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Effect of Organic Manure on Sorghum (*Sorghum bicolor*) Yield, Runoff and Soil Loss in Tahitay-Adiabo, North West Zone of Tigray, Ethiopia

Ekubay Tesfay Gebreigziabher* **and Solomon Shushay**

Department of Agricultural Research, Shire Maytsebri Agricultural Research Centre, 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 2018 and 2019 cropping seasons. The experimental design used was 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 m × 4 m and laid in a land slope of 4%. The results revealed that there was 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 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.

Key words: Organic matter • Run-off • Soil loss • Sorghum yield

Introduction

Soil productivity maintenance is a major constraint of tropical agriculture system. Crop cultivation is usually moved between fields to utilize only fertile soils for some years without use of fertilizers. However, this cannot be sustained to meet increased demand of an increasing population. Tropical soils are adversely affected by sub-optimal 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. The problem is becoming increasingly more urgent in developing countries like Ethiopia where the vast majority of the population are dependent on agriculture. According to the Ethiopian highlands that make up 46% of the total land area of the country with 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 on development efforts underway in the country. Various literatures indicated that sediment associated nutrient losses are beyond tolerable limit under low input agricultural systems of 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, soil physico-chemical and biological degradation. As a result, desirable outcomes were not achieved and still final solution is problematic and elusive. The highlands of Tigray are recognized as cereal belt where huge straw is produced annually. Furthermore, these highlands accommodate large number of livestock. In spite of these facts, the re-use of crop residues and farmyard manure within the farming systems to improve soil properties is much below expectation since these products are used for other domestic purposes. It is also not uncommon to see farmers burning crop residues with the intention to control weed and diseases. The soils of the study area are dominantly silt loam with poor structure, low moisture holding capacity. These soils remain devoid of vegetative cover between cropping seasons and are prone to fertile topsoil removal particularly during the onsets of rainfall. To

***Address for Correspondence:** Ekubay Tesfay Gebreigziabher, Department of Agricultural Research, Shire Maytsebri Agricultural Research Centre, Tigray, Ethiopia; E-mail: ekubaytesfay2023@gmail.com*

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date, no systematic study on effect of manure and crop residue on runoff, soil conservation and yield of sorghum under agro-climatic conditions of the study area has been made. Therefore, the present investigation was undertaken with the specific objectives of investigating soil loss and runoff under different surface management practices 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 assessing the productivity of sorghum as affected by surface management practices under the prevailing conditions of the study area [1-3].

Materials and Methods

Study area description

The experiment was conducted at Tahitay-Adiabo district, North western zone of Tigray, Ethiopia (Figure 1). Geographically, the experimental site is located at 37°47'2" East longitude and 14˚24'12" North latitude with an elevation of 1035 m above sea level. The soil of experimental site is silt loam (26% sand, 61% silt and 13% clay). The long term precipitation (1986-2016) of the experimental site ranged from 623 to 850 mm (CV=23%), with an annual average of 780 mm. The area has 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 plain with average slope gradient of 4%. Crop production in the study area is characterized by cereal dominated cropping system. Sorghum is extensively grown followed by Maize [4-5].

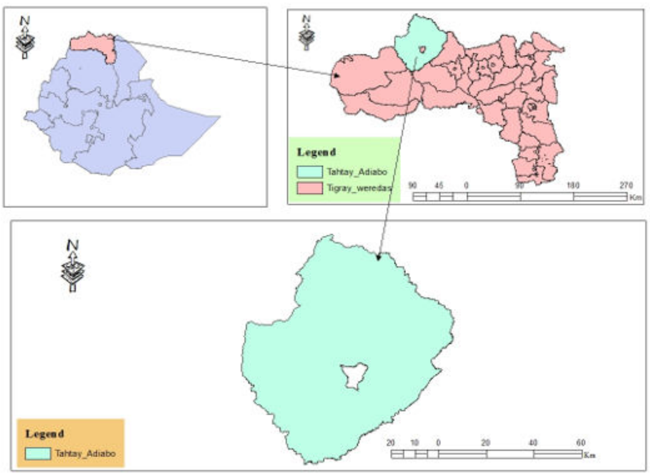

Figure 1. Map of study area.

Experimental design and procedure

Eighteen experimental runoff plots of 6 m long and 4 m wide were established. Each plot was framed by sheet metal that was embedded to a depth of 13 cm and extending 20 cm above the soil surface along the boundaries. The design adopted for collecting tanks was that of multi slot divisor as suggested. The collecting tanks were covered with lids to prevent direct entry of rainfall and evaporation losses. 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 Jun 18, 2017 and Jun 21, 2018 at locally recommended seed rate of 150 kg ha^{-1}. Planting was done by raw planting over the plots. Urea and Di-Ammonium Phosphate (DAP) were broadcasted and incorporated into the soil at the time of planting at specified rate of 30 kg ha^{-1} nitrogen (N) and 10 kg ha^{-1} phosphorus (P) to 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 were air dried and mixed before applying to the experimental plots. Composts were prepared according to compost preparation techniques and were made ready before planting period. One month before sowing, manure and compost were weighed and applied at the rate of 20 tons/ha according to plot sizes. During manure application, it was tried to keep uniform distribution over the surface, and further mixing to an approximate soil depth of 20 cm at the time of sowing [6-9].

Soil sampling

Bulk soil samples from each plot with a cross diagonal sampling line were taken. Three depth points (0 cm-10 cm, 10 cm-20 cm and 20 cm-30 cm) was 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 hydrometer method. The soil pH was measured potentiometrically in the supernatant suspension of 1:2.5 soils: Water ratio. Organic carbon content of the soil was determined by potassium dichromate wet combustion procedure. The available phosphorus content of soils was determined by 0.5 M sodium bicarbonate extraction procedures. Total nitrogen content of the soil was determined by wet oxidation procedures of the Kjeldahl method. Flame photometer was employed for determination of exchangeable potassium [10-13].

Runoff and sediment loss

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 graduated ruler in to 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, 1 L capacity graduated jar was immersed to a substantial depth beneath the surface of water in the collecting tank and 1 L sample of water sediment mixture was taken in pre-washed 1 L 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 Shire soil laboratory center. The sediment samples transferred to beakers and allowed to stand for 72 h until the sediments had completely settled. 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). Dry sediment concentration per liter of runoff was determined as:

$$Sc=Mw/Mcf$$

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:

$$Sc=(Sc \times Ro)/100$$

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 (Gen STAT). Duncan's multiple range test at 5%level of probability was used to separate the treatment means.

Results and Discussion

Runoff volume

Significant ($p<0.001$) runoff reduction was observed from organic treatments except animal manure as compared to control and inorganic fertilizer treatments. As indicated in Table 1, compost, compost+mulch, animal manure+mulch treatments resulted in considerably low runoff depth 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 M^3ha^{-1}) followed by the inorganic fertilizer treatment (872.1 M^3ha^{-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 [14-18].

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. This substantial reduction in runoff is attributed to increased infiltration due to detention of flow, and also residues dissipated the energy of raindrops, prevented surface sealing and ultimately reduced the quantity of rainwater that become runoff. The results further indicated that animal manure application without surface cover/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 a short duration experiments and their influence could be seen as residual effect in the subsequent crops. Similar findings are also available in many literatures. Ramos et al. observed that surface application of cattle slurry increased runoff volume. A research report by Cabrera, et al., also revealed 8% higher runoff in manure treated plots than in control in the first year of manure application.

Soil loss

Results of 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 who reported reduction in soil erosion through application of straw mulching. Soil erosion occurs by the mechanisms of particle detachment by raindrop impact, erosive power of runoff, sediment transportation by raindrop wash, and surface runoff flow. 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 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. found that insignificant soil loss reduction in dairy manure application.

Table 1. Runoff and sediment yield.

Treatments	Runoff Volume (M^3ha^{-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

Sorghum yield

The result of this study (Table 2) indicated that grain yield was influenced by different treatment applications. The highest grain yields of 2880 kg ha^{-1} were obtained from compost+mulch followed by compost (24.4 kg) and the treatments were statistically significant. This clearly indicates the need for nutrients to achieve a maximum grain yield is paramount. Compost improves nitrogen and phosphorus availability to plants and thereby improve grain yield of sorghum. These results agree with that of who reported that grain yield increased as organic manure levels of application increased. According to the finding that organic manure significantly increased 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 direct effect on growth and grain yield stated that proper rate and time of manure application are critical for meeting crop needs and considerable opportunities exist for yield improvement [19].

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	20.2	4287
LSD	5.4	526.8
CV (%)	20.1	19

Conclusion

Under the prevailing soil and agro climatic conditions of the study area (Silt loam soils, dry agro ecology), application of compost +mulch, compost and animal manure+compost resulted in 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 by compost and animal manure treatments.

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References

1. Eswaran, Hari, Rattan Lal, and PF Reich. “Land Degradation: An Overview.” (2019): 20-35.
2. El-Swaify, SA, and Hans Hurni. “Transboundary Effects of Soil Erosion and Conservation in the Nile Basin.” (1996): 5-21.
3. Sertsu, S. “Degraded Soil of Ethiopia and Their Management.” (2000)18-22.
4. Girmay, Gebreyohannes, B. R. Singh, Jan Nyssen, and T. Borrosen. “Runoff and Sediment-Associated Nutrient Losses under Different Land Uses in Tigray, Northern Ethiopia.” *Jou of hydro* 376 (2009): 70-80.
5. Erkosa, Teklu, and Selamyihun Kidanu. “Soil Erosion and Conservation in Ethiopian vertisols.” (2001).
6. Agriculture Organization of the United Nations. “Soil Resources, Conservation Service, Agriculture Organization of the United Nations. Land, Water Development Division, and International Institute for Applied Systems Analysis”. 1993.
7. Pathak, P. “Runoff and soil loss measurement.” (1999).
8. Bouyoucos, George John. “Hydrometer Method Improved for Making Particle Size Analyses of Soils 1.” *Agron jou* 54 (1962): 464-465.
9. Motsara, MR, and RN Roy. “Guide To Laboratory Establishment for Plant Nutrient Analysis.” (2008).
10. Walkley, Aldous, and I. Armstrong Black. “An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method.” *Soil Scie* 37 (1934): 29-38.
11. Olsen, Sterling Robertson. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. 1954.
12. Toth, SJ, and AL. Prince. “Estimation of Cation-Exchange Capacity and Exchangeable Ca, K, And Na Contents of Soils by Flame Photometer Techniques.” *Soil Sci* 67 (1949): 439-446.
13. Tang, KL, FL. Zheng, KL. Zhang, and BK. Wang, et al. “Research Subjects and Methods of Relationship between Soil Erosion and Eco-Environment in the Ziwuling Forest Area.” 17 (1993): 3-10.
14. Dickey EC, Shelton DP, Jasa PJ, Peterson TR (1994). Tillage, Residue and Erosion on Moderately Sloping Soils. *Trans ASAE* 27:1093-1099.
15. Edwards, Linnell, Jack Burney, and Ron DeHaan. “Researching the Effects of Mulching on Cool-Period Soil Erosion Control in Prince Edward Island, Canada.” *J Soils Water Conserv* 50 (1995): 184-187.
16. Bhatt, Rajan, and KL. Khera. “Effect of Tillage and Mode of Straw Mulch Application on Soil Erosion in the Submontaneous Tract of Punjab, India.” *Soil Till Res* 88 (2006): 107-115.
17. Ramos, María C, John N. Quinton, and Sean F. Tyrrel. “Effects of cattle manure on erosion rates and runoff water pollution by faecal coliforms.” *J Environ Manage* 78 (2006): 97-101.
18. Cabrera, VE, LJ. Stavast, TT. Baker, and MK. Wood, et al. “Soil and Runoff Response to Dairy Manure Application on New Mexico Rangeland.” *Agric. Ecosyst Environ* 131 (2009): 255-262.
19. Khaliq, T, A. Ahmad, A. Hussain, and MA. Ali. “Maize Hybrids Response to Nitrogen Rates at Multiple Locations in Semiarid Environment.” *Pak J Bot* 41 (2009): 207-224.

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