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Short-term effects of conservation agriculture on soil erosion and agronomic parameters of tef (*Eragrostis tef* (Zucc.) Trotter) in the northern Ethiopian highlands

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Introduction

Agriculture in Ethiopia is dominated by rainfed farming of low productivity. The annual grain production, which is on average 7 million tonnes, is too low to support national food demands (Eyasu, 2005). Land degradation in the form of soil erosion and declining soil quality is a serious challenge to agricultural productivity and economic growth (Mulugeta et al., 2005). Tigray, the northern-most region of the country, suffers from extreme land degradation as steep slopes have been cultivated for many centuries and are subject to serious soil erosion (Wolde et al., 2007). Rainfall is seasonal and erratic in Northern Ethiopia, particularly in Tigray. Consequently, there is strong seasonal (~8 months) moisture stress limiting the productivity of rainfed agriculture in the region (Haregeweyn et al., 2005). In addition to this problem, tillage in Ethiopia is carried out with a breaking ard plough, locally known as “maresha”, whose shape and structure have remained unchanged for thousands of years (Nyssen et al., 2000). Soil erosion due to high tillage frequency and other soil management problems has seriously affected over 25 % of the Ethiopian highlands (Kruger et al., 1996). Such detrimental effect of soil erosion and water stress can be improved to some extent by other management options like conservation agriculture (CA) practices, including permanent beds and semi-permanent beds. Conservation agriculture experiment was started in January 2005 in Adigudom to test the impact of the different soil management practices on agronomic properties of crops and soil erosion.

Materials and methods

The study site

The CA experiment begun in January 2005 in Gumselasa (Adigudom), Northern Ethiopia (13°14' N and 39°32' E) located ~740 km north of Addis Ababa at an altitude of 1960 m a.s.l. The area has a cool tropical semi-arid climate, characterized by recurrent drought induced by moisture stress. Rainfall in the study site is unimodal, with > 85 % falling in the period of July -September. The mean annual rainfall (26 yr) is 504.6 mm (MU-IUC, 2007) and the mean annual temperature is 23

°C. The soil has a clay content of 73 % and 24 % silt content with high calcium content (20 %) and high pH-$_{H2O}$ (8.1). Together with the swelling and shrinking characteristics, which is observed from large cracks during the dry season, the soil is classified as pelli Calcic Vertisol according to WRB (1998).

Experimental layout and data analysis

The experimental design was a randomised complete block with two replications for each of the following treatments: **1).** Traditional tillage practice (TRAD), **2).** *Terwah* (TERW): This is a traditional water conservation technique in which furrows are made with "*maresha*" along the contour at an interval of 1.5-2 m. It is similar to TRAD except for the furrows at regular interval and is repeated yearly. **3).** Permanent beds (PB): Beds and furrows of 60-70 cm width (middle of the furrow to the next one) were made after plowing the plots. The furrows were reshaped after every cropping season without any disturbance on the top of the bed.

Runoff volume was measured at 0800 after each storm that caused runoff, by measuring the depth of collected runoff in the trench using a graduated ruler and reducing the amount of direct rainfall into the ditches. The collected runoff was stirred thoroughly and ~ 4 l was collected from each trench using two 2 l plastic bottles for the determination of sediment concentration. Then the contents of runoff were filtered and sediment on the filter paper was then oven-dried for 24 hours at 105°C and weighed. Agronomic parameters were collected. The Harvest Index was also calculated as the ratio of grain yield to the dry aboveground biomass. ANOVA was used to test the statistical differences of runoff and sediment loss and crop parameters between the management treatments. Mean comparison (student t-test, at alpha = 0.5) was conducted for parameters that were significantly different. The JMP version 5.0 (SAS Institute Inc., 2002) software was used for analysis.

Results and discussion

Runoff and soil loss measured after each rainfall that caused runoff showed that both runoff and sediment loss were not significantly different among treatments on the first week after sowing (Figure not shown). This can be due to the disturbance of the field during reshaping and plowing at sowing. Once the soil was stabilized, (i.e after crop emergence), TRAD had a significantly higher runoff volume than PB for a given rainfall amount. Engel et al. (2009) found out variation in runoff during the different growth stages of crops grown on their research under simulated rainfall. However, they also found significantly lower runoff from the NT treatment over the total growing period, as has been the case in our site. TERW and TRAD had significantly higher runoff than PB especially at high rainfall periods. Soil loss was significantly lower in TERW and PB compared to TRAD especially during the end of rainy season

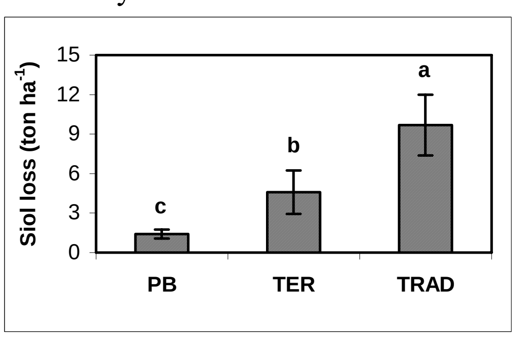

Figure 1. Mean total runoff depth (±SE) for the growing period (n=6)

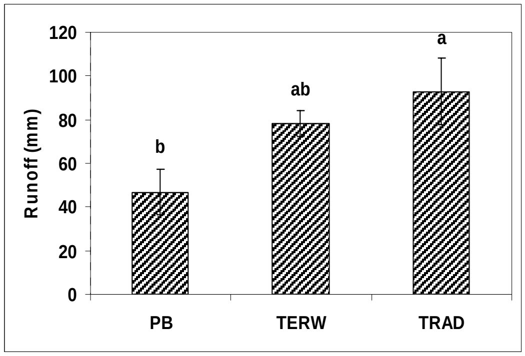

Figure 2. Mean total soil loss (±SE) from each treatment during the whole growing period (n=12)

The overall runoff volume over the complete growing period showed that PB had significantly lower runoff than TRAD (Fig. 1 and 2). PB also showed lower runoff compared with TERW, although it was not significant. The mean of total runoff volume collected from TRAD, TERW and PB was 92.8, 78.2 and 46.7 mm, respectively. Soil loss was significantly higher in TRAD than the other two treatments by the end of the rainy season, especially when high rainfall occurred, unlike runoff where TRAD and TERW had no significant difference. There were significant differences among all treatments (Fig. 2) in overall soil loss (p=0.0002).

PB resulted in the lowest grain yield, with a mean of 678 kg ha^{-1} (Table 1). There was also a significant difference in yield between TERW (mean yield of 925 kg ha^{-1}) and PB. Tef is a weed sensitive crop and needs more frequent plowing, especially in heavy clay soils (Rockström *et al.*, 2009; Seyfu, 1997) There was significantly high weed infestation (p=0.0016) among treatments. The mean mass of weed dry matter during the first weeding in the TRAD, TERW and PB was 77, 125 and 242 kg ha^{-1}, respectively. Therefore, the significantly lower production (p= 0.0174) of tef on PB compared to TERW and TRAD in this experiment could most probably be due to resource competition from high weed infestation. There was a strong negative correlation (r= -0.956) between weed dry matter and tef yield too.

Table 1: Agronomic parameters; mean tef yield, mean biomass, mean plant height, mean weed dry matter at first weeding and harvest index for the different treatments. Values between parentheses are standard error (α = 0.05, n = 6)

Treatment	*Tef yield (kg ha^{-1})*	*Weed dry matter (kg ha^{-1})*	*Tef biomass (kg ha^{-1})*	*Plant height at maturity (cm)*	*Harvest index*
TRAD	1173 (50) a	77 (4) c	6.7 (0.18) a	44 (2.5) a	0.18 (0.007) b
TERW	925 (99) b	125 (10) b	4.5 (0.64) b	39 (3.5) b	0.21(0.007) a
PB	678 (73) c	242 (17) a	3.0 (0.69) b	31(1.7) b	0.22 (0.004) a

Plant height at maturity was significantly higher for TRAD compared with both TERW and PB. The Harvest Index (HI) of PB and TERW was significantly (p=0.01) higher than TRAD (Table 1). Although there was a significant difference in yield between treatments, no difference in tef biomass was observed between PB and TERW. The significantly higher HI on PB and TERW compared to TRAD (p=0.0100) could be explained by the strong negative correlation of HI with yield and biomass of tef (r = -0.97 and r = -0.99, respectively).

Conclusions

The effectiveness of TERW and PB in runoff and soil loss reduction suggests that these soil managements systems could be a requirement for all crops for better soil and water conservation. However; TERW can be considered as first step towards conservation agricultural practice. This short-term research showed that yield, biomass and plant height of tef were significantly higher in TRAD than in PB. The significantly high weed dry matter at first weeding in PB, the types of weeds and their water uptake behavior may have caused the reduced tef yield. Appropriate rate of herbicides must be used while growing tef in CA experiments.

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