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Research Article

Soil Nutrients Loss due to Sweet Potato (Ipomea batata) Harvesting Under Different Tillage-mulch Practices in Uyo, Nigeria

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Abstract

An important factor responsible for the declining food production in south- west and other parts of Nigeria is the mismanagement of natural resources, and its resulting soil loss. A study was carried out in Uyo, Nigeria to evaluate the soil nutrient losses due to sweet potato harvesting under different tillage-mulch practices. The field was laid out using a 2 x 4 factorial arrangement in randomized complete block design. Treatments combinations included two types of tillage (No Tilled and Tilled) as well as four rates of cattle cud mulch (0, 10, 20 and 30 tons ha^{-1}) to give a total of eight treatment combinations in three replications. Sweet potatoes were planted in the experimental units which measured $9m^2$ each at the spacing of 1m x 0.5m, at one vine per stand, giving a total of 18 plants per plot. Soil data were collected at the pre-plant, mid-plant and at harvest. Data of sweet potatoes yield were also collected. Soil and nutrient losses were measured at harvest. Data were assessed using the Analysis of Variance and correlation analyses were also performed to determine the relationships between soil and crop parameters studied. Results showed that Cattle cud mulch reduced the bulk density of the soil and a corresponding increase of total porosity and saturated hydraulic conductivity with effect apparently increasing as the application rate of cattle cud mulch increased. Tuber girth and tuber length showed significant increase with increasing rate of cattle cud mulch application with the highest values of 19 cm and 21.07 cm, respectively being recorded with M_{30}. The application of cattle cud mulch significantly increased Soil Loss Due to Crop Harvest owing to the increase in soil organic matter and aggregation, which resulted in aggregated soils clinging more to roots of harvested crops than less aggregated soils. Based on the findings, it was recommended among others, that farmers should adopt the no till method in the cultivation of tubers crops and cattle cud should be adopted as a choice organic material.

Keywords: Aggregation; Animal Manure; Crop; Erosion; Mulching; Yield

Introduction

Unsuitable management practices cause degradation in soil health (depletion of organic matter and other nutrients) as well as decline in crop productivity [1]. Despite the immeasurable contributions of land to the existence of mankind, its quality is gradually being diminished due to misuse. Over the years, attention has been drawn to soil loss due to erosion neglecting soil loss due to crop harvesting which further leads to nutrient depletion from such areas [2]. An important factor responsible for the declining food production in south- west and other parts of Nigeria is the mismanagement of natural resources, and the resulting nutrients loss through overland flow as well as decline in crop productivity and huge economic loss, putting the food security and livelihood of farmers at risk [3]. Field observations and measurements have shown that considerable amounts of nutrient can be removed from the field due to soil sticking to the harvested roots and the export of clods during the crop harvest [4]. Not only does erosion reduce the cultivable soil depth but it also removes the fertile surface from the farmlands. The net effect is loss of agricultural productivity, increased expenditure on fertilizers, and a general decline in profitability of crop production [5].

Appropriate management practices are needed in humid tropical south-eastern Nigeria, where high population density and inappropriate and intensive land use cause soil erosion and degradation, and result in declining crop yields [6]. Good management practices which include crop rotations, cover crops, and reduced tillage will yield positive economic and environmental benefits to land ecosystem. Sustainable agricultural management strategies targeted to increase soil organic matter and reduce erosion include improvements in plant diversity, appropriate tillage and organic matter application [7].

Sweet potato (*Ipomea batatas* L.) is a eudicotyledonous warm season crop, which belongs to the *Convolvulaceae* or morning glory family. It is one of the major sources of food, animal feed and industrial raw materials and has a significant contribution as an energy supplement and phytochemical source of nutrition [8]. It is a nutritious root crop that contains significant amounts of fiber, beta carotene and vitamin C, particularly in varieties with highly colored roots [9]. Ware [10] reported that sweet potatoes may help maintain a healthy blood pressure and protect against cancer while their high fiber content help prevent constipation. There are several varieties of sweet potato but TIS/87/0087 was used for the study.

Surface mulch is an important factor of protection technology in the cultivation of potatoes [11]. Mulching is an essential cultural technique that can reduce the amount of work inherent in gardening, helping to produce healthier plants and potentially increasing vegetable yields. The use of mulches conserve the soil moisture, enhance the nutrients status of soil, control the erosion losses, suppress the weeds in crop plants, remove the residual effects of pesticides, fertilizers and heavy metals; improve the aesthetic value of landscapes and economic value of crops [12].

Adebisi., *et al.* [13] studied the effect of tillage and mulch combinations on soil's physical and chemical properties and sweet potato (*Ipomoea batatas* L.) performance and the application of mulch was found to increase the yield components of sweet potato compared with no mulch application. Mulch applied at 15 t/ha was found to be suitable for sweet potato in tropical Alfisol. The cattle-cud is the organic mulch that will be used in the study. It is portion of feed that is found in the rumen. While in the rumen, the partly digested feed is acted upon by rumen microbes which ferment the feed and make volatile fatty acids, B vitamins, vitamin K and amino acids [14].

Ghosh., *et al*. [15] concluded that mulch addition increased the total porosity in more compacted soil under reduced tillage. Tillage is one of the important factors affecting soil properties and crop yield. Appropriate soil tillage or seedbed type can be a suitable alternative to enhanced nutrient availability to crop and therefore reduce cost of fertility management as well as create favourable soil physical properties for germination and crop production [16]. Tillage disturbs the soil, causing it to move vertically and horizontally, often making it more susceptible to water and wind erosion associated with residue removal and soil loosening [17]. Appropriate use of tillage practices overcomes edaphic constraints, whereas inappropriate tillage may cause a variety of undesirable outcomes, for example, soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient.

Tillage methods and organic manure applications are two production practices that can affect the soil properties which influence the yield of sweet potatoes as well as the rate of soil loss due to crop harvesting sweet potato yield if handled properly. There is limited research study on the implications of tillage-mulching combination using cattle-cud as organic mulch material on soil properties and nutrient losses in sweet potato production in southeast Nigeria.

Objective of the Study

different tillage-mulch practices in Uyo, Nigeria.

Materials and Methods

Study area

This study was conducted in Uyo in Akwa Ibom State, Southeastern Nigeria. The State lies between latitude $04^0 32^1$ and $05^0 33^1$ north and longitude $07^0 25^1$ and $08^0 25^1$ east. The state is underlain by one geological formation, the coastal plain sands characterized by low physical and chemical fertility due to dominance of low-activity kaolinitic clays and low organic matter content [18]. There are two main seasons in Akwa Ibom State; the wet and dry seasons, depending on the movement of the Inter-Tropical Discontinuity (ITD) which is the zone separating the warm humid maritime air mass with its associated South westerly winds from North easterly winds. Uyo has a mean annual rainfall of about 2484 mm, mean annual temperature of 27°C, with varying relative humidity through the year from 70 - 80% [19]. The climatic factors favour luxuriant tropical rainforest, which has been almost replaced by secondary forest of predominantly wild oil palms, woody shrubs like siam weed (*Chromolaena odorata*), plantain plantations and various grass undergrowth.

Field layout

The experimental site was cleared manually with matchete. Seed beds requiring the conventional tillage method based on the research design were prepared by manual tillage using Indian hoe. Experimental plots were mapped out for a 2 x 4 factorial experiment with three replications. The experiment employed a split plot arranged in a randomized complete block design. The main plot was assigned the tillage methods while the sub plots were assigned the cattle cud-mulch at varying rates for precision. Each plot measured 3m x 3m and treatment combination consisted of two tillage methods and one mulching material at different rates: Tillage + Mulch at 0 tonnes/ha (TLM_0), Tillage + Mulch at 10 tonnes/ha (TLM_{10}), Tillage + Mulch at 20 tonnes/ha (TLM_{20}), Tillage + Mulch at 30 tonnes/ha (TLM_{30}), No Till + Mulch at 0 tonnes/ha (NTM_0), No Till + Mulch at 10 tonnes/ha (NTM_{10}), No Till + Mulch at 20 tonnes/ha (NTM_{20}) and No Till + Mulch at 30 tonnes/ha (NTM_{30}).

Procurement of materials

Random composite soil samples based on plots taken at depth 0 to 15cm from the experimental sites were collected and placed in labelled polythene bags as well as core samples and taken to the laboratory for routine analysis. Soil sampling was done during pre-planting, mid planting and at harvest. Hybrid sweet potato (TIS 87/0087) vines were obtained from the Research Centre in Michael Okpara University of Agriculture, Umudike. Cattle-cud were collected from where they were disposed of in Ntak Inyang Abbatoir and dried to reduce moisture content and weighed for application rates of 10, 20 and 30 ton/ha treatments, to the No Till and Tillage plots. During harvest, soil samples for the determination of soil loss and nutrient loss due to harvesting were carefully collected from the tubers and placed in label polythene bags for routine analysis.

Crop establishment

The vines measuring 25 cm each were planted in a plot size of $9m^2$ at the spacing of 1m x 0.5m, at one plant per stand (18 plants per plot). The cured cattle-cud was applied one week after planting. Weeding was carried out manually.

Determination of aggregate properties, yield parameters and nutrient loss

Soil samples collected were aggregate size classes using the wet sieve method. At harvest, the tuber length, tuber girth, number of tubers and yield were measured. The soils stuck on tuber during harvest for each plot were washed; oven dried and weighed in grams. Soil and nutrients loss were estimated by Han-qing., *et al.* [20], and sample was analysed for total nitrogen using micro kjeldahl digestion and distillation method in Faraji., *et al.* [21]. Available phosphorus was extracted by Bray p-1 method of Bray and Kurtz as described by Roohi., *et al.* (2020) and phosphorus in the extract was obtained by blue colour method of Murphy and Riley as described by Anschutz., *et al*. (2016). Exchangeable bases were extracted using 1 N ammonium acetate, calcium and magnesium were determined through EDTA (Ethylene Diamine Tetra Acetic Acid) titration as well as sodium and potassium measured by flame photometer.

Statistical analysis

Data obtained in the study were subjected to Analysis of Variance (ANOVA) using GenStat (Discovery edition 3) statistical software. Significant means were separated by Duncan Multiple range test (DMRT) at 5% probability level. Correlation analysis was used to access the relationship between yield data and soil loss.

Results and Discussion

Effect of tillage and cattle cud mulch (CCM) on the aggregate size distribution

Table 1 showed the effect of tillage and cattle cud mulch (CCM) on the aggregate size distribution. One (1) mm aggregate size was significantly affected by tillage type at the pre-planting and mid-planting stages, with 21.33g recorded with NT soil being significantly higher than that of TL soil (17.58g). At the pre-plant and mid-plant stages of soil study, TL soil had significantly higher 0.25 mm aggregate size (i.e. the small macro aggregates) than NT soil with values of 36.83 and 33.50 for TL soil and NT soil respectively at the pre-planting stage and 37.92 and 33.92g respectively at the mid-planting stage. Generally, no till soils had higher proportions of 2 mm, 1 mm and 0.5 mm and lesser proportions of 0.25 mm soil aggregates. There were no significant effects of tillage type on 2 and 0.5 mm aggregate size at the pre- and mid-planting periods. At the harvest period, there were no significant effects of tillage type on any of the aggregate sizes studied.

	Pre-plant					Mid-plant					Harvest				
	2 mm	1 mm	0.5 mm	0.25 mm	MWD	2 mm	1 mm	0.5 mm	0.25 mm	MWD	2 mm	1 mm	0.5 mm	0.25 mm	MWD
Tillage															
TL	3.00	17.58	25.00	36.83	0.67	2.83	17.58	25.00	37.92	0.67	0.00	13.33	26.25	30.42	0.51
NT	4.00	21.33	26.50	33.50	0.77	4.00	21.33	26.50	33.92	0.77	0.00	11.25	27.33	29.92	0.49
$LSD_{(0.05)}$	NS	3.51	NS	2.77	0.07	NS	3.53	NS	3.31	0.07	NS	NS	NS	NS	NS
Mulch Rate															
M_0	3.50	19.67	26.33	37.50	0.71	3.50	19.67	26.33	37.50	0.71	0.00	12.00	28.50	27.50	0.49
M_{10}	3.50	19.67	24.67	33.33	0.72	3.50	19.67	24.67	35.67	0.72	0.00	12.50	23.33	30.67	0.48
M_{20}	3.83	18.00	25.83	31.83	0.69	3.50	18.17	25.67	33.00	0.69	0.00	12.83	28.17	30.00	0.52
M_{30}	3.17	20.50	26.17	38.00	0.74	3.17	20.33	26.33	37.50	0.74	0.00	11.83	27.17	32.50	0.50
$LSD_{(0.05)}$	NS	NS	NS	3.92	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Tillage x Mulch Rate															
TLM_0	2.00	15.00	28.33	41.67	0.60	2.00	15.00	28.33	41.67	0.60	0.00	12.00	30.67	28.00	0.52
TLM_{10}	3.00	18.67	25.00	34.00	0.70	3.00	18.67	25.00	37.00	0.70	0.00	13.67	21.33	30.67	0.48
TLM_{20}	3.67	16.67	25.00	33.67	0.66	3.00	16.67	25.00	35.00	0.66	0.00	14.33	27.67	30.67	0.54
TLM_{30}	3.33	20.00	21.67	38.00	0.71	3.33	20.00	21.67	38.00	0.71	0.00	13.33	25.33	32.33	0.51
NTM_0	5.00	24.33	24.33	33.33	0.82	5.00	24.33	24.33	33.33	0.82	0.00	12.00	26.33	27.00	0.47
NTM_{10}	4.00	20.67	24.33	32.67	0.74	4.00	20.67	24.33	34.33	0.74	0.00	11.33	25.33	30.67	0.48
NTM_{20}	4.00	19.33	26.67	30.00	0.72	4.00	19.67	26.33	31.00	0.73	0.00	11.33	28.67	29.33	0.50
NTM_{30}	3.00	21.00	30.67	38.00	0.78	3.00	20.67	31.00	37.00	0.77	0.00	10.33	29.00	32.67	0.50
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 1: Means of aggregate size distribution and mean weight diameter as affected by tillage and Cattle-cud mulch rate during the pre-planting; mid-planting and harvest stages.

MWD: Mean Weight Diameter; TL: Tillage; NT: No Till; M_0: Mulch at 0 tonnes/ha; M_{10}: Mulch at 10 tonnes/ha; M_{20}: Mulch at 20 tonnes/ha; M_{30}: Mulch at 30 tonnes/ha; TLM_0: Tillage + Mulch at 0 tonnes/ha; TLM_{10}: Tillage + Mulch at 10 tonnes/ha; TLM_{20}: Tillage + Mulch at 20 tonnes/ha; TLM_{30}: Tillage + Mulch at 30 tonnes/ha; NTM_0: No Till + Mulch at 0 tonnes/ha; NTM_{10}: No Till + Mulch at 10 tonnes/ha; NTM_{20}: No Till + Mulch at 20 tonnes/ha; NTM_{30}: No Till + Mulch at 30 tonnes/ha; LSD: Least Significant Difference.

The only significant effect of CCM rate on aggregate sizes was observed in 0.25 mm at the pre-planting stage, in which M_{30} rate showed significantly higher 0.25 mm aggregate size (38g) than those of M_{20} (31.83g) and M_{10} (33.33g). There were no interaction effects of tillage type and mulch rate on aggregate sizes. Mean weight diameter of NT soil at the pre-plant and mid-plant stages (0.77 mm) were significantly higher than those of TL soil (0.67 mm) (Table 1). Apparently higher MWD were observed among soils with higher rates of CCM treatments, though there were no significant effect of CCM rates on MWD at the three stages of soil study.

The higher proportions of larger soil aggregates (2 mm, 1 mm and 0.5 mm), the lesser of 0.25 mm soil aggregate and the higher mean weight diameter (MWD) observed under untilled soils can be explained by the non-destruction of soil structure by tillage. No-tilled soils also had more of larger soil aggregates and higher MWD because of the high amounts of organic matter. On the other hand, frequent tillage deteriorates soil structure and weakens soil aggregates, causing them to be susceptible to decay [22].

Effect of tillage practices and cattle-cud mulch rates on the tuber yield of sweet potato

Tilled soils had higher quantity of marketable and non-marketable potato tubers, higher number of tubers, higher yield and Soil Loss due to Crop Harvesting (SLCH). However, these differences were not significant (Table 2). Tuber girth and tuber length of sweet potato were significantly affected by mulch rate. The highest tuber girth of potato (19 cm) was obtained with M_{30} which was significantly higher than those of M_{10} and M_{20}, which recorded tuber girths of 14.75 and 13.0 cm, respectively. Similarly, M_{30} produced the highest tuber length which was equal with that of M_{20} but significantly higher than that of M_{10} (Table 2).

Yield parameters of sweet potatoes generally showed increasing trend with increase in the quantity of cattle-cud mulch applied. There were no significant effect of the interaction of tillage method and cattle-cud mulch on the yield of sweet potatoes. However, apparent considerations showed that both tilled and no tilled plots that received the highest application rate of cattle-cud mulch recorded higher yields of sweet potatoes which were 4.74 tons ha^{-1} (for TLM30) and 3.37 tons ha^{-1} (for NTM30). Results obtained suggested lower yields with lower mulch inputs, though one of the high yields (3.87 tons ha^{-1}) was observed with No tillage and no mulch.

	Tuber Girth	Tuber Length	Marketable	Non Marketable	No of Tuber	Yield (tons ha^{-1})	RWUE (kg ha mm^{-1})
Tillage							
TL	16.91	19.51	24.25	18.83	43.08	2.78	1.63
NT	15.41	17.59	26.08	26.33	52.58	2.72	1.59
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS
Mulch Rate							
M_0	13.90	18.32	28.33	28.50	56.83	2.95	1.73
M_{10}	14.74	16.06	16.17	15.17	31.33	1.68	0.99
M_{20}	16.99	18.76	23.83	18.83	42.67	2.30	1.35
M_{30}	19.00	21.07	32.33	27.83	60.50	4.06	2.38
$LSD_{(0.05)}$	2.92	3.19	NS	NS	NS	NS	NS
Tillage x Mulch Rate Interaction							
TLM_0	16.67	19.94	11.33	18.00	29.33	2.04	1.19
TLM_{10}	15.76	17.54	15.33	12.33	27.67	1.69	0.99
TLM_{20}	13.58	20.46	29.33	22.00	51.33	2.63	1.54
TLM_{30}	21.63	20.10	41.00	23.00	64.00	4.74	2.78
NTM_0	17.31	16.70	45.33	39.00	84.33	3.87	2.27
NTM_{10}	13.71	14.57	17.00	18.00	35.00	1.67	0.98
NTM_{20}	14.23	17.06	18.33	15.67	34.00	1.96	1.15
NTM_{30}	16.37	22.03	23.67	32.67	57.00	3.37	1.98
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS

Table 2: Mean Tuber yield parameters of sweet potatoes as affected by tillage practices and cattle-cud mulch rates.

RWUE: Rain Water Use Efficiency; TL: Tillage; NT: No Till; M_0: Mulch at 0 tonnes/ha; M_{10}: Mulch at 10 tonnes/ha; M_{20}: Mulch at 20 tonnes/ha; M_{30}: Mulch at 30 tonnes/ha; TLM_0: Tillage + Mulch at 0 tonnes/ha; TLM_{10}: Tillage + Mulch at 10 tonnes/ha; TLM_{20}: Tillage + Mulch at 20 tonnes/ha; TLM_{30}: Tillage + Mulch at 30 tonnes/ha; NTM_0: No Till + Mulch at 0 tonnes/ha; NTM_{10}: No Till + Mulch at 10 tonnes/ha; NTM_{20}: No Till + Mulch at 20 tonnes/ha; NTM_{30}: No Till + Mulch at 30 tonnes/ha; LSD: Least Significant Difference.

Tuber girth, tuber length showed increasing trend with increase in the quantity of cattle-cud mulch applied owing to the increased input of soil nutrient from the applied mulch [23]. However, other yield parameters did not give significant results probably, owing to a similar non-significant difference in basic cations (soil nutrients) observed with different cattle-cud mulch rates in this study.

Effect of tillage practices and cattle-cud mulch rates on soil loss due potato harvesting

SLCH under TL was 69.42 kg kg^{-1} while that of NT was 71.92 kg kg^{-1}. In terms of mulch rate, the highest SLCH of 92.83 kg kg^{-1} was obtained under M_{30} followed in the order by M_{10}, M_{20} and M_0. The Analysis of variance however showed no significant effect of tillage, mulch rate and their interactions on SLCH (Table 3).

The particle size distribution of soils lost due to the harvesting of sweet potatoes was not also significantly affected by tillage practices, mulch rate and the interaction of the two but sand particles dominated the lost soils with TL and NT having sand content of 82% while those of M_0, M_{10}, M_{20} and M_{30} were 82.87, 81.20, 82.20 and 82.20%, respectively (Table 3). The contents of clay and silt were low but silt contents were generally lower than that of clay. While the contents of clay ranged from 11.17 % to 12.51% that of silt ranged from 5.29 to 6.96%. There were no significant effects of tillage, mulch rate and their interactions on the texture of soil lost to the harvesting of sweet potatoes (Table 3).

Soil loss due to crop harvest was apparently highest in no-tilled soils and also increased with increase in cattle-cud mulch rates because of the increase in organic matter in no-tilled soils and in soils with increase in cattle-cud mulch. Murphy [24] reported that soil organic matter binds soil particles together into stables aggregates. The higher SLCH in M_{30} compared to lower rates of cattle-cud mulch can be attributed to the increased soil organic matter input, which led to their increased aggregation as was presented earlier in this study. The result is an indication that well aggregated soils would cling more to harvested crops than less aggregated soils.

	SLCH (g)	sand (%)	Silt (%)	Clay (%)	Texture
Tillage					
TL	69.42	82.03	5.96	12.01	LS
NT	71.92	82.20	5.96	12.01	LS
LSD (0.05)	Ns	Ns	Ns	ns	
Mulch Rate					
M_0	47.33	82.87	6.29	11.17	LS
M_{10}	73.50	81.20	6.96	11.84	LS
M_{20}	69.00	82.20	5.29	12.51	LS
M_{30}	92.83	82.20	5.29	12.51	LS
LSD (0.05)	Ns	Ns	Ns	ns	
Tillage x Mulch Rate Interaction					
TLM_0	48.00	6.63	10.17	6.63	
TLM_{10}	69.00	5.29	13.51	5.29	
TLM_{20}	62.33	5.29	12.17	5.29	
TLM_{30}	94.67	6.63	12.17	6.63	
NTM_0	46.67	5.96	12.17	5.96	
NTM_{10}	74.33	8.63	10.17	8.63	
NTM_{20}	75.67	5.29	12.84	5.29	
NTM_{30}	91.00	3.96	12.84	3.96	
LSD (0.05)	Ns	Ns	Ns	ns	

Table 3: Mean Soil Loss parameters as affected by tillage practices and cattle-cud mulch rates.

SLCH: Soil Loss due to Crop Harvesting; TL: Tillage; NT: No Till; M_0: Mulch at 0 tonnes/ha; M_{10}: Mulch at 10 tonnes/ha; M_{20}: Mulch at 20 tonnes/ha; M_{30}: Mulch at 30 tonnes/ha; TLM_0: Tillage + Mulch at 0 tonnes/ha; TLM_{10}: Tillage + Mulch at 10 tonnes/ha; TLM_{20}: Tillage + Mulch at 20 tonnes/ha; TLM_{30}: Tillage + Mulch at 30 tonnes/ha; NTM_0: No Till + Mulch at 0 tonnes/ha; NTM_{10}: No Till + Mulch at 10 tonnes/ha; NTM_{20}: No Till + Mulch at 20 tonnes/ha; NTM_{30}: No Till + Mulch at 30 tonnes/ha; LSD: Least Significant Difference.

Effect of tillage practices and cattle-cud mulch rates on nutrient loss due to potato harvesting

Tillage practices significantly affected the concentration of available P and exchangeable Ca lost due to the harvesting of sweet potatoes. In both cases, higher concentrations were observed in TL soils (0.91 mg kg^{-1} available P and 1.51 cmol kg^{-1} exchangeable Ca) than in NT soils (0.58 mg kg^{-1} available P and 1.13 cmol kg^{-1} exchangeable Ca).There were no significant effect of tillage on the amount of total N, exchangeable Mg, Na and K lost during the harvesting of sweet potatoes but higher amounts of these nutrients were apparently lost under TL than NT (Table 4).

There were no significant effect of cud mulch rate on the amount of total N, available P, exchangeable Ca, Mg, Na and K lost during the harvesting of sweet potatoes (Table 4). However, the highest amounts of these nutrients were lost under M_0 and the trend decreased as the rate of cattle-cud mulch increased, leading to M_{30} with the lowest nutrient losses. There was no significant interactive effect of tillage practice and cattle-cud mulch rate on nutrient losses due to sweet potatoes harvesting (Table 4).

Significantly higher amounts of available P and exchangeable Ca as well as apparently higher amounts of total N, exchangeable Mg, Na, Ca and K lost under tilled soils compared to untilled soils showed that lesser nutrients were lost with increased organic matter content. Tillage-induced erosion is responsible for soil loss (> 20 t/ha) and thereby nutrient loss. Adoption of no-till system would help to reduce the rate of decomposition of organic matter [25], permits complex food webs to develop within the soil that more effectively recycles nutrients and will reduce the loss of nutrients experienced due to tillage. Apparent reduction in nutrient loss was also observed with increase in the rate of cattle-cud mulch application. It has been reported that organic matter is able to hold on to cations in a way that keeps them from leaching deep into the subsoil when water moves through the topsoil [26]. Through this mechanism, organic matter was probably the major source of negative charges that bound soil nutrients and prevented them from being lost.

	Total Nitrogen (%)	Av. P (Mg/Kg)	Ca (Cmol/Kg)	Mg (Cmol/Kg)	Na (Cmol/Kg)	K (Cmol/Kg)
Tillage						
TL	0.28	0.91	1.51	3.23	0.03	1.37
NT	0.25	0.58	1.13	2.74	0.02	1.26
LSD (0.05)	Ns	0.30	0.37	ns	Ns	Ns
Mulch Rate						
M_0	0.30	0.71	1.55	3.34	0.03	1.37
M_{10}	0.29	0.67	1.29	2.82	0.03	1.36
M_{20}	0.20	0.88	1.29	2.90	0.03	1.27
M_{30}	0.27	0.72	1.14	2.90	0.02	1.24
LSD (0.05)	Ns	Ns	Ns	ns	Ns	Ns
Tillage x Mulch Rate Interaction						
TLM_0	0.28	0.75	1.87	3.57	0.02	1.32
TLM_{10}	0.26	0.80	1.69	3.15	0.04	1.45
TLM_{20}	0.23	1.29	1.56	3.25	0.02	1.27
TLM_{30}	0.36	0.80	0.91	2.97	0.03	1.42
NTM_0	0.33	0.66	1.22	3.11	0.03	1.42
NTM_{10}	0.33	0.55	0.90	2.48	0.02	1.28
NTM_{20}	0.17	0.47	1.03	2.55	0.03	1.27
NTM_{30}	0.18	0.65	1.37	2.82	0.01	1.06
LSD (0.05)	Ns	Ns	Ns	ns	Ns	Ns

Table 4: Nutrient contents of the loss soil as affected by tillage practices and cattle-cud mulch rates.

Av.P: Available Phosphorus; Ca: Calcuim; Mg: Magnesium; TL: Tillage; Na: Sodium; K: Potassium; NT: No Till; M_0: Mulch at 0 tonnes/ha; M_{10}: Mulch at 10 tonnes/ha; M_{20}: Mulch at 20 tonnes/ha; M_{30}: Mulch at 30 tonnes/ha; TLM_0: Tillage + Mulch at 0 tonnes/ha; TLM_{10}: Tillage + Mulch at 10 tonnes/ha; TLM_{20}: Tillage + Mulch at 20 tonnes/ha; TLM_{30}: Tillage + Mulch at 30 tonnes/ha; NTM_0: No Till + Mulch at 0 tonnes/ha; NTM_{10}: No Till + Mulch at 10 tonnes/ha; NTM_{20}: No Till + Mulch at 20 tonnes/ha; NTM_{30}: No Till + Mulch at 30 tonnes/ha; LSD: Least Significant Difference.

Relationships between yield of sweet potatoes, soil properties and soil loss parameters

Table 5 presents the relationship between soil loss parameters and some soil physical properties. Soil loss due to crop harvesting (SLCH) correlated significantly and positively with total porosity (r = 0.430*). The amount of clay lost due to crop harvesting correlated significantly and positively with the amount of clay in the soil (r = 0.501*) and also with the mean weight diameter (r = 0.426*) while its correlation with bulk density was negative (r = -0.432*).

Table 6 presents the relationship between soil loss parameters and some soil chemical properties. Table total N concentration lost to crop harvest correlated significantly and positively with soil pH (r = 0.616**). Available P lost to crop harvest correlated significantly and positively with calcium lost to crop harvest (r = 0.533**), magnesium lost to crop harvest (r = 0.426**) and available P in the soil (r = 0.467**). Calcium lost due to crop harvesting correlated significantly and negatively with soil exchangeable Ca (r = -0.504*), Mg (r = -0.534**), total exchangeable bases (r = -0.516**) and effective cation exchange capacity (r = -0.513*). K lost due to crop harvesting correlated significantly and positively with soil pH (r = 0.450*).

	SLCH	Sand–L	Silt-L	Clay-L	Sand	Silt	Clay	Ksat	BD	TP	MWD
SLCH	1.000										
Sand-L	0.083	1.000									
Silt-L	-0.314	-.457*	1.000								
Clay-L	0.212	-.468*	-.558**	1.000							
Sand	-0.063	0.191	0.261	-.466*	1.000						
Silt	-0.025	0.203	-0.195	0.019	-.450*	1.000					
Clay	0.084	-0.350	-0.154	.501*	-.794**	-0.185	1.000				
Ksat	0.324	-0.128	-0.090	0.248	-0.390	0.397	0.162	1.000			
BD	-0.390	0.128	0.309	-.423*	0.128	0.306	-0.352	-0.032	1.000		
TP	.430*	-0.037	-0.332	0.365	-0.131	-0.211	0.292	0.233	-.941**	1.000	
MWD	0.048	-0.260	-0.117	.426*	-0.178	0.104	0.121	0.317	-0.152	0.141	1.000

Table 5: Correlation between soil loss parameters and some soil physical properties.

SLCH: Soil Loss due to Crop Harvest; Sand-L: Amount of Sand Lost; Silt-L: Amount of Silt Lost; Clay-L: Amount of Clay Lost; Ksat: Saturated Hydraulic Conductivity: BD: Bulk Density; TP: Total Porosity; MWD: Mean Weight Diameter.

	TN-L	AvP-L	Ca-L	Mg-L	K-L	pH	OM	TN	AP	Ca	Mg	K	TEB	EA	ECEC	BS
TN-L	1.000															
AvP-L	-0.190	1.000														
Ca-L	-0.087	0.533**	1.000													
Mg-L	0.000	0.426*	0.328	1.000												
K-L	-0.162	0.504*	0.194	0.225	1.000											
pH	0.616**	0.398	0.105	0.003	.450*	1.000										
OM	-0.361	-0.118	0.134	-0.069	-0.325	-0.151	1.000									
TN	-0.388	0.040	0.163	-0.123	-0.280	0.080	.812**	1.000								
AP	-0.269	0.467*	0.099	0.021	0.188	.581**	-0.081	0.126	1.000							
Ca	0.221	-0.259	-0.504*	-0.168	-0.227	-0.141	-0.328	-0.379	-0.069	1.000						
Mg	0.209	-0.203	-.534**	-0.139	-0.136	-0.117	-.434*	-.520**	-0.158	.933**	1.000					
K	-0.296	-0.388	-0.103	-0.180	-0.185	-0.124	0.322	0.262	-0.379	-0.202	-0.210	1.000				
TEB	0.219	-0.254	-.516**	-0.165	-0.213	-0.138	-0.350	-.408*	-0.089	.998**	.955**	-0.199	1.000			
EA	0.033	0.013	0.147	0.091	0.073	0.087	-0.059	-0.219	0.238	0.311	0.279	-.460*	0.306	1.000		
ECEC	0.202	-0.251	-.513*	-0.148	-0.220	-0.142	-0.333	-0.398	-0.089	.995**	.950**	-0.215	.996**	0.341	1.000	
BS	0.149	-0.126	-0.367	-0.238	-0.027	0.019	-0.310	-0.252	-0.027	.723**	.754**	-0.068	.737**	-0.013	.686**	1.000

Table 6: Correlation between soil loss parameters and some soil chemical properties.

TN-L: Total Nitrogen Lost to Crop Harvesting; AvP-L: Available P Lost to Crop Harvesting; Ca-L-exchangeable Ca Lost to Crop Harvesting; Mg-L: Exchangeable Mg Lost to Crop Harvesting; K-L: Exchangeable K Lost to Crop Harvesting; OM: Organic Matter; TN: Total Nitrogen; AP: Available Phosphorus; TEB: Total Exchangeable Bases; ECEC: Effective Cation Exchange Capacity; BS: Base Saturation.

The significant positive correlation between total N lost to crop harvest and soil pH is due to the fact that nitrification is pH-depended and reduces with decrease in soil pH and can be inhibited under the pH of 5 [27].

Conclusion and Recommendation

Tuber girth and tuber length showed significant increase with increases rate of cattle-cud mulch application. Though there was no significant effect of cattle-cud mulch application on Marketable Tubers, Non Marketable Tubers, Number of Tuber and Yield of Tuber, the general trend was similar to those of tuber girth and tuber length. The application of cattle-cud mulch significantly increased Soil loss on harvested crop owing to the increase in soil organic matter and aggregation, which resulted in aggregated soils clinging more to the tuber of harvested crops than in less aggregated soils. Significantly higher amounts of available P and exchangeable Ca as well as apparently higher amounts of total N, exchangeable Mg, Na, Ca and K were loss under tilled soils compared to untilled soils.

Based on the findings of this study, it is imperative that farmers should adopt no till method of seed bed preparation in the cultivation of sweet potatoes as well as other root and tuber crops as this approach preserves the soil structure as it improves infiltration and hydraulic conductivity; thereby improving water availability at the rooting zone. Also, tuber crop should be harvested at optimum moisture content to reduce the quantity of soils carried away from the field as well as the corresponding nutrient lost from such soils.

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