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Effects of Vetiver (Vetiveria nigritana) on Infiltration Characteristics of Kaolinitic Alfisol of Ibadan, South-Western Nigeria

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Abstract: *The importance of erosion in relation to variability of water and soil losses from a parcel of land can be revealed in the measurements of the infiltration characteristics and runoff under a comparable vetiver grass strips and collection tanks within the plots. This experiment is aimed at assessing the variability of runoff and soil loss due to infiltration characteristics of the runoff plots. This study involved three vetiver plots of 20 m interval measured out of six plots (40 m × 3 m each) randomly distributed over a land area of 0.072 ha. The study was conducted on a 6 % slope experimental plot, along Parry Road of the University Ibadan, during the 2007 raining season. The texture of the soil was generally loamy sand. Mean total runoff among the plots was in the trend of no-vetiver plots > vetiver plots (13.50mm > 4.99 mm), the same was true for mean total soil loss (28.78kg/ha > 12.96kg/ha). Variability in the amounts of runoff was moderate in vetiver plots and highly variable in no-vetiver plots (CV = 24 % and 40 % respectively. The correlation between measured soil physical properties and infiltration characteristics with runoff revealed that fine sand content of the soil was negatively related with runoff (r = 0.6450*), but the reverse relationship was true for porosity inferred from soil bulk density and sorptivity of the soil (r = -0.7650*, and -0.8956* respectively).*
Key words*: Vetiver, Infiltration capacity, kaolinite, Alfisol, Erosion and Root zone*

I. Introduction

When water is supplied to the soil surface, whether by rainfall or irrigation, some of the arriving water penetrates the surface and is absorbed into the soil, while some may fail to penetrate but instead accrue at the surface or flow over it (Edem *et al.*, 2012). The rate of infiltration relative to the rate of water supply, determines how much water will enter the root zone and how much, if any, will runoff. Hence the rate of infiltration affects not only the water economy of the plant communities, but also the amount of surface runoff and its attendant danger of soil erosion. Where the rate of infiltration is restricted, plants may be denied sufficient moisture while the amount of erosion increases (Hillel, 1982). Therefore knowledge of infiltration process under vetiver hedge as it affects soil properties and management is a pre-requisite for efficient soil and water management.

II. Materials and methods

2.1 Field Infiltration Measurement

Soil and runoff collecting devices were installed at the bottom of each plots using oil drums of 90 cm, high and 58 cm wide in each of the plots after every storm that caused runoff, aliquots of the soil sediment and runoff water were sampled and determined. Computation was done to determine the total runoff water and soil loss of the entire plots.

Field infiltration test at two points on each experimental plot was conducted using double ring infiltrometer as described by Bouwer (1986). The first point of infiltration run was quite close to the vetiver hedges (25cm away, with respect to the inner ring) while the other point was 50cm away from the vetiver hedges (that is the outer ring was placed at the vertex of the former) in each of the strips. The inner ring (30 cm in diameter) was positioned at the center of the outer ring (50cm in diameter) (Plate 1). The two rings were driven down uniformly with a hammer to a depth of 15 cm, with a cross bar on top of the rings. In order to prevent the puddling of the soil surface when adding water into the infiltrometer, some pieces of dried grasses were laid within the rings. Water was added to the outer ring and the inner ring simultaneously. Water, however was maintained at the same level in both the inner and the outer rings. The outer ring acted as a buffer to prevent lateral flow of water from the inner ring, while vertical flow of water into the profile was achieved. Measurement of infiltrated water was taken at 1 minute interval, up to 30 minutes. Thereafter, the measurements were taken every 5 minutes until steady state at about 120 minutes. A ruler (float), graduated in centimeters was fixed vertically inside of the inner ring to record the falling in height of the water level at the successive times.

The results of the infiltration obtained were fitted into Philip's and Kostiakov's models, and the infiltration characteristics were determined.

2.2. Fitting of the data into infiltration equations

Infiltration data were fitted into Phillip's vertical flow equation (Phillip, 1957) and Kostiakov's equation (Kostiakov, 1932). From these equations, estimates of saturated hydraulic conductivity, sorptivity rates, and stability of aggregates, were possible.

(i)Phillip's equation:

$I = St^{½} + At$ ----------------------------(1)

Where, I = cumulative infiltration (cm), S = soil sorptivity (cm/hr), it is a measure of the rate at which water is absorbed into the soil. t. = time interval (min). A = saturated hydraulic conductivity of the soil's upper layer (Transmission zone)

(ii) Kostiakov's equation

$I = Ct^{\alpha}$ ------------------------------- (3)

Where, I = cumulative infiltration (cm), C = index of the rate at which water enters the soil. The higher the value of C, the larger the soil pores and vice versa

α. = a measure of stability of the soil aggregates as water moves down the soil profile. The higher the value of α, the more stable is the soil aggregates.

t. = time interval (min.)

2.3 Statistical Concepts and Analysis of Experimental Data

The experiment consisted of two treatments; vetiver and non-vetiver plots replicated three times on a 6% slope. The treatments were arranged in a Randomized Complete Block Design (RCBD). Least significant difference (LSD) was used to compare the means. Coefficient of variation and Correlation analyses were carried out to measure degree of variation of infiltration characteristics among plots and the relationship of infiltration characteristics with soil properties. In order to establish a rational basis for selecting soil properties predictive of infiltration process, multiple regressions were performed according to the SPSS manual (Nie et al., 1970) using stepwise selection and backward elimination techniques.

III. Results and discussion

3.1 Determination of Infiltration characteristics using Philips and Kostiakov's models

Infiltration data generated were fitted into Philip's and Kostiakov's equations (Table 1) for determination of the sorptivity and transmisivity of the soil. The R^2 Value for both infiltration models range between 0.63 and 0.99 implying that both models fit the data very well and can adequately predict infiltration rates into the soil under vetiver and non-vetiver hedge management. At a distance of 25cm infiltration point away from the vetiver, absorptivity of the soil's upper layer (A) had a mean value of 3.9cmmin^{-1}

while the infiltration points at 50cm distance away from vetiver recorded a mean of 2.2 cmmin^{-1} . Relatively, infiltration rate at 25cm distance away from the vetiver grasses transmit water more than the distance of 50cm away from the vetiver hedges. The same trend was true for rate of water Sorptivity (S), Kostiakov's index of soil pore sizes(C), and index of soil stability (α). (S = 242.22 cmmin^{-1} > 171.79 cmmin$^{-1)}$ and (C = 4.19 cmmin^{-1} > 3.59 cmmin$^{-1,}$ α.= 2.88 cmmin^{-1} > 2.54 cmmin^{-1}). Soils at the distance of 25cm from the vetiver were relatively seen to be more structurally stable than those at 50cm distance away from the vetiver hedges. The results in no-vetiver plots were similar to 50 cm distance in the vetiver plots (not significantly different).

In Philips' model, the mean sorptivity (S) of water in the soil ranged from 28.36 -94.36 cm/min. The mean values were 80.73 cm/min, 63.28 cm/min, 84.57 cm/min, 53.58 cm/min 44.05 cm/min and 38.45 cm/min for plots 1, 2. 3, 4, 5 and 6 respectively. The highest sorptivity was observed in plot 3 (Point 3A = 94.36 cm/min).

Mean hydraulic conductivity (A) ranged from 0.35 – 2.0cm/min and the respective plot mean values were 1.9 cm/min, 1.1 cm/min, 1.5 cm/min, 0.35 cm/min, 2.0 cm/min, and 0.5 cm/min. The highest hydraulic conductivity (A) was recorded in plot 4 (Point 4A = 3.0cm/min). In Kostiakov's model, the index at which water enters the soil (C) recorded mean range of 0.35 – 2.26cm/min. But the respective plot means value were1.75 cm/min, 1.51 cm/min, 2.26 cm/min, 2.14 cm/min, 0.35 cm/min, and 0.50 cm/min. Plot 4 recorded the highest intake of water (Point 4A = 3.02cm/min).

The index that measured the stability of soil aggregate (α) had a mean range value from 0.87- 0.97. The respective plot mean values were, 0.92, 0.97, 0.91, 0.87, 0.90 and 0.97. Equilibrium infiltration was moderate at 25cm distance near vetiver hedges and the highest was recorded in plot 1 (2.02cm/hr), while the highest in the control was 0.84cm/hr. Generally, it ranged from 0.4 – 2.02 cm/hr. with a mean value of 0.64cm/hr. in vetiver plots and from 0.3 - 0.64 cm/hr with a mean of 0.51cm/hr. in non-vetiver plots

Cumulative infiltration under vetiver plots ranged from 86.8 -94.72cm/120min and 44.7-94.9cm/120min. in the control, while the respective plot means values were 86.8 cm/120min, 69.1 cm/120min, 94.8 cm/120min, 94.9 cm/120min, 46.2cm/120min, and 44.7 cm/120min., the seventh infiltration point also recorded the highest cumulative infiltration (Point 4A = 108.9 cm/120 min.)

As shown in Table 2, the relationship of selected soil properties and infiltration characteristics with runoff water revealed a positive correlation between find sand and runoff (r = 0.6450) and negative correlation with porosity and sorptivity (r = -0.7650 and -0.895 respectively)

3.2 Infiltration characteristics under vetiver and non- vetiver plots

Comparatively (figures 1 and 2), infiltration characteristics under vetiver hedges were higher than those in the non- vetiver plots although the reverse was true for the index that measured soil stability (α). This may be attributed to the state of the soil structure at 50cm distance away from the vetiver hedges which constituted the measurement. The gap between 25cm and 50cm in vetiver plots was so wide apart when compared with the non-vetiver plots. This is an indication of higher intake and conductivity of water at position near vetiver hedges resulting from the sink created by the vetiver roots that enhances infiltration. Infiltration characteristics of soils at 25cm away from the vetiver hedges were comparatively higher than the infiltration points of 50cm away from the vetiver hedges. The line graphs of cumulative infiltration against elapsed time revealed a continuous rise in water infiltration throughout the period of 120minutes at all the points measured. Although there were some differences among the points, the mean value of equilibrium infiltration and cumulative infiltration at 120 minutes was relatively higher at 25cm distance away from vetiver (260.10cm/120min.> 195.4cm/120min.). But when cumulative infiltration in vetiver plots was compared with the non – vetiver (control) the mean value of vetiver plot was higher than that of control (455.50cm/120min.> 417.20cm/120min

IV. Conclusion

There was continuous rise in water infiltration at 25 cm points near vetiver grass strips throughout the period of the experiments, whereas within short time, equilibrium infiltration rate was quickly noticed in no-vetiver plots. Runoff was directly proportional to fine sand content, but inversely related with total porosity and soil's sorptivity.

The point where the infiltration is low indicates potential high runoff on the plot. This confirms the reports of Babalola *et al.,* (2003 and 2007) that vetiver hedges reduce runoff than the control plot. This is because restricted infiltration enhances the accumulation of runoff and the hazard of erosion during a rainstorm. It also affects the availability of water in the soil and water economy of the rooting zone of plants. Generally, the infiltration category in no-vetiver plots was slow while that of the vetiver averaged moderate.

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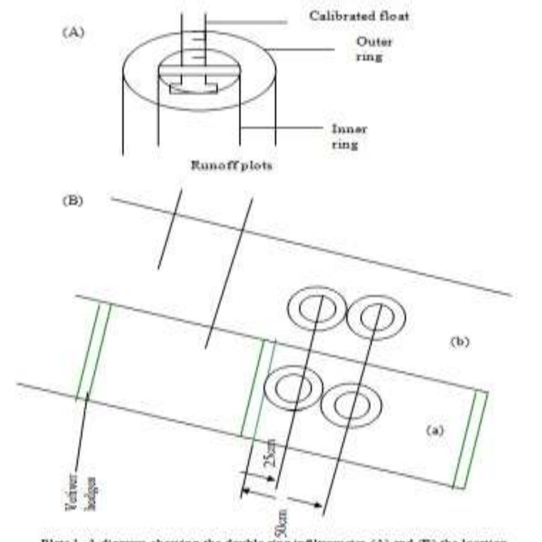

Plate 1. A diagram showing the double ring infiltrometer (A) and (B) the location of Double-Ring Infiltrometer on the (a) vetiver plot and (b) non-vetiver plot

Table 1 Infiltration characteristics of soils under Vetiver and No - Vetiver plots determined at 25cm (A) and 50cm (B) from the line of vetiver hedge

.	Philips' Model				Kostiakov's Model					Cumulative infiltration
Infil. Pts	S	Mean	A	Mean	C	mean	α	Mean	i.(cm/hr)	(cm/2hr)
1A	93.525		1.4		1.99		0.94		2.02	97.2
1B	67.94	80.73	1.0	1.9	1.51	1.75	0.9	0.92	0.65	76.4
2A	69.78		1.2		1.62		0.98		0.67	81.9
2B	56.77	63.28	1.0	1.1	1.4	1.51	0.95	0.97	0.41	56.2
3A	94.36		2.0		2.29		0.99		1.87	102.1
3B	74.78	84.57	1.0	1.5	1.99	2.14	0.83	0.91	0.57	87.4
4A	65.86		3.0		3.02		0.91		0.8	108.9
4B	41.65	53.58	0.5	2.0	1.5	2.26	0.83	0.87	0.84	80.9
5A	54.74		0.5		0.2		0.95		1.44	60.8
5B	30.65	44.05	0.2	0.35	0.5	0.35	0.84	0.9	0.29	31.6
6A	46.82		0.5		0.5		1.02		0.46	58.8
6B	28.36	38.45	0.5	0.5	0.5	0.5	0.93	0.97	0.21	30.5

Where, i. = equilibrium infiltration; S =sorptivity; A = absorptivity; C = rate of water entry (Kostiakov constant); α = measure of soil stability. Infil. Pts. = Infiltration points,
(Odds numbers = Vetiver plots and Even numbers = Non- vetiver plots).

Table 2. Relationship between selected soil properties and infiltration Characteristics with runoff water

	Regression model	r	R^2
Runoff	0.0404 – 19.416 CS	- 0.5932	0.3519
	0.1475 + 2.2301 FS	0.6450	0.9943
Soil properties	0.1397 – 3.9607 SL	-0.9971	0.2972
	-0.039 + 11.95 CL	0.545	0.0416
	-27.881 + 46.647 BD	0.2502	0.0626
	1.6863 – 73.146 P	-0.7650	0.5867
	-0.0078 + 7.6232 I	0.1435	0.0206
Infiltration characteristics	0.0821 + 1.379 CM	0.4188	0.1754
	0.055 – 0.0629 S	- 0.8956	0.2298
	5.1643 -1.6824 A	-0.2300	0.0716
	1.2935 + 5.8887 C	0.4793	0.0529
	457.5 – 408.71 α	-0.2676	0.8022

CS= Coarse sand; FS = Fine sand; SL= Silt; CL = Clay; BD = Bulk density; P = porosity;
I = equilibrium infiltration; CM = Cumulative infiltration; S= Sorptivity; A=Absorptivity; C = Index of water entry into the soil; α = Index of soil stability

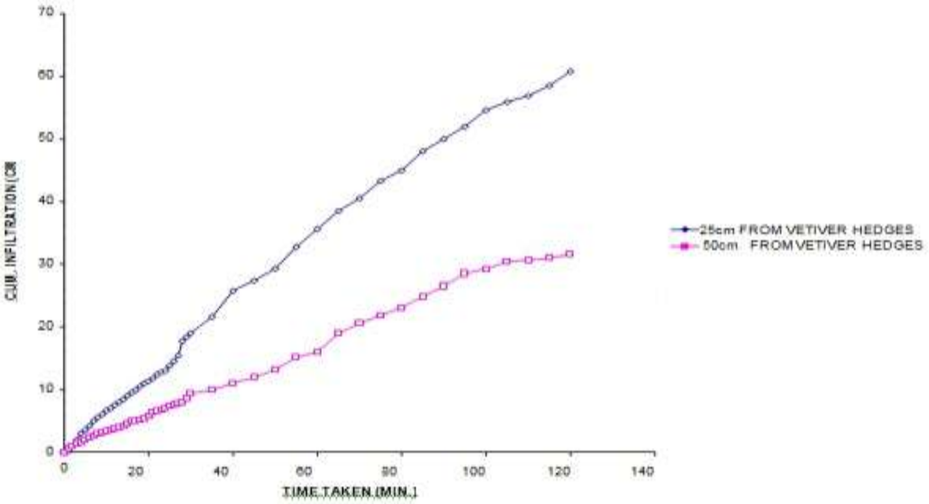

Fig. 1: Cumulative infiltration against time elapsed for vetiver plot at 25 and 50cm distances

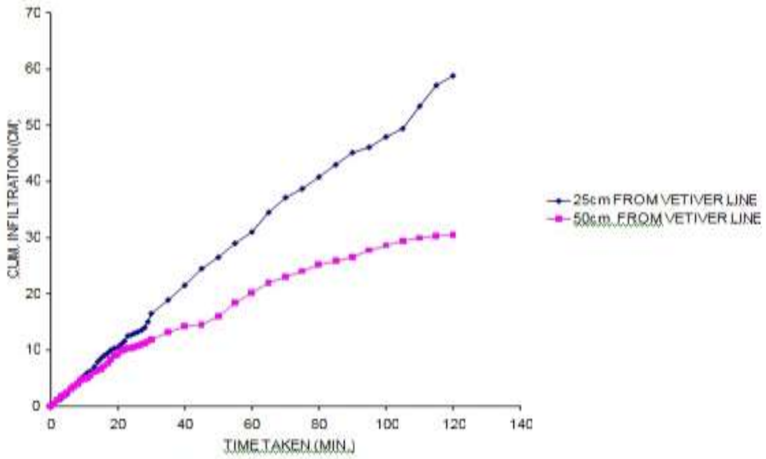

Fig. 2: Cumulative infiltration against time elapsed for no-vetiver plot at 25 and 50cm distances