Effect Of Mulching On Soil Physico-Chemical Properties Of Soil Under Semiarid Of Rain Fed Fersiallitic Soil Condition In Eastern Of Rwanda

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Abstract – Mulches provide essential soil environment and economic benefits. Mulching is an agricultural and horticultural practice in which the use of organic is involved. This method is very convenient in protecting the roots of the plants from heat, cold. Mulch is used to cover soil surface around the plants to create congenial condition for the growth. This may include temperature moderation, reduce salinity and weed control. Unfortunately, this study has not been done much under different local conditions. This study was carried out to determine the effect of various mulches application on some soil physico-chemical properties of fersiallitic soil in semiarid ecosystem, eastern of Rwanda. A control (no mulch) factor was also included in the experiment. The findings for soil indicated the higher organic matter for rice straw than control, the highest pH of 7.6 for rice straw and 6.0 for control, there was a positive variation in EC across the depth from control to mulched land. The highest and the lowest values for soil moisture content obtained were 39.25% under rice straw and 25.01% for the control respectively and the obtained results showed that straws and grass conserved moisture at root zone level; there was a change in soil BD, porosity for mulched land from control. For moisture conservation rice and beans straw may be recommended.

Keywords – Mulches, Phaseolus vulgaris, pH, EC, OM, Porosity, BD, Soil moisture, yield.

I. INTRODUCTION

Mulching is an agricultural technique widely used as soil management practice, they are used to cover bare soil especially in dry landscape with variable impact on the soil properties and plant growth, mulching have been widely used in agricultural lands, orchards, forests, and landscapes in many parts of the world (M A Kader, 2017). Mulch is any material that influences soil characteristics and sometimes plant growth (Bell, 2009). Today sub-Saharan countries are facing a big challenge of climate change which is resulting in water scarcity and large food deficiency(Green & Green, 2019). Several studies have showed that Overpopulation in sub-Saharan countries is resulting in food deficiency due to increased food demand under small land and less Agricultural technology. To improve how we produce food under small scale surface, mulching materials could be applied to improve soil health status this means that it improves soil structural properties directly and indirectly by promoting the biological activity(Ali, Islam, & Zaman, 2014) As the applied organic materials nourish the soil little by little while they decompose as after a long period in a farm or garden which promotes nutrient release from organic matter (Alharbi, 2017; Rees et al., 2002). Mulching
plays soil environment and economic benefits; the environment benefits include that it conserves soil water, reduces evaporation, regulates soil temperature and improves soil health status. The economic benefits include that increases water use efficiency, improves water holding capacity and profitable (Mohammad Abdul Kader, Singha, Begum, Jewel, & Khan, 2019). The application of organic mulches reduce evaporation especially in summer period as they retain the humidity of soil being accumulated during the spring rains that help to hydrate the plant, different production byproducts like rice straw increases water retention and prevents soil evaporation(Id et al., 2019) The previous research showed that mulching reduces quick infiltration of runoff, the presence of crop residue mulch at the soil-atmosphere interface has a direct influence on infiltration of rainwater and evaporation (Bhardwaj, 2013) and (Kwambe, Masarirambi, Wahome, & Oseni, 2015). This study was carried out to study about the effects of rice straw, beans straw and cut grass as mulches, on soil physical and chemical properties of soil in comparison with un-mulched land.

II. MATERIALS AND METHODS

The study was carried out at Nyagatare dry valley near the town of Nyagatare district located in Eastern province, close to Rwanda's International borders with both Uganda and Tanzania. Its location lies about 168.7 kilometers by road North-East of Kigali the Rwanda's capital and largest city. The coordinates of the town are: 1° 18' 0.00"S, 30° 19' 30.00"E (Latitude:-1.3000; Longitude: 30.3250). The Nyagatare Soils are fersiallitic oxisol loams, pH of 5.8-6.5 with 30% clay, 3.2% organic matter; it experiences small quantity of rains around 827mm and hot temperatures (RAB, 2016). The temperature varies between 15°C to 30°C depending on the location (REMA, 2011).

The study was set up as a Randomized complete Block design (RCBD), four (4) Treatments each with three (3) replicates were established for the study; Rice straw, beans straw, cut grass and un-mulched bare soil. Beans (*Phaseolus vulgaris*) were used as experimental crop during this experiment.

Soil sampling, data collection and analysis

For each treatment, three random soil samples at depths 0–10, 10–20, and 20–30 cm were collected. Each sample were then placed in bags and transported to the laboratory. The soil sample was passed through a sieve of 2 mm and stored in a plastic bottle. The sample was then passed through a 2-mm sieve to remove all wastes, also a portion of approximately 20 grams of soil of 2 mm were passed through a sieve of 0.5 mm and also being stored in a plastic bottle. Both Fractions of soil were used for the various analyzes according to their procedures. The soil samples for dry matter purposes were taken from the field using weighed cylindrical cores. The soil samples were oven-dried at 105°C for 8 hours and were used to analyze the physical and chemical properties of soil. The soil moisture was evaluated by taking the ration between the difference in weight before and after oven drying and the weight of the sample soil then percent. The bulk density of the sampled soil was measured by the ratio of oven dried soil excluding the mass of cores and the volume of core cylinders. The porosity was calculated by measuring the total water volume filled in the soil pores. To determine the organic matter and carbon, an approximate 0.5 grams of crashed and dried samples were weighed and put in a dry and weighed crucible where it was incinerated for 3 hours in a furnace at 550°C until obtaining ashes through a technique of loss Ignition method. The soil pH was determined using a pH meter by H-Selective electrode at a soil to water ratio of 2:5.

To attain the accurate information for this research study, some primary data by experiment and secondary (quantitative) data were collected and analyzed. Different literatures were collected by reviewing books, journals, etc. Based on how they are related and relevant to the topic of study. All the data analysis were done using SPSS software package (version 20.0) (IBM Corporation, Armonk, New York) and the data were subjected to Two-way of variance (ANOVA) with the least significant difference test at P < 0.05.

III. RESULTS AND DISCUSSIONS

Physical properties

There is a great significance difference between mulched and control treatments and of the top depth (0-20 cm) but it shows no change at the depth (20-30) compared to un-mulched bare soil.
Table 1: Soil physical properties at along treatments in Nyagatare dry valley treated with Rice straw, beans straw, cut grass and control.

| Treatments    | Stats | M.C (%) | Porosity (%) | B.D (gm/cm<sup>3</sup>) |
|---------------|-------|---------|--------------|--------------------------|
| T1 (Rice Straw) | Mean  | 32.233  | 49.933       | 1.755                    |
|               | P50   | 32.440  | 50.500       | 1.378                    |
|               | SD    | 5.447   | 2.839        | 0.674                    |
|               | Min   | 25.010  | 45.100       | 1.219                    |
|               | Max   | 39.250  | 54.000       | 2.650                    |
|               | CV    | 0.169   | 0.057        | 0.384                    |
|               | N     | 9       | 9            | 9                        |
| T2 (Beans straw) | Mean | 29.580  | 48.667       | 1.804                    |
|               | P50   | 28.940  | 49.800       | 1.458                    |
|               | SD    | 2.994   | 3.258        | 0.639                    |
|               | Min   | 25.700  | 41.600       | 1.283                    |
|               | Max   | 34.100  | 51.600       | 2.650                    |
|               | CV    | 0.101   | 0.067        | 0.354                    |
|               | N     | 9       | 9            | 9                        |
| T3 (Cut grass) | Mean  | 31.500  | 51.167       | 1.749                    |
|               | P50   | 31.330  | 50.900       | 1.333                    |
|               | SD    | 3.649   | 1.378        | 0.677                    |
|               | Min   | 26.570  | 49.600       | 1.224                    |
|               | Max   | 36.600  | 53.800       | 2.650                    |
|               | CV    | 0.116   | 0.027        | 0.387                    |
|               | N     | 9       | 9            | 9                        |
| T0 (Bare soil) | Mean  | 31.473  | 47.000       | 1.834                    |
|               | P50   | 30.520  | 47.100       | 1.442                    |
|               | SD    | 4.240   | 2.204        | 0.614                    |
|               | Min   | 26.300  | 42.700       | 1.336                    |
|               | Max   | 37.600  | 49.600       | 2.650                    |
|               | CV    | 0.135   | 0.047        | 0.334                    |
|               | N     | 9       | 9            | 9                        |
| Total average of the experimental sites | Mean  | 31.197  | 49.192       | 1.786                    |
|               | P50   | 30.930  | 49.700       | 1.418                    |
|               | SD    | 4.120   | 2.875        | 0.624                    |
|               | Min   | 25.010  | 41.600       | 1.219                    |
|               | Max   | 39.250  | 54.000       | 2.650                    |
|               | CV    | 0.132   | 0.058        | 0.349                    |
|               | N     | 36      | 36           | 36                       |

Soil moisture contents, S.M.C (%)

Mulching has significantly affected the soil moisture content where the maximum moisture was observed to be 39.25% in a treatment mulched with rice straw and it is 1.3 times for rice straw, 1.25 times for beans straw and 1.24 times for cut grass than control in the top soil of the depth between (0-10) cm, the experiment shows no great significance in the lower depth (10-30) cm compared to mulched and un-mulched treatments. Mulching increased 11.05% of soil moisture compared to the initial soil moisture.
status of 28.2%, some research shows that mulching has significant benefits on crops including an increase in soil moisture (4.70-12.50%). Thus similar findings were found by (Bhardwaj, 2013) who concluded that mulching can be effective in increasing horticultural crop production in water scarcity regions.

### Table 2: Analysis of Variance of moisture content records.

| Physical property | Source         | Partial SS | DF | MS    | F      | P>F  |
|-------------------|----------------|------------|----|-------|--------|------|
| Moisture content  | Model          | 574.5576   | 11 | 52.2325 | 64.22  | 0.000*|
|                   | Treatments     | 34.7116    | 3  | 11.5705 | 14.23  | 0.000*|
|                   | Depth          | 309.1451   | 2  | 154.5725 | 190.05 | 0.000*|
|                   | Treatments X Depth | 230.701   | 6  | 38.4502 | 47.27  | 0.000*|
|                   | Residual       | 19.52      | 24 | 0.8133  |        |      |
|                   | Total          | 594.0776   | 35 | 16.9736 |        |      |
| Number of Obs     | =              | 36         |    | R²    | =      | 0.9671|
| Root MSE          | =              | 0.902      |    | Adj R²| =      | 0.9521|

a, b, c correspond to statistical significance difference at 5% level of significance

### Soil Bulk density, BD (gr/cm³) and Porosity (%)

Both BD and porosity are good indicators for soil permeability and suitability for root growth refers to soil-plant-atmosphere system. The use of high density straws as mulches created the compactness at the upper depths (10-20) cm of the soil. The impact of mulching on bulk density may depend on soil properties, climate and type of mulch, whereas mulching had no effect on the bulk density (Ni, Song, Zhang, Yang, & Wang, 2016). The results showed that porosity and bulk density varied along the depths, therefore porosity and bulk density of the soil at lower depths is improved (Id et al., 2019). Due to rain water, mulches (Rice straw, beans straw, and cut grass) released organic matter which created the conditions favorable to microorganisms; these enhanced the improvement in porosity at lower depths. Much scientific researchers have shown that the use of surface mulch combined with minimum tillage showed significance increase in porosity (Science, 2019).

### Table 3: Analysis of Variance of soil Bulk Density and porosity records

| Physical property | Source         | Partial SS | DF | MS    | F      | P>F  |
|-------------------|----------------|------------|----|-------|--------|------|
| Porosity          | Model          | 210.9275   | 11 | 19.1752 | 5.88   | 0.0001|
|                   | Treatments     | 85.7675    | 3  | 28.5892 | 8.76   | 0.0004*|
|                   | Depth          | 4.655      | 2  | 2.3275  | 0.71   | 0.5001|
|                   | Treatments X Depth | 120.505   | 6  | 20.0842 | 6.16   | 0.0005*|
|                   | Residual       | 78.3       | 24 | 3.2625  |        |      |
|                   | Total          | 289.2275   | 35 | 8.2636  |        |      |
| Number of Obs     | =              | 36         |    | R²    | =      | 0.7293|
| Root MSE          | =              | 1.806      |    | Adj R²| =      | 0.6052|
| Bulk Density      | Model          | 0.104946   | 11 | 0.0095 | 0.02   | 1.0000|
|                   | Treatments     | 0.045198   | 3  | 0.0151  | 0.03   | 0.9939|
|                   | Depth          | 0.003046   | 2  | 0.0015  | 0.00   | 0.9973|
|                   | Treatments X Depth | 0.056702  | 6  | 0.0095  | 0.02   | 1.0000|
|                   | Residual       | 13.51828   | 24 | 0.5633  |        |      |
|                   | Total          | 13.62323   | 35 | 0.3892  |        |      |
| Number of Obs     | =              | 36         |    | R²    | =      | 0.0077|
| Root MSE          | =              | 0.751      |    | Adj R²| =      | -0.4471|

a, b, c correspond to statistical significance difference at 5% level of significance
Soil chemical Properties

The chemical properties of the soil during experiments after mulching have been represented in figure below:

Table 4. Soil chemical properties at along treatments in Nyagatare treated with various mulches and control

| Treatments         | Stats | pH of soil | E.C of soil | O.M of soil | O.C of soil |
|--------------------|-------|------------|-------------|-------------|-------------|
|                    | Mean  | 6.660      | 178.667     | 15.000      | 8.700       |
| T1 (Rice Straw)    | P50   | 6.570      | 202.000     | 10.000      | 5.900       |
|                    | Variance | 0.315   | 1401.310    | 57.250      | 19.403      |
|                    | SD     | 0.561      | 37.434      | 7.566       | 4.405       |
|                    | Min    | 6.000      | 127.000     | 10.000      | 5.400       |
|                    | Max    | 7.600      | 207.200     | 27.000      | 15.500      |
|                    | CV     | 0.084      | 0.210       | 0.504       | 0.506       |
|                    | N      | 9          | 9           | 9           | 9           |
| T2 (Beans straw)   | Mean  | 6.567      | 258.333     | 11.667      | 6.767       |
|                    | P50   | 6.400      | 298.000     | 10.000      | 5.900       |
|                    | Variance | 0.190   | 5474.250    | 7.050       | 2.140       |
|                    | SD     | 0.436      | 73.988      | 2.655       | 1.463       |
|                    | Min    | 6.100      | 158.000     | 9.400       | 5.600       |
|                    | Max    | 7.300      | 326.000     | 16.800      | 9.000       |
|                    | CV     | 0.066      | 0.286       | 0.228       | 0.216       |
|                    | N      | 9          | 9           | 9           | 9           |
| T3 (Cut grass)     | Mean  | 6.670      | 289.000     | 11.667      | 8.867       |
|                    | P50   | 6.700      | 304.000     | 10.200      | 5.900       |
|                    | Variance | 0.162   | 2857.250    | 6.668       | 21.180      |
|                    | SD     | 0.402      | 53.453      | 2.582       | 4.602       |
|                    | Min    | 6.200      | 223.000     | 9.300       | 5.600       |
|                    | Max    | 7.200      | 374.000     | 16.000      | 15.200      |
|                    | CV     | 0.060      | 0.185       | 0.221       | 0.519       |
|                    | N      | 9          | 9           | 9           | 9           |
| T0 (Bare soil)     | Mean  | 6.533      | 232.333     | 13.333      | 7.333       |
|                    | P50   | 6.200      | 233.000     | 10.000      | 5.800       |
|                    | Variance | 0.285   | 2582.000    | 25.433      | 8.645       |
|                    | SD     | 0.534      | 50.813      | 5.043       | 2.940       |
|                    | Min    | 6.000      | 168.000     | 9.200       | 5.700       |
|                    | Max    | 7.400      | 295.000     | 21.000      | 12.700      |
|                    | CV     | 0.082      | 0.219       | 0.378       | 0.380       |
|                    | N      | 9          | 9           | 9           | 9           |
| Total of the site | Mean  | 6.608      | 239.583     | 12.917      | 8.017       |
|                    | P50   | 6.500      | 227.500     | 10.000      | 5.900       |
|                    | Variance | 0.221   | 4500.892    | 23.999      | 12.469      |
|                    | SD     | 0.470      | 67.089      | 4.899       | 3.531       |
|                    | Min    | 6.000      | 127.000     | 9.200       | 5.400       |
|                    | Max    | 7.600      | 374.000     | 27.000      | 15.500      |
|                    | CV     | 0.071      | 0.280       | 0.379       | 0.440       |
|                    | N      | 36         | 36          | 36          | 36          |
Soil pH

Mulching highly affected the PH of the soil, the pH of the soil treated with mulches was significantly affected than un-mulched or control soil. There was a great significance between the treatments treated with mulches and control, the pH is 1.2 times than that of control, much research reported that the application of straw mulch has shown a slight improvement in the pH rise (Khan et al., 2002). In facts, under organic farming pH is a result of two processes namely ammonification and nitrification, by applying mulches it increases soil moisture contents which decreases soil air percentages so ammonification process increases which also increases soil reaction or pH, the PH in the top depth 0-10 cm was higher than in deep layer, the pH of soil at depths 0–10 and 10–20 cm were 7.8% and 6.6% higher than that of CK. Hence these findings agree with the research conducted by (Id et al., 2019)

Table 5. Analysis of Variance of Soil acidity (pH) records

| Chemical property | Source     | Partial SS | DF | MS   | F     | P>F  |
|-------------------|------------|------------|----|------|-------|------|
| Soil pH           | Model      | 6.665475   | 11 | 0.6060 | 13.61 | 0.0000 |
|                   | Treatments | 0.124475   | 3  | 0.0415 | 0.93  | 0.4406 |
|                   | Depth      | 2.40855    | 2  | 1.2043 | 27.04 | 0.0000b |
|                   | Treatments X Depth | 4.13245 | 6  | 0.6887 | 15.47 | 0.0000c |
|                   | Residual   | 1.0688     | 24 | 0.0445 |       |      |
|                   | Total      | 7.734275   | 35 | 0.2210 |       |      |
| Number of Observation | 36          | R²         |     |      | 0.8618 |      |
| Root MSE          | 0.211      | Adj R²     |     |      | 0.7985 |      |

a, b, c correspond to statistical significance difference at 5% level of significance

Soil electric conductivity (mS/m)

The highest electric conductivity in plots treated with rice straw was 374 milliSiemens per meter. The present research has shown that rice straw mulches improved the soil electric conductivity, the same findings were reported that the application of straw improved soil electric conductivity(Khan et al., 2002) the electric conductivity of soil surface layer was lower than subsurface in mulched treatments. In contrast, the electric conductivity in soil treated with beans straw and cut grass were reduced than of control. According to Pakdel et al. (2013) reported that mulches can reduce the soil electric conductivity in two ways 1. Mulching reduce soil water evaporation which also might reduce the accumulation in the soils. 2. Water soluble salts might be absorbed by mulch layer and water reaches soil layer with reduced EC, the fact that the straw mulches increased the soil electric conductivity were due to decomposing of applied organic mulch to suitable nutrients, released to the soil lead to increased accumulation of soluble salts in soil surface so the soil electric conductivity increased. These results are similar to(Sadek, Youssef, Solieman, Abdul, & Alyafei, 2019)

Table 6. Analysis of Variance (ANOVA) of electric conductivity (EC) records.

| Chemical property         | Source     | Partial SS | DF          | MS     | F     | P>F  |
|---------------------------|------------|------------|-------------|--------|-------|------|
| EC (Soil Salinity)        | Model      | 154556.8   | 11          | 14050.6136 | 113.37 | 0.0000 |
|                           | Treatments | 59012.75   | 3           | 19670.9167 | 158.72 | 0.0000a |
|                           | Depth      | 5946.5     | 2           | 2973.2500 | 23.99  | 0.0000b |
|                           | Treatments X Depth | 89597.5 | 6  | 14932.9167 | 120.49 | 0.0000c |
|                           | Residual   | 2974.48    | 24          | 123.9367 |       |      |
|                           | Total      | 157531.2   | 35          | 4500.8923 |       |      |
| Number of Obs             | =          | 36         | R²          | =      | 0.9811 |      |
| Root MSE                  | =          | 11.133     | Adj R²      | =      | 0.9725 |      |

a, b, c correspond to statistical significance difference at 5% level of significance
Soil organic matter and carbon (%)

The organic matter in plots treated by mulches was higher at the depths 0-10 and 10-20 cm than deeper layer. The organic matter in plots treated with mulches was highly significant than in control, the earlier studies have shown that mulches increase organic matter (Id et al., 2019), the research has shown that the application of straw mulch improved organic matter (Khan et al., 2002), Similar results were observed in the present study. The addition of organic mulches has increased the accumulation of organic carbon in the soil, an increased soil organic carbon was obtained in plots treated with beans straw and cut grass due quick decomposition, soil organic carbon in plots mulched with rice straw was higher than in un-mulched plots. The results from other studies confirmed that the application of organic mulches positively influences the amount of soil Organic carbon (Bajorien, Jodaugien, Pupalien, & Sinkevi, 2013).

Table 7: Analysis of Variance of soil organic Matter (SOM) and organic carbon (SOC) records.

| Chemical property | Source          | Partial SS | DF | MS    | F      | P>F   |
|-------------------|-----------------|------------|----|-------|--------|-------|
| SOM               | Model           | 818.75     | 11 | 74.4318 | 84.26  | 0.0000 |
|                   | Treatments      | 68.75      | 3  | 22.9167 | 25.94  | 0.0000*|
|                   | Depth           | 387.5      | 2  | 193.7500 | 219.34 | 0.0000B|
|                   | Treatments X Depth | 362.5   | 6  | 60.4167 | 68.4   | 0.0000C|
|                   | Residual        | 21.2       | 24 | 0.8833  |        |       |
|                   | Total           | 839.95     | 35 | 23.9986 |        |       |
| Number of Obs     | 36              |            |    | R²     |        | 0.9748 |
| Root MSE          | 0.940           |            |    | Adj R² |        | 0.9632 |

| SOC               | Model           | 430.25     | 11 | 39.1136 | 151.9  | 0.0000 |
|                   | Treatments      | 25.49      | 3  | 8.4967  | 33     | 0.0000a |
|                   | Depth           | 250.685    | 2  | 125.3425 | 486.77 | 0.0000b |
|                   | Treatments X Depth | 154.075 | 6  | 25.6792 | 99.72  | 0.0000c |
|                   | Residual        | 6.18       | 24 | 0.2575  |        |       |
|                   | Total           | 436.43     | 35 | 12.4694 |        |       |
| Number of Obs     | 36              |            |    | R²     |        | 0.9858 |
| Root MSE          | 0.507           |            |    | Adj R² |        | 0.9793 |

a, b, c correspond to statistical significance difference at 5% level of significance

IV. CONCLUSIONS AND RECOMMENDATIONS

Our findings suggests that organic mulches of straw of rice, beans, and cut grass exhibited positive effect by improving porosity, bulk density, moisture, pH, Electrical conductivity (EC), organic carbon and organic matter as soil physico-chemical properties comparatively to control (bare soil) in our study area. Mulching had no significant difference on bulk density. However soil organic matter and moisture content increased along the depths. Considering the effect of mulching on soil properties, straw mulches like rice and cut grass created a healthy environment than that of beans straw and can be recommended to be used by farmers in Eastern region of Rwanda.

ACKNOWLEDGEMENT

I would like to thank the government of Rwanda, particularly Office of the Prime Minister of Rwanda, Higher Education Council, University of Rwanda for their support and for granting me the opportunity to upgrade my studies.

CONFLICT OF INTEREST

The author of this article declare that there is no conflict of interest related to this publication manuscript.
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