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Effect of much and biochar on soil runoff, drainage and ET under different rainfall rate

Mariam Diop [1,*], Sory Sissoko [2] and Ginette Dembélé [3]

[1] *Department of Soil Science College of Basic and Applied Science School of Agriculture, University of Ghana.*

[2] *Department of Biology, Faculty of Sciences and Techniques, University of Sciences, Techniques and Technologies of Bamako; PO. Box E. 3206 Bamako, Mali.*

[3] *Institute of Rural Economy (IER)/ Regional Agricultural Research Center/Sotuba, BP 262, Bamako, Mali,*

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Abstract

A two months experiment was carried out at the Department of Soil Sciences, the University of Ghana to study the effect of soil amendments and rainfall rate per hour to runoff, drainage and evaporation. The experiment design was 1 x 8 factorial in a complete randomized design with 3 replications in total 24 plot. The six-rainfall rate were 18 ml/mm (R1) ; 21 (R2) ; 26 (R3); 51, (R4); 67,(R5) and 84 ml/mm (R6) . The soil amendments were biochar (B) and mulching (M) their combination and control (C) in a total of eight amendments (M20B20, M10B20, M20, M10, M10B10, B20, B10 and C). A soil use during the experiment was Toje soil whish was a Sandy clay loam. The results were analyzed by ANOVA and means compared by using (Lsd at 5%). The effectiveness of soil amendment on soil water balance components improvement was generally in a decreasing other of M20B20> M10B20> M20>M10B10>B20>B10>C which ranges from 25.83 to 81.94 ml and 225 to 397.22 ml for runoff and drainage respectively, 475 to -200 ml for change in weight and 738.41 to 291.75 ml evapotranspiration.

Keyword: Biochar; Runoff; Drainage; Evapotranspiration

1. Introduction

Many Ghanaian cultivated soils especially those of northern Savannah Zone of Ghana have least considerable amount of topsoil due to inappropriate land management which consequently make them more vulnerable to runoff and reduce their water holding capacity. Therefore, that combine by the increasing of temperature (1^{0}C) as reported by (FAO 1998) can result in high soil water evaporation. Hence several studies showed the positive effect on biochar and mulching on soil water balance by improving soil water holding capacity. Along them work done by Karhuet al., (2011) showed biochar application as amendment to increase soil's water retention by retaining water in its pores by capillarity and reduce drainage (Karhuet al., 2011). It also has high potential to mitigate water stress by reducing soil temperature (Zhang *et al.,* (2013). The use of the crops residue as mulching is also one of best management practice to improves soil quality and productivity through favorable effects on soil properties (Lal and Stewart, 1995). The mulching can increase soil water holding capacity through the residue decomposition to soil organic matter content and increase therefore the percent water-stable aggregates for the surface layer (Havlin et al., 1990). Moreover, these effects depend on the rate of application and the type of residue applied (Reeves 1997). However, the combination of biochar and mulching to soils at different rate of application may positively affect soil water balance in the different way. Therefore, it is the aim of this research to evaluate the effect of mulch and biochar application on soil water balance components under different rainfall rate application.

* Corresponding author: Mariam Diop

2. Methods

2.1. Screenhouse studies

A screenhouse was constructed in the Sinna Garden at the University of Ghana. The experiment involved rainfall at different rate of application (ml/mm) (18, R1; 21, R2; 26, R3; 51, R4 ;67, R5; 84, R6) and 8 soil amendments at different rate of application been 10 to 20 ton/ha for both biochar (B) and mulching (M) their combination and control (M20B20, M10B20, M20, M10, M10B10, B20, B10 and Control C). the experiment was 1 x 1 x 8 factorial at 3 replecation in a total of 24 . Polyvinyl (PVC) pipes of length 20 cm and 16 cm internal diameter served as soil columns and a rainfall similiter was used to measure the different rate of application per hour. The columns were filled with Toje soils to a height of 15 cm, leaving a border of 5 cm at the top. The soils were packed into the columns to a bulk density of 1.35 g/cm^3. A hole was drilled at the top level of the soil for runoff collection during irrigation. Also, drainage holes were drilled at the bottom of the columns. Drained water was collected in plastic containers.

To study the effect of soil amendment and rainfall rate on soil water balance 24 36 columns plots were established to determine the appropriate amendment to reduce runoff, drainage, and evaporation. Each column was measured 16 cm in diameter and 20 cm in height where 15 cm was filled with soil. For biochar treatment soil was mixed with biochar. The mass of soil was calculated using soil bulk density (equation 1). The bottom of each column was covered by aluminium permeable sheets to allow water to drain, above which a plastic container was placed to collect drainage water. At the upper ends of each column, there was a plastic runoff tube connected to 0.5-litre plastic containers as measuring equipment of the water that was not able to infiltrate to the soil (runoff) from each water regime.

$$Pb = \frac{m}{v}\ , therefore\ m = Pb * V \qquad EQ1$$

$$V = \pi d2/4 * h$$

Where Pb is bulk density, m is masse, V is volume

2.2. Data collection

At an interval of ten days the different rainfall rates were applied. After every rainfall rate application both runoff and drainage water were collected in each specific plastic container and measured, where runoff was collected just after irrigation and drainage the next day norming. At the beginning of the experiment, the initial weight of each column was taken (initial weight) and after every 10 days all the columns were weighed again, which was considered as the final weight of the first 10 days, but the initial weight for the next ten days. The difference between the two weights was considered as the value of change in weight (change in water content). Therefore, at every 10 days intervals known as the amount of the water irrigated, runoff, water drained and change in weight, the evaporation was estimated for each treatment (equation2). Between the different rainfall rate application there were an interval of ten days.

$$E = I - (R + D) - \Delta W \qquad Eq2$$

Where ET = Evaporation, I= irrigation, R = runoff, D = drainage, ΔW is change in weight

2.3. Statistical analysis

Data collected during the experiment was statistically analyzed using ANOVA with GenStat statistical software 12th version. The means were compared using the least significant difference test at $P < 0.05$ and the graphs and the relationships were drawn using Excel software 10.

3. Result and discussion

3.1. Effect of amendments on runoff and drainage under the different rainfall rate

Drainage and runoff recorded during the experimental period under the various treatments was showed a significant difference under both rainfall rate (table 1) and soil amendments (figure 1). The mean of runoff and drainage followed almost the same trends under the different rainfall in a decreasing other of R6 > R5> R4 > R3> R2 > R1 excepted for drainage R5 which significantly recorded less amount than R4 this may be attributed no runoff recorded under R4. The mean runoff were 0, 78.75 and 139.53 ml

Table 1 Runoff and drainage under different rainfall rate

Rainfall	Runoff (ml)	Drainage(ml)
R 6	139.58 c	690.79 d
R 5	78.75 b	499.58 b
R 4	0 a	621.88 c
R 3	0 a	0 a
R 2	0 a	0 a
R 1	0 a	0 a

the latter two were differ significantly ($p<0.01$) each other and also from the first. However, mean drainage ranged from 0 to 690.79 ml where the R1, R2 and R3 recorded the lowest drainage which were significantly different than the other three rainfall rate. The main effect of soil amendments on runoff and drainage gave values ranging from 25.83 to 81.94 ml and 225 to 397.22 ml respectively where C always generated the highest runoff and drainage and M20B20 the lowest. The drainage was almost similar under the various treatments (figure 1).

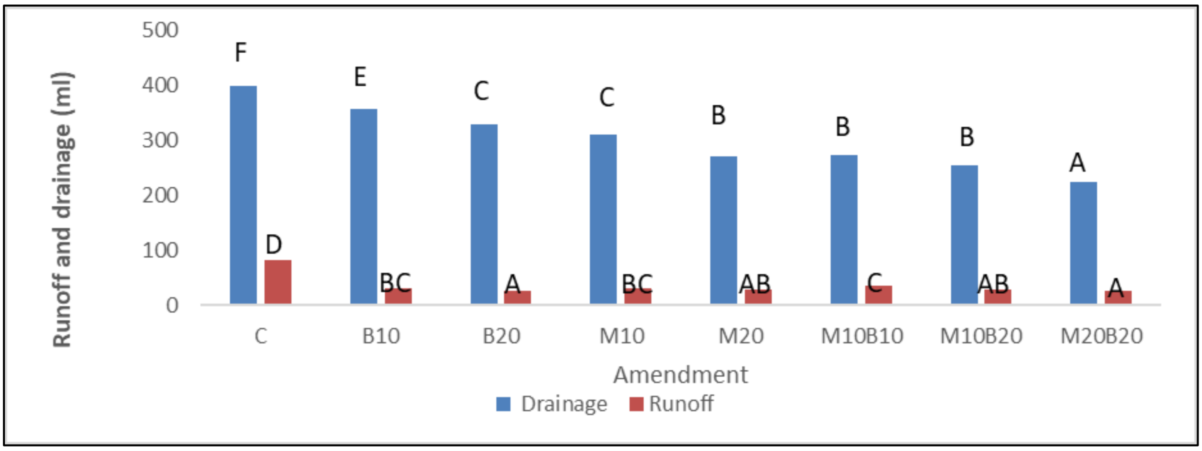

Figure 1 Drainage and runoff under different amendments

The results of the study have shown that the magnitude of reduction of runoff+drainage depends on the type of amendment and the intensity of rainfall rate (figure 2). Therefore R1, R2 and R3 combine with M20B20 regenerated the lowest runoff+drainage since under lower rainfall rate the soil may not be saturated for runoff or drainage to occur. Hence C x R6 significantly increase runoff+drainage compared to other treatments. The underlying reasons for this observation may be found in how biochar and mulch can improve soil water holding capacity by reducing runoff and drainage (Karhuet al., 2011, Findeling et al., 2003) which can be attributed to the macro and micropores in the biochar structure (Novak et al., 2012) and the capacity of mulch to increase soil water infiltration (Reeves, 1997).

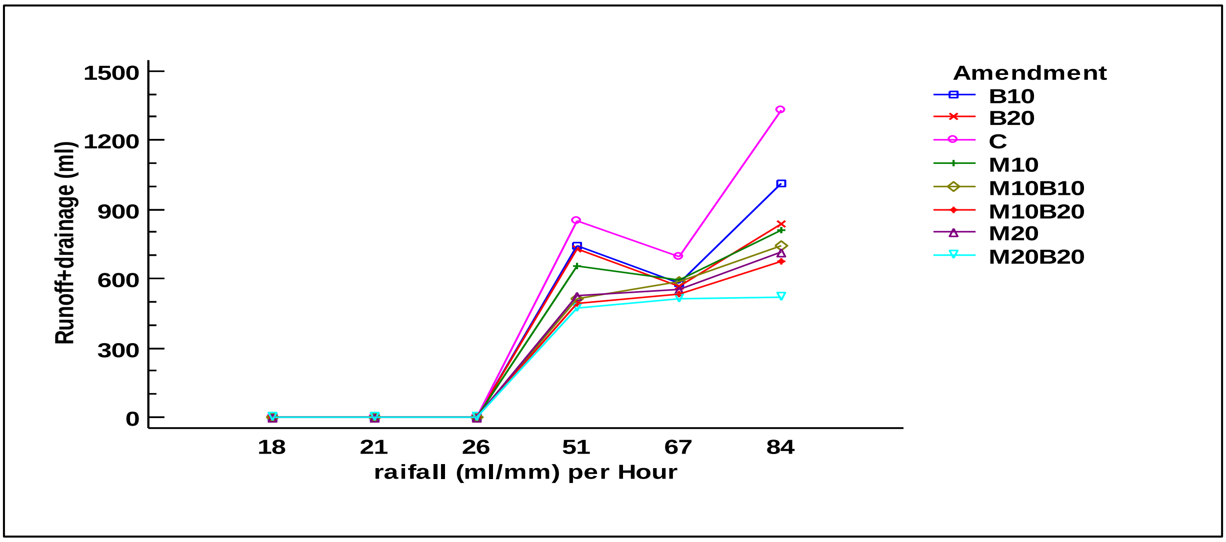

Figure 2 Interaction effect of amendment x rainfall rates on runoff+drainage

3.2. Effect of amendments on Change in weight under the different rainfall rate

The mean change in weight under the various soil amendments and rainfall rate are presented in (figure 3). ΔW under rainfall rate ranged from 475 to -77.9167 ml in a decreasing order of R6> R5> R3 > R4>R2>R1. R1 recorded the highest reduction change in weight which was significantly ($P < 0.01$) less than all other rainfall rate. The R6 significantly ($P < 0.05$) generated more positive change in weight than all the remaining rainfall rate, while R3 and R4 were not differed significant. Hence this study showed that soil weight increase as rainfall rate increase this may be due to large amount of water under the grater rater to be store in soil and consequently increase soil weight. The impact of soil amendments indicated change in weight range of 475 to -200 ml in an order of M20B20> M10B20> M20>M10B10>B20>B10>C. They were all significantly different except the case of M20 and M10B10 where the differences were not significant (figure 3)

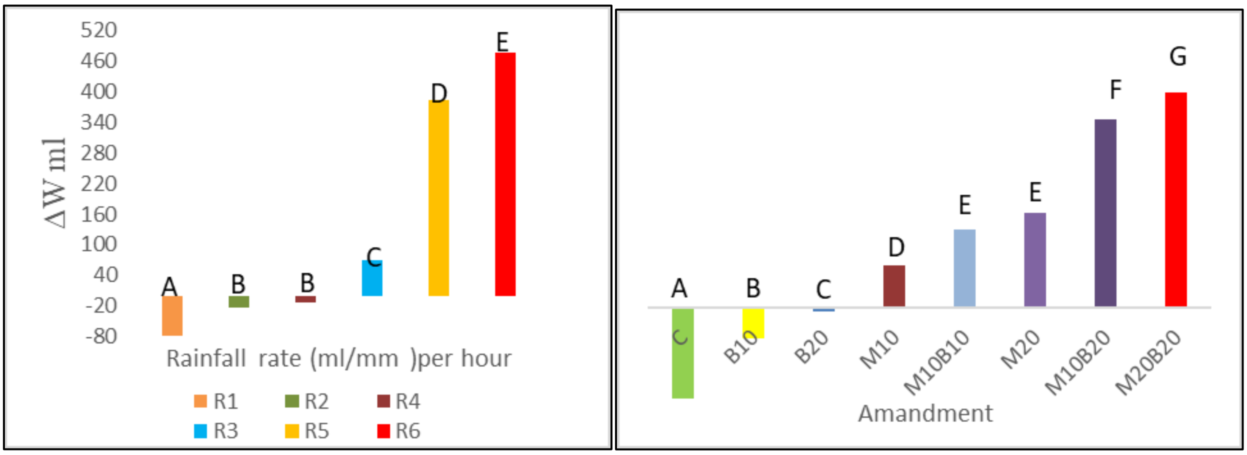

Figure 3 ΔW under different amendments and rainfall rate

The analysis further showed that the magnitude of ΔW is significantly affected by amendment x rainfall rate interactions (Figure 3). The amendment M20B20 and M10B20 generated the highest change in weight and significantly different ($P<0.05$) than the remaining amendment, this effectiveness increases as rainfall rate increase. Hence the interaction between Control and any other amendment recorded the lowest change. The underlying reasons for this observation may be due to high amount of rainfall applied control plot to be loss as runoff + drainage and evaporation compared to amendment plot which water holding capacity has been improved by biochar and mulch application.

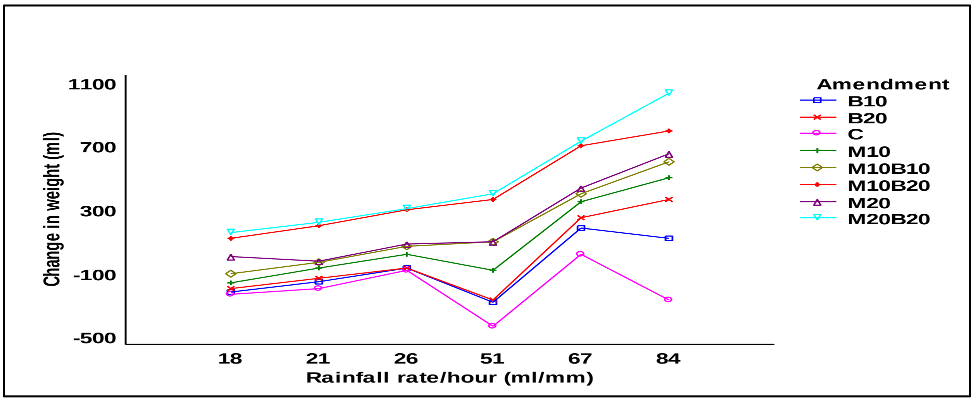

Figure 4 Interaction effect of amendment x rainfall rates on ΔW

3.3. Effect of amendments on soil evaporation under the different rainfall rate

The results (figure 5) showed the mean soil water evaporation values to range from 614.625 to 489.40 ml under rainfall rates. The magnitude of the values was in the order of R6> R5> R4 > R3>R2>R1. The soil water evaporation under R^1 was significantly less than the remaining rainfall rate except from R^2 due to less soil availability for evaporation. It is not surprising that R6 under which soil is supposed to be saturated compared to less rate to water application showed the highest evaporation. The order of evaporation under the various water application treatments followed the same trend as rainfall rate.

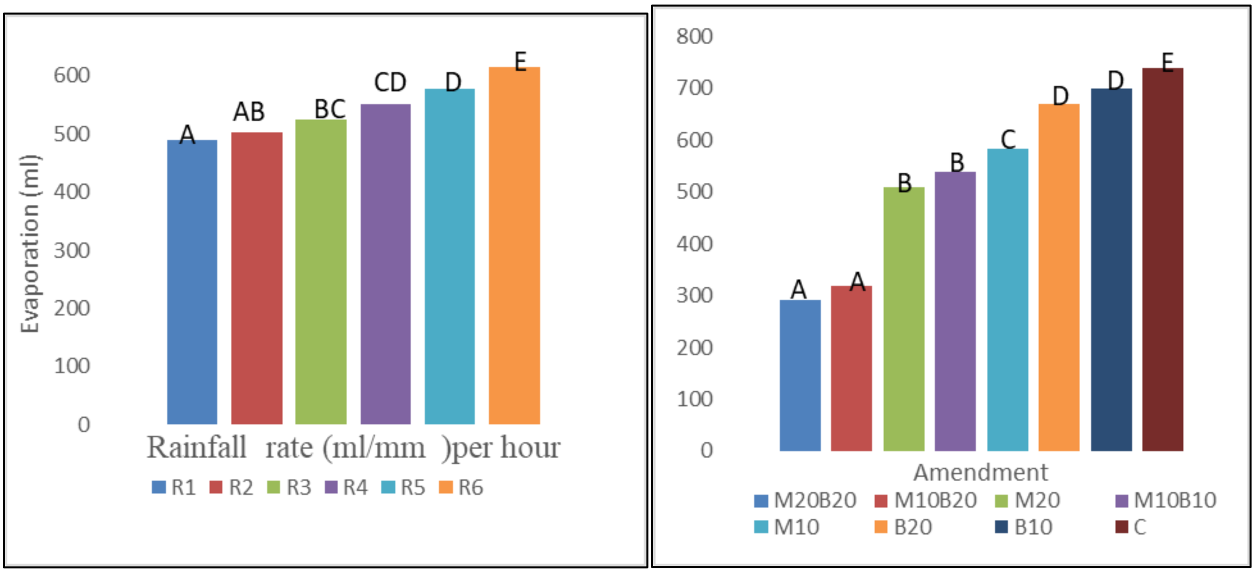

Figure 5 Soil evaporation under different amendments and rainfall rate

Under soil amendment the mean soil water evaporation ranged from 738.41 to 291.75 ml (figure 5). Evaporation differed significantly (P<0.05) among different amendment with the least evaporation from M20B20 and M10B20 which was not differ significantly and the highest from control which was significantly different from the remaining amendment. This effect can be attribute to the typical capacity of mulch by conserving soil from soil water loss and by improving it ecologies (Erenstein, 2003). Therefore, this combines biochar potentiality to reducing soil temperature (Zhang *et al.,* (2013) can consequently reduce soil evaporation. During this study it was surprise to see that there was no interaction effect of amendment and rainfall rate on soil evaporation.

4. Conclusions and recommendations

The merit of soil amendment by reducing runoff+drainage and soil evaporation and consequently increase soil water content (positive change in soil weight) in a decreasing M20B20> M10B20> M20>M10B10>B20>B10>C. The study showed that in most of the case M20 and M10B10 had the similar effect on the above parameters. Therefore, based on this finding combination of biochar and mulch can be applied by smallholders'farms to avoided soil moisture lost especially where crops residues are not very available.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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