	3	0.023133	15.25	0.025	9.28
Columns	0.00605	1	0.00605	3.99	0.140	10.13
Error	0.00455	3	0.001517			
Total	0.08	7				

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APPENDIX

Test Result for Zero Tillage

S/N	Time	Cumulative Time	Infiltration	Cumulative Infiltration	Infiltration rate	Infiltration rate
	minutes	minutes	mm	(mm)	mm/minute	mm/hr
1	2	2	8	8	4	240
2	3	5	7	15	2.33	140
3	5	10	10	25	2	120
4	10	20	13	38	1.3	78
5	10	30	11	49	1.1	66
6	10	40	7	56	0.7	42
7	20	60	6	62	0.3	18
8	20	80	6	68	0.3	18

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