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Effect of tillage, FYM, and mulch on soil physicochemical properties in Hamelmalo Region, Eritrea

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Abstract

Land degradation and water conservation are serious problems in Eritrea, hence to arrest degradation and conserve water, a field experiment was conducted in the watershed area of Hamelmalo Agricultural College, Keren, Eritrea during the summer season of 2018 intending to study the effect of tillage, FYM, and mulch on soil physicochemical properties with sorghum crop, under rainfed conditions. A split-split plot experimental design was chosen with tillage (conventional tillage, CT; reduced tillage, RT and no-till, NT) as the main plot, FYM (0, 5, 10, 15 t ha^{-1}) as sub-plot and mulch (0, 4 t ha^{-1}) as sub-sub-plot in three replications. Each sub-sub-plot was 15 m^2. The plots were bunded to avoid any run-off, in or out. The distance between subplots and sub-sub plots was 40 cm. Results showed that tillage affected infiltration rate and bulk density and FYM bulk density, and infiltration rate, positively influenced soil aggregation and soil chemical properties significantly ($p<0.05$). The highest mean weight diameter was observed in NT (6.12 mm), and the lowest was in CT (2.8 mm). Soil organic matter was highest in NT with 15 t ha^{-1} FYM, which elevated the organic matter content of the soil by 62 % as compared to pre-sowing. Phosphorus level in soil improved from very low to low in 15 t ha^{-1} FYM with mulch over 0 t ha^{-1}. FYM of 15 t ha^{-1} with Mulch brought a slight change in exchangeable cations (Na, K, Ca, and Mg).

Keywords: Farmyard manure, Mulch, Soil, Physico-chemical properties, Tillage.

Introduction

In Eritrea, high rainfall intensities, steep slopes, shallow soils, and poor ground cover result in high runoff and soil loss; with the disappearance of the topsoil and exposure of the compacted subsoil which would worsen land degradation. Soil and water management techniques are not effectively put into practice or utilized due to a host of factors including insecure land tenure system, weak agricultural extension services, low educational level of farmers, lack of confidence in adopting or adapting improved water harvesting and nutrient management measures (Tesfay et al. 2020). Thus, as a result of agroecosystem degradation, the land is unable to retain moisture and hence farmers are unable to harvest acceptable levels of crops even during the normal rainy season. Efforts are needed to develop techniques to increase the infiltration of soil and soil moisture retention capacity in the root zone and management practices such as minimum tillage, mulching, and application of farmyard manure can contribute almost in all aspects of soil quality and fertility. Soil biota increased under mulched soil environment thereby improving nutrient cycling and organic matter build-up for several years (Holland 2004). Low soil fertility is one of the most severe constraints to smallholder crop production and to sustain food security in dry lands (Alemu and Bayo 2005); to improve the fertility of the soil, incorporation of Farmyard Manure (FYM) into the soil is an alternative practice in dry land farming.

The present study, therefore, was undertaken to optimize tillage, the use of mulch, and the application of farmyard manure as soil and water management practices to improve the soil physical and chemical properties and fertility with sorghum as a test crop.

Materials and methods

The field experiment was conducted in the Model Integrated Watershed Management site at Hamelmalo Agricultural College (HAC), Keren, Eritrea, 15°52'21" N and 38°27'42" E latitude and longitude, respectively at an elevation of about 1285 m above mean sea level. The study area has a semi-arid climate with an average annual rainfall of 434 mm. Soil physicochemical properties of the experimental field were determined before sowing and after harvest using standard methods and procedures. The results of the physicochemical properties of the composite sample of the area are presented in Table 1.

Table 1: Soil physicochemical properties of the experimental field before sowing

Soil parameters	Value
Sand (%)	55.1
Silt (%)	31.5
Clay (%)	13.5
Textural class	Sandy loam
Bulk density (g cm^{-3})	1.45
Saturated hydraulic conductivity (cm hr^{-1})	4.2
Field capacity (%) by volume (cm^3cm^{-3})	0.27
EC (1:5) (dSm^{-1})	0.07
pH (1:5)	8.26
Organic matter (%)	0.47
Available nitrogen (%)	0.007
Extractable phosphorous (ppm)	2.6
Exchangeable potassium (mol kg^{-1})	0.87
Exchangeable Ca ($cmolkg^{-1}$)	26.3
Exchangeable Mg ($cmolkg^{-1}$)	4.6
Exchangeable Na+($cmolkg^{-1}$)	0.17
CEC (cmolkg-1)	28.4

Soil aggregates were determined as described by Kember and Rosenau (1986). The basic infiltration rate was measured using a double-ring infiltrometer before sowing and after harvesting following the procedure outlined by Brouwer et al. 1988. The saturated hydraulic conductivity (K_s) of soil was determined using the Porchet method.

$$K_s = 1.15r\,(\mathrm{Log}\,(ho+0.5r) - \log\,(ht + 0.5r)/t)$$

Where: K_s = hydraulic conductivity; t = time since the start of measuring (s); ht = the height of the water column in the hole at time t (cm), $h_0 = h_0$ at time t = 0; r = radius of the hole (cm).

The experiment was planned to have three tillage practices: conventional tillage (CT) reduced tillage (RT) and no-till (NT). Land leveling was done carefully to ensure an equal flow of water within the experimental plot except in no-till to avoid soil disturbances.

FYM in t ha^{-1} were; $F_0 = 0$, $F_1=5$, $F_2 = 10$, and $F_3 = 15$
Mulch in t ha^{-1} were; $M_0= 0$, $M_1 = 4$

Split-split plot design was used with three replications. Each replication consisted of 24 plots. For convenience tillage was taken as the main plot, FYM as a subplot, and mulch as sub-sub plots. Each sub-subplot had a dimension of 4.0 m x 3.75 m. The plots were bunded, (0.40 m wide and 0.30 m height,) appropriately to avoid any run-off or run-on. The distance between sub-plots and sub-sub plots was 40 cm and the size of replication was 26.8 m×17 m. The gross size of the study area was 80.8 m x 17 m. Sorghum variety [ICSV 210 (Bushika)] was sown at a seed rate of 15 kg ha^{-1}. The seeds were sown in rows 0.75 m apart at an average depth of (0.03 - 0.05) m manually.

The effect of tillage, FYM, and mulch on bulk density, infiltration rate, and saturated hydraulic conductivity, dry soil aggregate, chemical properties of composite soil were estimated. The data obtained from all the measured parameters of the experiment under various treatments were subjected to statistical analysis (Snedecor and Cochran, 1994) using the GEN STAT software (12th ed) and the treatment means were compared with Least Significant Difference (LSD) at a 5 per cent level of probability.

Results and discussions

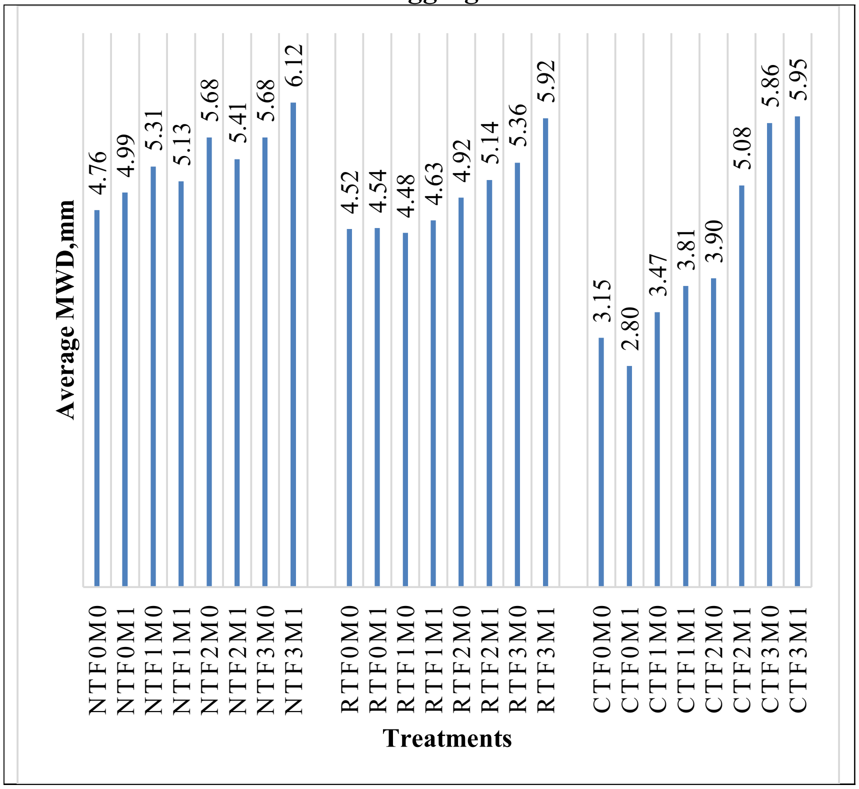
Table 2: The effect of tillage, FYM, and mulch on bulk density, infiltration rate, and saturated hydraulic conductivity (cm hr^{-1})

Treatments	BD Mgm^{-3}	IR cm hr^{-1}	Ks cm hr^{-1}
NTF$_0$M$_0$	1.53	3.23	4.43
NTF$_0$M$_1$	1.44	4.23	5.23
NTF$_1$M$_0$	1.46	5.20	5.43
NTF$_1$M$_1$	1.44	6.20	4.10
NTF$_2$M$_0$	1.40	7.07	4.40
NTF$_2$M$_1$	1.37	6.73	5.03
NTF$_3$M$_0$	1.42	7.57	4.70
NTF$_3$M$_1$	1.45	8.47	5.20
RTF$_0$M$_0$	1.41	4.00	3.93
RTF$_0$M$_1$	1.37	4.07	4.33
RTF$_1$M$_0$	1.37	6.53	4.97
RTF$_1$M$_1$	1.35	5.13	4.40
RTF$_2$M$_0$	1.38	6.40	4.83
RTF$_2$M$_1$	1.44	7.00	4.67
RTF$_3$M$_0$	1.39	7.80	5.07
RTF$_3$M$_1$	1.36	8.60	4.13
CTF$_0$M$_0$	1.37	4.27	3.70
CTF$_0$M$_1$	1.36	5.40	4.00
CTF$_1$M$_0$	1.32	6.67	4.53
CTF$_1$M$_1$	1.31	6.60	3.70
CTF$_2$M$_0$	1.36	6.80	4.70
CTF$_2$M$_1$	1.33	8.53	4.27
CTF$_3$M$_0$	1.31	10.6	5.13
CTF$_3$M$_1$	1.31	10.5	5.57
LSD*	NS	NS	NS
CV (%)	2.10	18.3	14.1
Factors	LSD*	LSD*	LSD*
Tillage	0.04	NS	NS
FYM	0.03	1.12	NS
Mulch	0.00	NS	NS

Note: *M_0=0 tha^{-1} and M_1=4 tha^{-1}, F_0=0 ton/ha, F_1=5 t ha^{-1} F_2=10 t ha^{-1} and F_2=15 t ha^{-1}, CT=conventional-tillage, NT=no-tillage and RT=reduced-tillage, BD-bulk density, IR-infiltration rate, Ks-hydraulic conductivity, LSD = Least Significance of Difference and CV = coefficient of variation, *p=0.05.*

Tillage showed a statistically significant difference in soil bulk density (BD) at harvest, $p<0.05$ (Table 2); perhaps because tillage disturbed soil particles and increased its volume as compared to non-plowed soils in the upper 10 cm depth. Hence, the highest (1.44 Mg m^{-3}) and lowest (1.34 Mg m^{-3}) BD after harvest were recorded in NT and CT, respectively. The finding was in agreement with Kashif (2006). Brady (1964) also reported that tillage significantly decreased the bulk density of the upper soil surfaces due to plowing. FYM incorporation into soil reduced soil bulk density. Moreover, increasing the FYM level facilitated the restoration of soil organic matter in the soil which helped to develop soil aggregates, thus increasing the infiltration rate. The highest and lowest BD at harvest was recorded in F_0, and F_3, respectively; F_1 was at par with F_2. These results were in agreement with Bloom et al. (1999), Kashif (2006), and Majid and Feredoun (2008) work. The perusal of data indicated a statistically significant difference in BD at harvest due to mulch. The decrease in bulk density might be due to mulch which had protected the soil from rainfall impact in comparison to non-mulched. This was in agreement with Kashif (2006) and Brady (1964). The effects of tillage, FYM, and mulch interactions on bulk density were statistically non-significant with the interaction of different treatments; however, a slight numerical decrease was observed, which might be due to the application of FYM and mulch. This finding was in agreement with Bandyopadhyay (2010).

Figure 1: Effect of tillage, FYM, and mulch interaction on dry soil aggregate



Note: M_0=0 t ha-1 and M_1=4 t ha-1, F_0=0 t ha-1, F_1=5 t ha-1, F_2=10 t ha-1 and F_2=15 t ha-1, CT=conventional-tillage, NT=no-till and RT=reduced-tillage.

There were statistically significant ($P<0.05$) differences in IR due to FYM application at harvest; Highest and lowest IR were recorded in treatments F_3 and F_0, respectively. The results of the interaction between tillage, FYM, and mulch on IR (cm hr^{-1}) revealed that after harvest, all treatments maintained statistically non-significant differences on the IR with a grand mean value of 6.57 cm hr^{-1}. However, numerically IR was increasing with an increasing rate of FYM and mulch application. The highest and lowest were in CT F_3 M_1 (10.60 cm hr^{-1}) and NT F_0 M_0 (3.23cm hr^{-1}), which was in agreement with Biamah et al. (2003). FYM also enhanced infiltration and reduced soil crusting and compaction.

There were no significant differences in hydraulic conductivity (Ks) due to tillage.

This could be mainly due to undisturbed porosity in NT and an immediate increase of porosity as a result of tillage in CT only in the upper soil layer which might not have affected the Ks of the profile. The results were in line with the reports of Tesfalem (2016). However, the effect of FYM on saturated hydraulic conductivity was found to be non-significant. The effects of tillage, FYM and mulch interactions were statistically non-significant for Ks in all the plots; however, an increment in hydraulic conductivity rate was observed with the increasing application of FYM, with mulch and tillage. Highest Ks was recorded in CT F_3 M_1 and the lowest in CT F0 M0. This finding was in agreement with Bandyopadhyay (2010) who reported that recommended dose of FYM resulted in a significant ($P < 0.05$) decrease in bulk density and an increase in hydraulic conductivity.

Table 3: Pre-sowing and post-sowing mean chemical properties of composite soil samples

Treatment	pH (1:5)	EC (1:5)	OM (%)	P (ppm)	N (%) avai	Na+ cmol/kg	K+ cmol/kg	Ca++ cmol/kg	Mg++ cmol/kg	CEC (cmol/kg)
Pre-sowing	8.26	0.07	0.47	2.60	0.01	0.17	0.87	26.30	4.60	28.40
Post-sowing										
Tillage										
NT	8.33	0.07	0.68	5.60	0.01	0.17	0.81	24.45	4.90	30.40
RT	8.25	0.06	0.60	7.52	0.01	0.15	0.89	22.98	4.61	28.74
CT	8.20	0.07	0.46	4.23	0.01	0.19	1.00	27.74	5.54	34.30
FYM										
F_0	8.30	0.06	0.35	3.32	0.01	0.17	0.87	26.10	5.20	32.32
F_1	8.27	0.06	0.46	4.76	0.01	0.16	0.83	24.05	4.82	29.90
F_2	8.23	0.07	0.66	6.21	0.01	0.16	0.94	23.88	4.80	29.78
F_3	8.23	0.07	0.85	8.84	0.01	0.20	0.95	26.18	5.25	32.58
Mulch										
M_0	8.26	0.07	0.55	6.16	0.01	0.19	0.91	25.67	5.14	31.93
M_1	8.25	0.06	0.60	5.41	0.01	0.15	0.89	24.44	4.89	30.36
Interaction of FYM *Mulch										
F_0+M_0	8.28	0.07	0.45	4.74	0.01	0.18	0.89	25.88	5.17	32.13
F_0+M_1	8.27	0.06	0.48	4.37	0.01	0.16	0.88	25.27	5.05	31.34
F_1 +M_0	8.27	0.07	0.51	5.46	0.01	0.18	0.87	24.86	4.98	30.92
F_1 +M_1	8.26	0.06	0.53	5.09	0.01	0.15	0.86	24.25	4.85	30.13
F_2+M_0	8.25	0.07	0.60	6.18	0.01	0.17	0.93	24.78	4.97	30.86
F_2+M_1	8.24	0.06	0.63	5.81	0.01	0.15	0.92	24.16	4.85	30.07
F_3+M_0	8.25	0.07	0.70	7.50	0.01	0.20	0.93	25.93	5.20	32.26
F_3+M_1	8.24	0.06	0.72	7.13	0.01	0.17	0.92	25.31	5.07	31.47
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15

The effect of tillage, FYM, and mulch interaction on dry soil aggregate is shown in Figure 1. The impact of tillage on soil aggregate decreased with increased FYM dose and with much; while mulch material and FYM led to improvement in soil conditions. The severity of the reduction in soil aggregate was strongly related to soil disturbances mainly because of more disturbed soil without FYM and mulch ranked the lowest in soil aggregation. Therefore, the lowest soil aggregates were observed in CT F_0 M_0. An increase in the application of FYM and mulch improved the soil aggregation conditions. The tillage practices negatively affected soil aggregation, which emphasized the removal of the soil sticking agents of soil aggregates. This result was in agreement with Tesfalem (2016) and Isaac (2008).

Relatively highest (8.30) and lowest (8.22) pH values were recorded in NTF0M0 and CTF3M1, respectively (Tables 3, 4, and 5). Compared with the pre-sowing soil pH (8.26), slight changes were observed in the pH of all treatments might be due to tillage, FYM, and mulch, yet the soil pH of all treatments after harvest remained unchanged at moderate alkaline. Short-term experiments might not bring considerable change in pH. Wagh et al. (2016) reported that a slight change in pH was observed under FYM and no specific trend was observed due to various treatments.

Table 4: Pre-sowing and post-sowing mean chemical properties of composite soil samples

Treatment	pH (1:5)	EC (1:5)	OM (%)	P (ppm)	N (%) avai	Na+ cmol/kg	K+ cmol/kg	Ca++ cmol/kg	Mg++ cmol/kg	CEC (cmol/kg)
Pre-sowing	8.26	0.07	0.47	2.60	0.01	0.17	0.87	26.30	4.60	28.40
Post-sowing of the Interaction of tillage *FYM										
NT+F_0	8.31	0.06	0.51	4.46	0.01	0.17	0.84	25.28	5.05	31.36
NT+F_1	8.30	0.06	0.57	5.18	0.01	0.17	0.82	24.25	4.86	30.15
NT+F_2	8.28	0.07	0.67	5.91	0.01	0.16	0.88	24.17	4.85	30.09
NT+F_3	8.28	0.07	0.76	7.22	0.01	0.18	0.88	25.32	5.08	31.49
RT+F_0	8.27	0.06	0.47	5.42	0.01	0.16	0.88	24.54	4.91	30.53
RT+F_1	8.26	0.06	0.53	6.14	0.01	0.15	0.86	23.51	4.71	29.32
RT+F_2	8.24	0.07	0.63	6.87	0.01	0.15	0.91	23.43	4.71	29.26
RT+F_3	8.24	0.06	0.72	8.18	0.01	0.17	0.92	24.58	4.93	30.66
CT+F_0	8.25	0.06	0.41	3.78	0.01	0.18	0.94	26.92	5.37	33.31
CT+F_1	8.23	0.06	0.46	4.50	0.01	0.18	0.92	25.89	5.18	32.10
CT+F_2	8.21	0.07	0.56	5.22	0.01	0.17	0.97	25.81	5.17	32.04
CT+F_3	8.21	0.07	0.66	6.54	0.01	0.20	0.97	26.96	5.39	33.44
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15
Interaction of tillage *Mulch										
NT+M_0	8.29	0.07	0.62	5.88	0.01	0.18	0.86	25.06	5.02	31.17
NT+M_1	8.29	0.06	0.64	5.51	0.01	0.16	0.85	24.45	4.90	30.38
RT+M_0	8.25	0.07	0.57	6.84	0.01	0.17	0.90	24.32	4.88	30.34
RT+M_1	8.25	0.06	0.60	6.47	0.01	0.15	0.89	23.71	4.75	29.55
CT+M_0	8.23	0.07	0.51	5.19	0.01	0.19	0.95	26.70	5.34	33.12
CT+M_1	8.22	0.06	0.53	4.82	0.01	0.17	0.95	26.09	5.21	32.33
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15

Highest (0.71%) and lowest (0.46%) values of SOM were recorded in NTF3M1 in CTF0M0, respectively. Both individual and interactive (combined) effects of the given treatments showed a numerical increase in soil organic matter. Out of all the treatments applied, NT+F3 showed a relatively highest increment in SOM, which elevated the organic matter content of the experimental soil by 61.7 % as compared to pre-sowing SOM content. Yet, the organic matter content of the soil after harvest was very low as per Charman and Roper (2007) rating standards of soil chemical properties. Since this result was found from a one-year experiment, long-term experiments might be recommended to achieve optimum organic content.

There was no considerable change in soil electrical conductivity (EC) as affected by the different treatments. The highest value recorded was 0.07 which was the same as the original soil EC, depicting no change in EC despite the applied treatments. The lowest value recorded was 0.06, which showed a slight change as compared to the pre-sowing soil EC. Based on the results of the analysis, it could be concluded that there was no change in soil electrical conductivity due to the applied treatments under the one-year experimental condition. Wagh et al. (2016) reported that a slight change in electrical conductivity was observed under FYM and no specific trend was observed due to various treatments.

Table 5: Pre-sowing and post-sowing mean chemical properties of composite soil samples

Treatment	pH (1:5)	EC (1:5)	OM (%)	P (ppm)	N (%) avai	Na$^+$ cmol/kg	K$^+$ cmol/kg	Ca^{++} cmol/kg	Mg^{++} cmol/kg	CEC (cmol/kg)
Pre-sowing	8.26	0.07	0.47	2.60	0.01	0.17	0.87	26.30	4.60	28.40
Post-sowing of the interaction of tillage, FYM, and mulch										
NTF$_0$M$_0$	8.30	0.07	0.53	5.03	0.01	0.18	0.89	25.41	5.08	31.55
NTF$_0$M$_1$	8.29	0.06	0.54	4.78	0.01	0.16	0.88	25.00	5.00	31.03
NTF$_1$M$_0$	8.29	0.07	0.56	5.51	0.01	0.18	0.88	24.72	4.95	30.74
NTF$_1$M$_0$	8.28	0.06	0.58	5.26	0.01	0.16	0.87	24.31	4.87	30.22
NTF$_2$M$_0$	8.27	0.07	0.63	5.99	0.01	0.17	0.91	24.67	4.95	30.71
NTF$_2$M$_1$	8.27	0.06	0.64	5.74	0.01	0.16	0.91	24.26	4.86	30.18
NTF$_3$M$_0$	8.27	0.07	0.69	6.87	0.01	0.19	0.91	25.43	5.10	31.64
NTF$_3$M$_1$	8.27	0.06	0.71	6.62	0.01	0.17	0.91	25.03	5.01	31.11
RTF$_0$M$_0$	8.27	0.07	0.50	5.67	0.01	0.17	0.93	24.91	4.98	31.00
RTF$_0$M$_1$	8.26	0.06	0.52	5.42	0.01	0.15	0.92	24.51	4.90	30.47
RTF$_1$M$_0$	8.26	0.07	0.54	6.14	0.01	0.17	0.91	24.23	4.86	30.19
RTF$_1$M$_1$	8.25	0.06	0.55	5.90	0.01	0.15	0.91	23.82	4.77	29.67
RTF$_2$M$_0$	8.25	0.07	0.60	6.63	0.01	0.16	0.95	24.18	4.85	30.15
RTF$_2$M$_1$	8.24	0.06	0.62	6.38	0.01	0.15	0.94	23.77	4.77	29.63
RTF$_3$M$_0$	8.25	0.07	0.67	7.50	0.01	0.18	0.95	24.94	5.00	31.08
RTF$_3$M$_1$	8.24	0.06	0.68	7.26	0.01	0.16	0.95	24.53	4.92	30.56
CTF$_0$M$_0$	8.25	0.07	0.46	4.57	0.01	0.18	0.86	26.50	5.29	32.85
CTF$_0$M$_1$	8.25	0.06	0.47	4.32	0.01	0.17	0.86	26.09	5.21	32.33
CTF$_1$M$_0$	8.24	0.07	0.49	5.05	0.01	0.18	0.85	25.82	5.17	32.04
CTF$_1$M$_1$	8.24	0.06	0.51	4.80	0.01	0.17	0.84	25.41	5.08	31.52
CTF$_2$M$_0$	8.23	0.07	0.56	5.53	0.01	0.18	0.89	25.76	5.16	32.01
CTF$_2$M$_1$	8.22	0.06	0.57	5.29	0.01	0.16	0.88	25.35	5.08	31.48
CTF$_3$M$_0$	8.23	0.07	0.62	6.41	0.01	0.20	0.89	26.53	5.31	32.94
CTF$_3$M$_1$	8.22	0.06	0.64	6.16	0.01	0.18	0.88	26.12	5.23	32.41
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15

There was no difference in available nitrogen level (N) among all the treatments. Available soil nitrogen in the experimental area was very low (Bruce and Rayment 1982). The phosphorous level (P) of the soil before sowing was very low (2.6 ppm), but after harvest, the highest values were recorded in RT (7.52 ppm), F3 (8.8 ppm), M$_0$ (6.16 ppm), RT+F$_3$ (8.18 ppm), RT+M$_0$ (6.84 ppm), F$_3$+M$_0$ (7.50 ppm) and RTF$_3$M$_0$ (7.50 ppm) when all treatments are independently considered. Out of all the different treatments applied, however, the highest increment in P was recorded in F3 and soil P was increased by 238.5 % as compared with the level of soil P before sowing. This might be attributed to the application of FYM, which was rich in phosphorous. The lowest values, on the other hand, were recorded in CT (4.23 ppm), F$_0$ (3.32 ppm), M$_1$ (5.41 ppm), CT+F$_0$ (3.78 ppm), CT+M$_1$ (4.82 ppm), F$_0$+M$_1$ (4.37 ppm) and CTF$_0$M$_1$ (4.32 ppm). When the mean value of all the aforementioned treatments was evaluated, soil P showed an overall increment of 122.3

%. Despite the great increment in soil P after harvest, as compared to the pre-sowing P-level, the current P-level in the soil was still low (Holford and Cullies, 1985; Verde et al. 2013). Therefore, continuous application of the recommended dose of FYM might bring soil P to the optimum level with time.

A slight numerical change was observed in exchangeable cations due to tillage treatment. Highest values were recorded in conventional tillage (CT) for sodium (0.19 cmol/kg), calcium (27.74 cmol/kg), and magnesium (5.54 cmol/kg) and in Reduced Tillage (RT) for potassium (1.0 cmol/kg). Similarly, the application of FYM and mulch brought a slight change in exchangeable cations and the highest values were recorded in F3 0.2 cmol/kg, 0.95 cmol/kg, 25.67 cmol/kg, and 5.25 cmol/kg for Na, K, Ca and Mg, respectively and M_0 0.19 cmol/kg, 0.91 cmol/kg, 25.67 cmol/kg and 5.14 cmol/kg for Na, K, Ca and Mg, respectively for all of the exchangeable cations studied. Similar to the individual treatment, the synergetic effect also showed a numerical but very slight change in exchangeable cations, and the highest values were observed in treatment combinations of CT+F_3, CT+M_0, F_3+M_0, and CTF_3M_0, almost for all the cations considered under this study. The changes observed in exchangeable cations due to the applied treatment were very negligible and this slight change might have a role in improving the levels of these cations for plant nutrition but did not have any negative impact on the soil environment as their level was still low except for Ca rated as very high and Mg high both pre-sowing and after harvest (Metson 1961).

The Cation Exchange Capacity (CEC) of the experimental soil was slightly changed when it was evaluated after harvest under all the treatments applied. Relatively highest values were recorded in CT (34), F_3 (32.58), M_0 (31.93), CT+F_3 (33.4), CT+M_0 (33.12), F_3+M_0 (32.26) and CTF_3M_0 (32.92) in tillage, FYM, Mulch, the interaction between tillage and FYM, between tillage and mulch, between FYM and mulch, and among tillage, FYM, and mulch, respectively. Out of all the treatments applied, the highest CEC was observed in Tillage (CT) followed by a combination of tillage and FYM (CT+F_3) and tillage and mulch (CT+M_0). Though the relative change in CEC was observed in the experimental soil after harvest, the change was negligible as CEC values both pre-sowing and after harvest was under the same rating as per Metson (1961). This current result indicated that short-term experiment was less probable to bring significant change in soil chemical properties.

Conclusions

Interactions of tillage, FYM, and mulch have a positive impact on soil properties. Tillage showed a statistically significant difference in BD at harvest at 0-10 cm depth. Hence conventional tillage was detrimental to the soil's physical properties. Leveled bunded land, no-till with mulch had a less negative impact on soil properties. Application of FYM also had a significant effect on BD, infiltration rate (IR), and soil aggregation at harvest. In addition, all the soil's chemical properties showed improvements.

Recommendations

Continuous application of FYM during tillage practices will have less negative impact on soil physical properties due to tillage practice. To keep soil potentiality and productivity continuous application of FYM is desired. Even the soil nutrient capacity was improved in the first application. These recommendations are based on one-year research, hence to make them more concrete and sounder, the experiment should be repeated.

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