

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 analyses 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 ³)
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 change 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^a
	Depth	309.1451	2	154.5725	190.05	0.000^b
	Treatments X Depth	230.701	6	38.4502	47.27	0.000^c
	Residual	19.52	24	0.8133		
	Total	594.0776	35	16.9736		
Number of Obs	=	36		R ²	=	0.9671
Root MSE	=	0.902		Adj R ²	=	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^a
	Depth	4.655	2	2.3275	0.71	0.5001
	Treatments X Depth	120.505	6	20.0842	6.16	0.0005^c
	Residual	78.3	24	3.2625		
	Total	289.2275	35	8.2636		
Number of Obs	=	36		R ²	=	0.7293
Root MSE	=	1.806		Adj R ²	=	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		R ²	=	0.0077
Root MSE	=	0.751		Adj R ²	=	-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
T1 (Rice Straw)	Mean	6.660	178.667	15.000	8.700
	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	7.733
	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	0.0000^b
	Treatments X Depth	4.13245	6	0.6887	15.47	0.0000^c
	Residual	1.0688	24	0.0445		
	Total	7.734275	35	0.2210		
Number of Observation		36		R ²		0.8618
Root MSE		0.211		Adj R ²		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	0.0000^a
	Depth	5946.5	2	2973.2500	23.99	0.0000^b
	Treatments X Depth	89597.5	6	14932.9167	120.49	0.0000^c
	Residual	2974.48	24	123.9367		
	Total	157531.2	35	4500.8923		
Number of Obs	=	36		R ²	=	0.9811
Root MSE	=	11.133		Adj R ²	=	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^a
	Depth	387.5	2	193.7500	219.34	0.0000^b
	Treatments X Depth	362.5	6	60.4167	68.4	0.0000^c
	Residual	21.2	24	0.8833		
	Total	839.95	35	23.9986		
Number of Obs	=	36		R ²	=	0.9748
Root MSE	=	0.940		Adj R ²	=	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		R ²	=	0.9858
Root MSE	=	0.507		Adj R ²	=	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.

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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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