Original Research Article

Effect of Organic Manure on Sorghum (*Sorghum Bicolor*)Yield, Runoff and Soil Loss at Tahitay-Adiabo District, Tigray, Ethiopia

ABSTRACT

A field experiment was conducted under natural rainfall conditions to investigate the effects of manure and compost on soil loss, run-off, and yield of sorghum in the 2019 and 2020 cropping seasons. The experimental design used was a randomized complete block design (RCBD) with six treatments (control, compost, animal manure, compost + mulch, animal manure + mulch, and recommended NP fertilizer) with three replications. Each plot had a dimension of 6 x 4 m and a land slope of 4%. The results revealed that there was a significant difference ($P<0.001$) between the treatments regarding their effect on runoff volume, soil loss, and sorghum yield. Application of compost, compost + mulch, and animal manure + mulch was found to be significantly effective in reducing soil loss and run-off volume as compared to other treatments. Additionally, the soil loss and run-off volume measured for control, animal manure, and inorganic fertilizer (NP-fertilizer) treatments were high, implying that the compost, compost+ mulch, and animal manure+ mulch treatments can effectively check soil erosion and run-off rate under the existing slope and rainfall conditions of the study area.

Keywords: Organic matter,Run-off,Soil Loss, Sorghum Yield[1]

1. INTRODUCTION

Soil productivity maintenance is a major constraint of the tropical agriculture system. Crop cultivation is usually moved between fields to utilize only fertile soils for some years without the use of fertilizers. However, this cannot be sustained to meet the increased demand of an increasing population. Tropical soils are adversely affected by suboptimal soil fertility and erosion, causing deterioration of the nutrient status and changes in soil organism populations. Soil erosion is second only to population growth as the biggest environmental problem that threatens agriculture in Africa and other parts of the world (Eswaran *et al*., 2001). The problem is becoming increasingly urgent in developing countries like Ethiopia, where the vast majority of the population is dependent on agriculture. According to El-Swaify and Hurni (1996), the Ethiopian highlands, which make up 46% of the total land area of the country and account for over 95% of the regularly cropped land, constitute one of the most degraded lands in Africa. This accelerated soil erosion aggravated the problem of soil fertility depletion by removing organic carbon and other essential plant nutrients and exacerbated household and national food insecurity, thereby negatively impacting development efforts underway in the country. Various literatures (Sertsu, 2000; Girmay *et al*., 2009) indicated that sediment-associated nutrient losses are beyond the tolerable limit under low-input agricultural systems in Ethiopia. Meanwhile, considerable efforts have been made in the past to arrest large-scale soil erosion, but the major emphasis was given to mechanical soil and water conservation measures in arable lands with little attention to soil organic matter depletion, soil fertility decline, and soil physico-chemical and biological degradation (Teklu and Selamyihun, 2001). As a result, desirable outcomes were not achieved, and the final solution is still problematic and elusive. The highlands of Tigray are recognized as a cereal belt where huge amounts of straw are produced annually. Furthermore, these highlands accommodate a large number of livestock. In spite of these facts, the re-use of crop

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residues and farmyard manure within farming systems to improve soil properties is much below expectations since these products are used for other domestic purposes. It is also not uncommon to see farmers burning crop residues with the intention of controlling weeds and diseases. The soils of the study area are predominantly silt loam with poor structure and low moisture holding capacity. These soils remain devoid of vegetative cover between cropping seasons and are prone to fertile topsoil removal, particularly during the onset of rainfall. To date, no systematic study on the effect of manure and crop residue on runoff, soil conservation, and yield of sorghum under the agro-climatic conditions of the study area has been made. Therefore, the present investigation was undertaken with the specific objectives of (1) investigating soil loss and runoff under different surface management practices, (2) evaluating the degree to which rainfall, runoff, and sediment losses are related in the presence of surface management practices under the study area conditions, and (3) assessing the productivity of sorghum as affected by surface management practices under the prevailing conditions of the study area.

2. METHODS AND MATERIALS

2.1. Study Area Description

The experiment was conducted in Tahitay-Adiabo district, in the north-western zone of Tigray, Ethiopia (Figure 1). Geographically, the experimental site is located at $37^{0}47'2''$ East longitude and $14^{0}24'12''$ North latitude, with an elevation of 1035 m above sea level. The soil at the experimental site is silt loam (26% sand, 61% silt, and 13% clay). The long-term precipitation (1986–2016) at the experimental site ranged from 623 to 850 mm (CV = 23%), with an annual average of 780 mm. The area has a bimodal rainfall pattern, with distinct peaks in July and August. The seasonal rainfall varies from 430 to 750 mm during the experimental season. The mean annual maximum and minimum temperatures are 30 and 15°C, respectively. Topographically, the area consists of gently undulating plains with an average slope gradient of 4%. Crop production in the study area is characterized by a cereal-dominated cropping system. Sorghum is extensively grown, followed by maize.

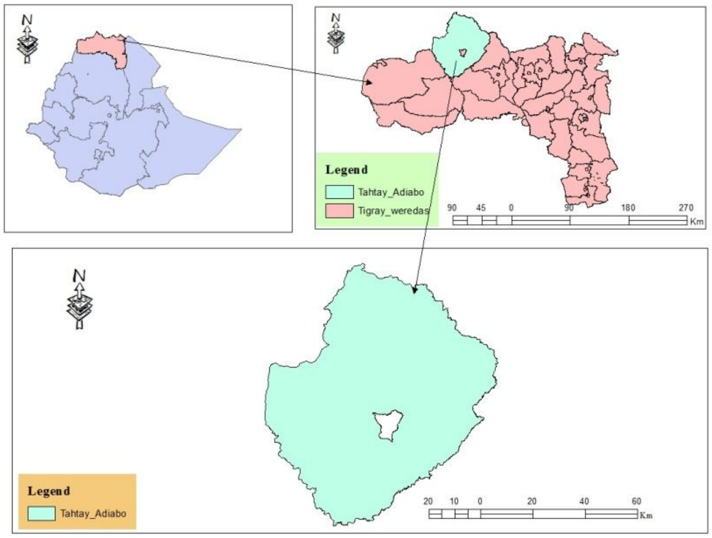

Fig 1. Map of Study Area

2.2. Experimental Design and Procedure

Eighteen experimental runoff plots 6 m long and 4m wide were established. Each plot was framed by sheet metal that was embedded to a depth of 13 cm and extended 20 cm above the soil surface along the boundaries. The design adopted for collecting tanks was that of a multi-slot divisor, as suggested by FAO (1993) and Pathak *et al*. (1997). The collecting tanks were covered with lids to prevent direct entry of rainfall and evaporation losses. The daily rainfall amount during measurement was recorded using a non-recording rain gauge.

The experiment involved six treatments (control, compost, compost+ mulch, animal manure, animal manure+ mulch, and recommended inorganic fertilizer (NP)). The trial was laid out in a randomized, complete block design with three replications. Agronomic aspects like tillage, time and method of planting, seed rate, and weeding were carried out according to local practices and conditions. Sorghum was used as a test crop. This crop was selected due to its high yield and being the most widely grown in the area. The cultivar was sown on June 18, 2019 and June 21, 2020, at the locally recommended seed rate of 150 kg ha1. Planting was done by planting over the plots. Urea and di-ammonium phosphate (DAP) were broadcasted and incorporated into the soil at the time of planting at a specified rate of 30 kg ha^{-1} nitrogen (N) and 10 kg ha^{-1} phosphorus (P) in inorganic fertilizer plots only. All weeds were removed three times by hand weeding according to the locally recommended practices. Cattle and small ruminant manure were collected from the local farmers and air-dried and mixed before being applied to the experimental plots. Composts were prepared according to compost preparation techniques and were made ready before the planting period. One month before sowing, manure and compost were weighed and applied at a rate of 20 tons/haaccording to plot sizes. During manure application, it was tried to maintain uniform distribution over the surface, and further mixing was done to an approximate soil depth of 20 cm at the time of sowing.

2.3. Soil Sampling

Bulk soil samples from each plot with a cross-diagonal sampling line were taken. Three depth points (0–10 cm, 10–20 cm, and 20–30 cm) were selected, and soil samples were taken using Augur prior to the start of the experiment and immediately after harvest. The samples were taken to the laboratory. Physical and chemical properties (Table 1) were determined following the standard procedure. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962). The soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil-to-water ratio (Motsara and Roy, 2008). The organic carbon content of the soil was determined by the potassium dichromate wet combustion procedure (Walkley and Black, 1934). The available phosphorus content of soils was determined by sodium bicarbonate extraction procedures (Olsen *et al*., 1954). The total nitrogen content of the soil was determined by wet oxidation procedures of the Kjeldahl method (Motsara and Roy, 2008). A flame photometer (Toth and Prince, 1949) was employed for the determination of exchangeable potassium.

2.4. Runoff and SedimentLoss

The total volume of daily runoff from each plot was measured in the collecting tanks after each rainstorm event. The runoff depth collected in the collecting tank was measured directly after the rainstorm by means of inserting a graduated ruler into the tanks. The contents of the tanks were vigorously stirred with a wooden stick to ensure a uniform distribution of sediment throughout the depth of water in the collecting tank. Immediately after stirring, a 1 liter capacity graduated jar was immersed to a substantial depth beneath the surface of water in the collecting tank, and a 1 liter sample of the water-sediment mixture was taken in pre-washed 1-liter bottles from each collecting tank. Whenever overflow occurred from the collecting tank, the volume of runoff in the second collecting tank was multiplied by a factor of three to obtain the total volume of overflow from the first tank. The runoff samples were taken to the Shire Soil Laboratory Center. The sediment samples were transferred to beakers and allowed to stand for 72 hours until the sediments had completely settled (Tang *et al.,* 1993). The clear water was then carefully decanted, and the weight of wet sediment per liter of runoff was measured, air dried, and kept for further physicochemical analysis, except that 2 to 5 g of wet sediments were oven dried at 105°C for 24 h for the determination of moisture correction factor (mcf). The dry sediment concentration per liter of runoff was determined as follows:

$$Sc = \frac{Mw}{Mcf}$$

Where: Sc is the Sediment concentration (g/L); Mw is the mass of wet sediment (g/L); mcf is the moisture correction factor given as: mcf = (100 + Mc)/100; where, Mc is the moisture content of sediment (%). The product of the sediment concentration and the total runoff per plot per day was used to determine the daily sediment loss as:

$$SL = {}^{(Sc * Ro)}/_{100}$$

2.5. Data Analysis

The effects of treatments on runoff, soil loss and yield of sorghum were analyzed by subjecting the data collected to analysis of variance (ANOVA) using general linear model (GLM) procedures of statistical analysis system of computer software (GenSTAT). Duncan's Multiple Range Test at 5% level of probability was used to separate the treatment means.

3. RESULT AND DISCUSSION

3.1. Runoff Volume

Significant ($p< 0.001$) runoff reduction was observed from organic treatments except animal manure as compared to control and inorganic fertilizer treatments (Tabl-1). As indicated in **Table 1**, compost, compost + mulch, and animal manure + mulch treatments resulted in considerably lower runoff depths than all other treatments. Numerically, application of compost with mulching resulted in lower runoff volume (515.8 M^3ha^{-1}) than other treatments. Conversely, the highest runoff volume was recorded at the control treatment (1050.7 M3 ha-1), followed by the inorganic fertilizer treatment (872.1 M3 ha-1), as shown in Table 1. However, the manure treatments did not show significant runoff reduction, which might be on account of the longer time required for the manure to impact soil physicochemical and hydraulic properties.

The runoff reduction as compared to the control was 50.91, 50.1, and 39.82% for compost + mulch, compost, and animal manure + mulch, respectively, and similar findings were also reported in other investigations (Dickey *et al.*, 1994; Edwards *et al.*, 1995; Bhatt and Khera, 2006). This substantial reduction in runoff is attributed to increased infiltration due to detention of flow, and residues also dissipated the energy of raindrops, prevented surface sealing, and ultimately reduced the quantity of rainwater that became runoff. The results further indicated that animal manure application without surface cover or mulch was less effective in reducing runoff as compared to compost application. Statistically significant runoff reduction was not observed by animal manure application as compared to the control treatment as well as inorganic (NP) treatment applications. This suggests that the benefits of animal manure in reducing runoff cannot be realized under such short-duration experiments, and their influence could be seen as a residual effect on subsequent crops. Similar findings are also available in much of the literature. Ramos *et al.* (2006) observed that surface application of cattle slurry increased runoff volume. A research report by Cabrera *et al*. (2009) also revealed 8% higher runoff in manure-treated plots than in control in the first year of manure application.

3.2. Soil Loss

Results of the analysis of variance revealed that the effect of compost, mulch, and compost on soil loss was significant ($p<0.01$). The mean soil loss from experimental plots is indicated in **Table 1**. The compost, compost + mulch, and animal manure + mulch treatments were significantly more effective in checking soil loss than the other treatments considered in the study. However, it was observed that animal manure was not significantly different from that of the control and inorganic (NP) treatments. The substantial reduction in soil loss with compost and compost + mulching is in agreement with the finding of Döring *et al*. (2005), who reported a reduction in soil erosion through the application of straw mulching. Soil erosion occurs through the mechanisms of particle detachment by raindrop impact, erosive power of runoff, sediment transportation by raindrop wash, and surface runoff flow (Gajri*et al*., 2002; Kinnell, 2004). Soil surface cover and roughness reduce the raindrop impact and, hence, soil loss. The present result indicates that compost and surface mulching not only reduced the surface runoff but also provided a cover to the soil surface and hence decreased soil detachment by raindrop impact, reduced runoff erosivity, provided more infiltration opportunity, and trapped the sediments carried by surface runoff.

As illustrated in **table 1**, compost, compost + mulch, and animal manure with mulch substantially reduced soil loss and sediment concentration in runoff. Soil loss reduction as compared to the control was 78.28, 91.14, and 90.8%, respectively. Soil loss from plots that received animal manure and inorganic fertilizer was not significantly different from that of the control. This could be partially attributed to the higher runoff volume (Table 1) and the longer time required for the organic matter in the animal manure to become incorporated into the soil and impact soil properties. Similarly, Cabrera *et al*. (2009) found an insignificant reduction in soil loss in dairy manure application.

Table 1. Runoff and Sediment Yield

Treatments	Runoff Volume (M^{3}ha^{-1})	Sediment Loss(Tonha^{-1})
Control	1050.7^b	17.50^c
Compost	523.5^a	3.80^b
Animal manure	821.54^b	15.9^c
Compost + mulch	515.8^a	1.55^a
Animal manure + mulch	632.3^a	1.61^a
Recommended NP Fertilizer	872.1^b	16.50^c
Mean	735.9	9.48
LSD	117.6	2.12
CV (%)	32.1	17.6
P-value	0.001	0.001

3.3. SorghumYield

The result of this study (**Table 2**) indicated that grain yield was influenced by different treatment applications. The highest grain yields of 2880 kg ha1 were obtained from compost and mulch, followed by compost (24.4 kg), and the treatments were statistically significant. This clearly indicates that the need for nutrients to achieve a maximum grain yield is paramount. Compost improves nitrogen and phosphorus availability for plants and thereby improves the grain yield of sorghum. These results agree with those of Khaliq *et al*. (2009) who reported that grain yield increased as organic manure levels of application increased. According to Arunah *et al*. (2006), the finding that organic manure significantly increased the growth and grain yield of sorghum is attributable to improved soil physical and chemical properties. The increased porosity and moisture content should have enhanced root growth and water and nutrient uptake, apart from the fact that nutrients released from poultry manure had a direct effect on growth and grain yield. Blankenau*et al.* (2012) stated that the proper rate and timing of manure application are critical for meeting crop needs, and considerable opportunities exist for yield improvement.

Table 2. Grain and Above Ground Biomass Yield

Treatments	Grain Yield (Qha^{-1})	Biomass Yield (kgha^{-1})
Control	10.34^{c}	2410^{c}
Compost	24.4^{a}	3851^{bc}
Animal manure	18.5^{b}	4183^{ab}
Compost + mulch	28.8^{a}	4753^{ab}
Animal manure + mulch	23.6^{a}	5555^{a}
Recommended NP Fertilizer	15.6^{b}	4968^{ab}
Mean	20.20	4287
LSD	5.4	526.8
CV (%)	20.1	19

CONCLUSIONS

Under the prevailing soil and agro climatic conditions of the study area (silt loam soils, dryagro-ecology), the application of compost + mulch, compost, and animal manure + compost resulted in a significant reduction in sediment concentration in runoff and, hence, annual soil loss. However, it was observed that animal manure without mulch resulted in annual soil loss, which was not significantly different from that of the control and inorganic fertilizer treatments. Grain yield was affected by both compost and animal manure treatments.

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