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Effect of some soil and water management practices on soil profile moisture under rain-fed conditions in Hamelmalo Region, Eritrea

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Abstract

The irregular and torrential nature of rainfall in Eritrea necessitate improving the water storage capacity and its distribution in the soil profile to sustain livelihood of rural household; hence a field experiment was conducted in the watershed area of Hamelmalo Agricultural College during the cropping season of 2018, to study the effect of tillage, farm yard manure (FYM) and mulch on water retention capacity and its distribution in the soil profile under rainfed conditions with sorghum as test crop. 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 with three replications. Each sub-sub-plot was 15 m^2. The plots were well bunded to avoid any run-off or run-in. The distance between sub-plots and sub-sub-plots was 40 cm. The results showed that the soil moisture profile storage was affected by different soil management practices; mulch showed considerable effects on soil profile moisture content; tillage caused the reduction in moisture in the upper layers; reduced tillage with 15 t ha^{-1} FYM performed better than all other treatments in soil profile water storage and its distribution.

Keywords: Farmyard manure, Moisture content, Moisture distribution, Mulch, Soil profile, Soil profile, Tillage.

Introduction

Rainfall in Eritrea is torrential, of high intensity, short duration, and varies greatly from year to year. Average precipitation in the country is about 384 mm yr^{-1} (MoA, 2002) with only 1% of the total area receiving more than 650 mm of annual rainfall (FAO, 1994). The rationale is to conserve this water in the soil profile to eliminate soil water deficit during naturally occurring dry spells using soil and water management techniques. Although, various types of soil and water management techniques have been implemented in Eritrea for the last decades; these are not effectively put into practice or utilized due to a host of factors (Tesfay *et al.,* 2020). Rainfall that the country receives if conserved and managed properly can be enough to meet the national water need but most of it is lost through runoff, evaporation, and drainage. Hoogmoed and Stroosnijder (1984) reported that runoff losses from a field with bare soil can amount to 30-35% of storm rainfall. To reduce runoff, and thereby increase available soil water; the infiltration rate and water-holding capacity of soil have to be increased through management practices such as minimum tillage, mulching, and application of farmyard manure. If the technology is adapted by rural households, it would be possible to produce enough food for them with surplus for sale to compensate for their household demands. Bissrat *et al.,* (2012) suggested that policy makers should introduce sustainable land management practices, including efficient water harvesting and water management strategies to cope with water scarcity and high runoff.

In view of the above background, production in arid and semi-arid areas of Eritrea could be ameliorated through effective soil and rainwater management practices. Therefore, the present study was intended to study the effect of tillage, FYM, and mulch as an effort to solve one of the major constraints i.e. available soil water to sustain the agricultural production in the country.

Materials and methods

The field experiment was conducted in Hamelmalo Agricultural College, Eritrea at 15°52'21" N and 38°27'42" E latitude and longitude, respectively and an elevation of 1285 m above mean sea level under rain-fed conditions during the summer season of 2018; annual rainfall in the growing season was 477 mm (Table 1).

Table 1: Distribution of rainfall in Hamelmalo (Eritrea) during the months of 2018

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ran-fall (mm)	0	0	0	6.6	58.5	27.8	227	135	87.3	0	7.4	0

A soil split with dimensions 1.5 m by 1.5 m was dug to a depth of 2.0 m in the center of the research plot to examine the soil profile and describe the morphological properties of the soil. FAO (1990) guidelines were used to determine the soil structure, stickiness, and plasticity. Bulk density was measured before sowing and after harvest using the core sampler Method (Blake and Hartge 1986).

Soil profile moisture per representative plot was recorded after sowing (0–100 cm) at 10 days intervals during the crop growing period to study the distribution and redistribution of soil water in the profile. A soil moisture meter (Delta-T, 2017) was used to measure the soil moisture profile with a probe from the installed access tube, inserted at 0 -110 cm depth in the soil profile.

Gravimetric water from the saturated plot was allowed to drain out and surface water content was measured gravimetrically every day till it became constant, this was attained in two days, and this constant value of water content was taken as field capacity.

Tillage - Conventional tillage (CT), reduced tillage (RT), and no-till (NT).
Farmyard manure (t ha^{-1}); F0 = 0, F1=5, F2 = 10, and F3 = 15
Mulch (t ha^{-1}); M0 = 0, M1 = 4

Split-split plot design was used with three replications. Each replication consisted of 24 plots. Tillage was taken as the main plot, FYM as the sub-plot, and mulch as the sub-sub-plot. Sorghum variety [ICSV

210 (Bushika)] was sown at a seed rate of 15 kg ha^{-1}.

The data obtained from all the measured parameters of the experiment under various treatments were subjected to statistical analysis using the GENSTAT software (12^{th}ed) and the treatment means were compared with Least Significant Difference (LSD) at a 5 per cent level of probability.

Results and discussions

Soil profile characteristics were studied to examine any kind of hindrances to restrict moisture movement through the profile. The soil of the study area is dominantly alluvial deposits from the surrounding hilly terrains. Six distinct layers/horizons with little difference were identified in the profile pit. The important profile characteristics are summarized in Table 2. The soil structure in the surface layers was granular but harder in consistency and blocky in the lower layers. The bulk density of the 0-20 cm was 1.43 Mgm^{-3} and 1.74 Mgm^{-3} in the lower layer. The increase in density might be due to lower organic matter content, low aggregation, and overload of the upper layers. The groundwater table in the area ranged from about 7m during the rainy season up to 9 m in the dry season.

Table 2: Soil profile characteristics of the study area

Layer	Depth cm	Bulk density Mg m^{-3}	Color		Texture	Structure	Consistency		Hardpan	Crop Root
			Dry	Moist			Dry	Moist		
A1	0-20	1.43	5YR 4/6 Brown	5YR 4/4 Dull Reddish Brown	Sandy Loam	Granular	Hard	Loose	None	Common
A2	20-50	1.39	5YR 5/6 Light Brown	5YR 3/2 Dark Reddish Brown	Sandy Loam	Granular	Hard	Loose	None	Common
A3	50-80	1.4	5YR 4/4 Brown	5YR 2/3 Very Dark Reddish Brown	Sandy Loam	Blocky	Loose	Loose	None	Common
A4	80-115	1.64	5YR 3/6 Dark Red	5YR 2/3 Very Dark Reddish Brown	Sandy Loam	Blocky	Loose	Loose	None	Few
A5	110-125	1.66	5YR 5/3 Dull Reddish	5YR 3/3 Dark Reddish Brown	Sandy Loam	Blocky	Loose	Hard	None	Few
A6	>125	1.74	5YR 4/3 Dull Reddish Brown	5YR ¾ Dark Reddish Brown	Sandy Loam	Blocky	Hard	Hard	None	Very Few

Soil profile moisture content was measured at depths 10 cm, 20 cm, 30 cm, 40 cm, 60 cm, and 100 cm, during the various phonological phases from sowing up to harvest (Figures 1-6). The moisture data were recorded after every ten-day interval, except the last reading which was taken after 26 days from the previous record.The results showed that the soil moisture profile storage was affected by different soil management practices. Out of the factors, mulch showed considerable effects on soil profile moisture content (Figures 1-6). Within the factors reduced tillage with 15 t ha^{-1} FYM (RTF3M1) increased soil water storage. Hence, the availability of soil moisture in every mulched plot with 10 and 15 t ha^{-1} dose of FYM was at an optimum level, as a result statistically significant yield of sorghum was recorded in mulched plots than non-mulched. In contrast to mulch and FYM, soil tillage decreased moisture content at a depth of 10-20 cm, which might be due to increased evaporation, especially in the control non-mulched plots. However, in the control and non-mulched treatments (plots) without FYM, during the flowering stage, the crop experienced moisture stress. Similar results were reported by Sahindomi, (2003); he reported that the application of straw mulches and soil tillage can maintain the availability of soil moisture at a depth of 20 to 60 cm.

Figure 1: The average distribution of soil profile moisture content in NO TILL without mulch

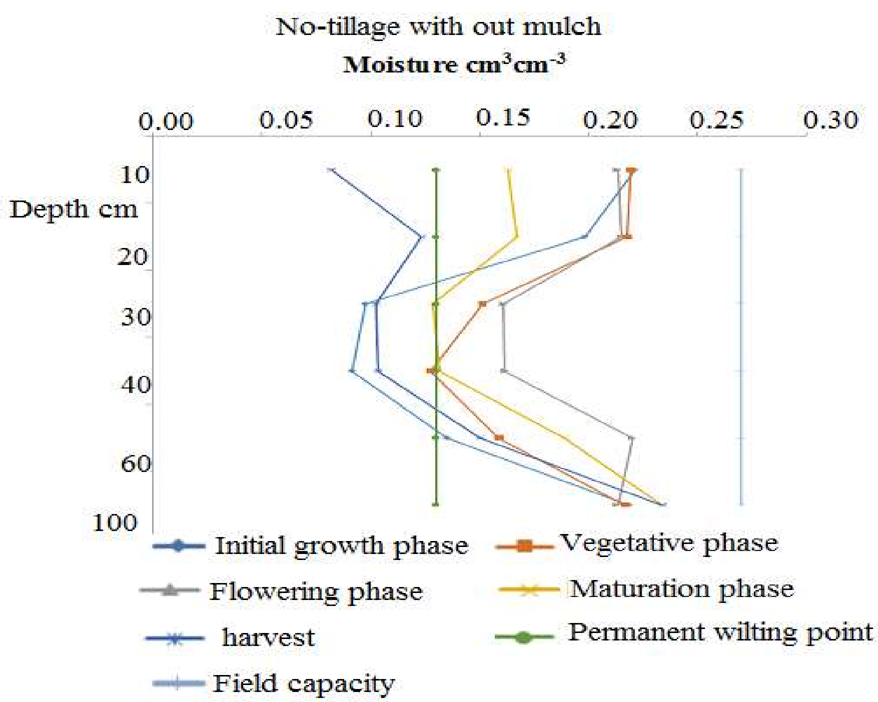


Figure 2 represented the seasonal moisture distribution in the soil profile with no tillage practices with mulch. In the mulched plots, the moisture level remained above FC up to 30 cm depth during the whole growing season; whereas in the case of non-mulched plots (Figure 2), the soil moisture was near the permanent wilting point. Hence, mulch helped to conserve soil moisture in the root zone. A review of tillage studies in Nigeria (Opara, 1990) showed that NT with residue mulch was appropriate for Luvisols.

Fig 2: The average distribution of soil profile moisture content in NO TILL with mulch

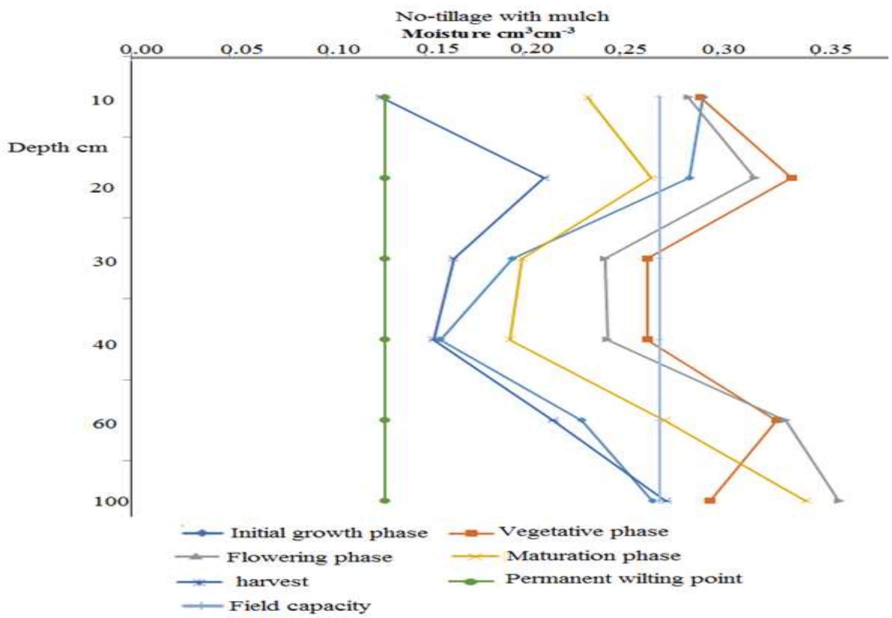
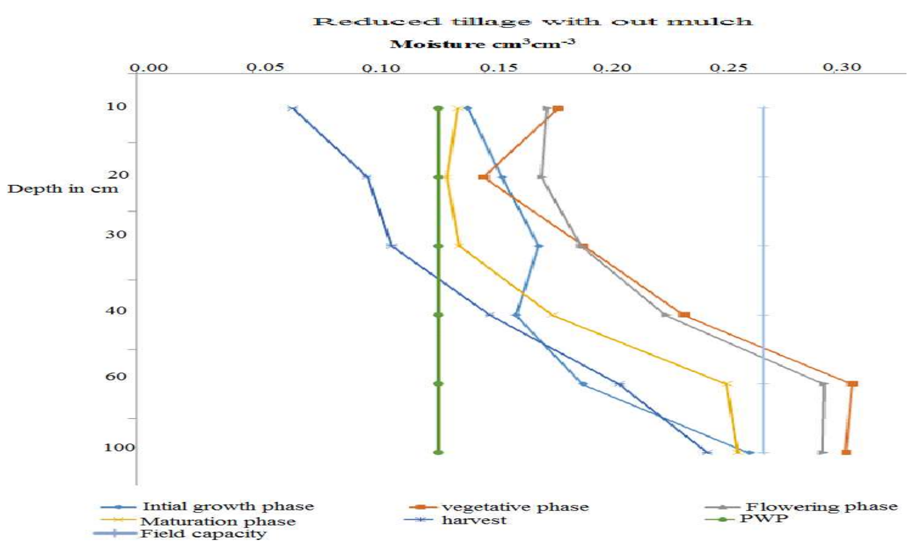


Fig 3: The average distribution of soil profile moisture content in reduced tillage without mulch



Figures 3 and 4 represented the seasonal moisture distribution in the soil profile of the reduced tillage practices without and with mulch. In non-mulched plots, soil moisture remained near permanent wilting points up to 30 cm depth. In mulched plots, it was near FC but less than the similar plots in NT, this decrease might be due to increased evaporation loss in non-mulched plots and also due to increased infiltration into down layers due to tillage in both cases; mulched plots performed better in conserving soil moisture as moisture content remained near field capacity in these plots. Zhang, (2015) also reported that in dry land farming conditions, straw mulch decreased the rate of evaporation which allowed more soil water to be accumulated as compared with untreated control.

Fig 4: The average distribution of soil profile moisture content in reduced tillage with mulch

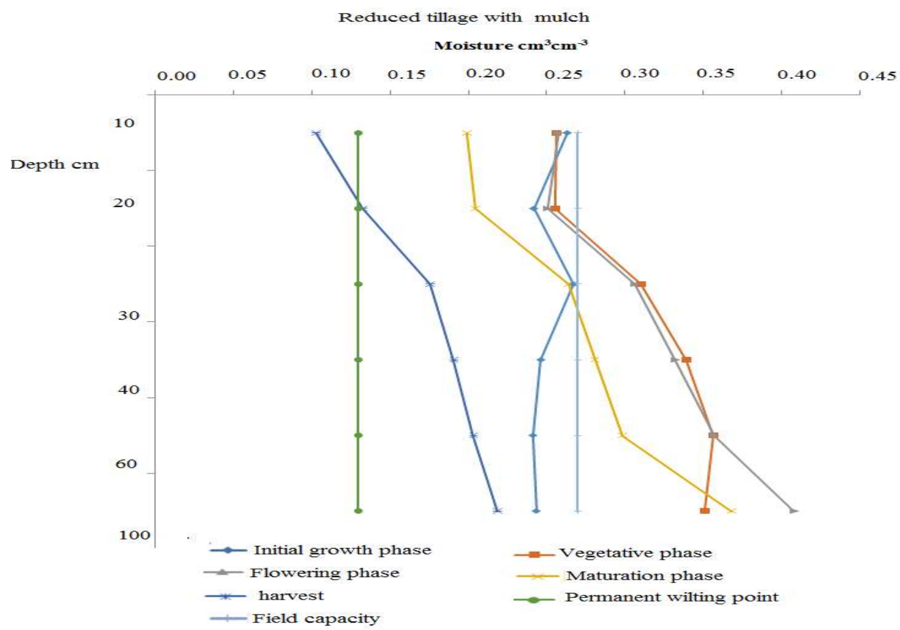
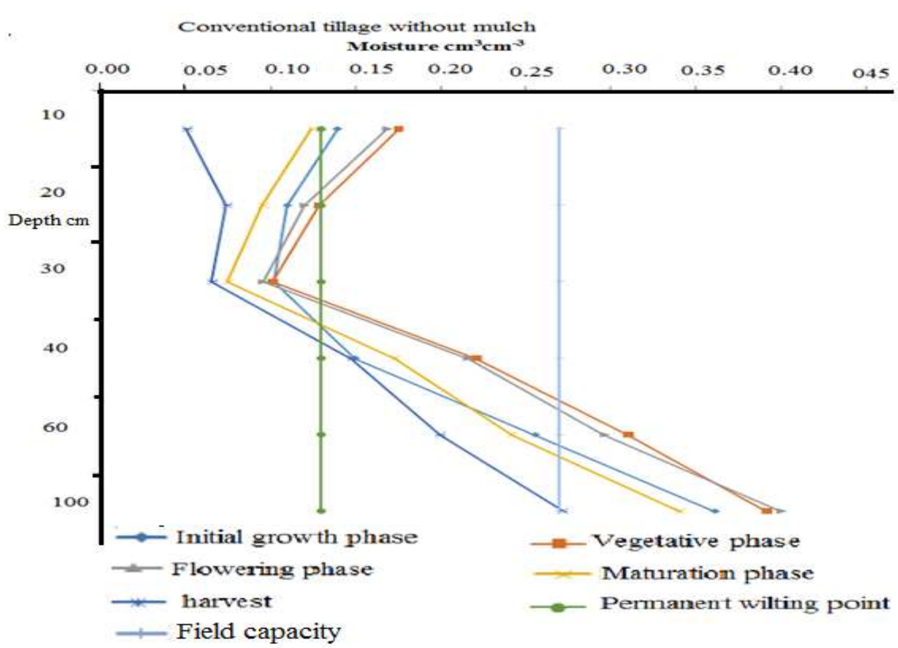
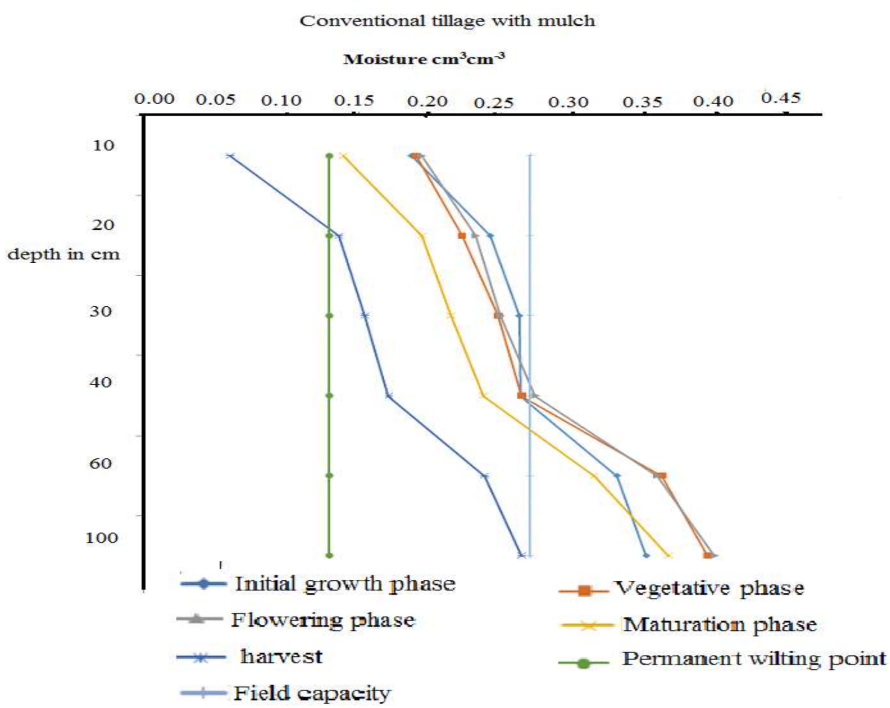


Fig 5: The average distribution of soil profile moisture content in conventional tillage without mulch



Figures 5 and 6 presented the seasonal moisture distribution in the soil profile of conventional tillage practices without and with mulch. In this case, the soil moisture content was below permanent wilting points up to 30 cm depth in non-mulched plots; whereas in mulched plots it was below FC up to 40 cm depth but above permanent wilting point. This showed that tillage enhanced the evaporation and infiltration, which caused the reduction in moisture in the upper layers, however mulching resulted in reduced evaporation loss which was responsible for higher moisture content in mulched plots. Similar results were reported by Halfmann *et al.,* (2005) regarding infiltration i.e virgin soils showed a much lower infiltration rate for the tension infiltrometer, while the conventional tillage system showed higher infiltration rate.

Fig 6: **The average distribution of soil profile moisture content in conventional tillage with mulch**



Conclusions

Conventional tillage was detrimental to soil physical properties, as a result, less soil moisture was conserved in the upper soil profile in conservation tillage within none mulched plots.The availability of soil moisture in every mulched plot specifically with 10 and 15 t ha^{-1} dose of FYM was at optimum level. In no-till and conventional tillage the green water was above and below 60 cm, respectively. Soil moisture in mulched plots conserved more moisture in comparison to non-mulched plots. Reduced tillage with 15 t ha^{-1} FYM performed better than all other treatments in soil profile water storage and distribution.

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