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EFFECTS OF SOIL PROPERTIES ON SOIL LOSS DUE TO HARVESTING OF YAM ON A SANDY LOAM SOIL IN SOUTHWEST NIGERIA

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ABSTRACT

Globally, soil degradation is becoming more of an issue since it limits the amount of fertile topsoil available for food production. This study examines the soil property effects on soil loss due to harvesting of yam (SLHY) on a sandy loam soil in south west Nigeria. The experiment was laid out in a 3 x 2 factorial in a Randomized Complete Block Design (RCBD) with three replicates. Three cultivars of yam (Tropical *Dioscorea rotundata* TDr 95/18544, Tropical *Dioscorea alata* TDa 00/00194 and Tropical *Dioscorea alata* TDa 00/00006*)* and two cultural practices (staked and unstaked) were the treatments used. Yam tubers were harvested manually and the amount of soil attached to the yam tubers were measured. Post soil analysis result showed that selected soil physical properties examined were significantly different in the interaction between cultural practices and yam cultivars. Among the three cultivars, TDa00/00194 (1.40 g cm^{-3}) had the highest bulk density and least by TDr95/18544 (1.23 g cm^{-3}) under staked. TDa00/00006 (1.30 g cm^{-1}) had the highest bulk density and least by TDa00/00194 (1.18 g cm^{-3}) under unstaked cultural practices. Root hair had positive correlation with soil loss. Highest total soil loss due to harvesting of yam was recorded in TDa00/00006 (253.4 kg ha^{-1}) under staked while TDa00/00194 (229 kg ha^{-1}) had the highest total soil loss under unstaked. Root hairs were significantly ($p \leq 0.05$) higher in TDa00/00194, which could have responsible for significant difference in soil loss due to harvesting of yam (SLHY) among the three cultivars. The study revealed that growing yam cultivars with less root-hair will reduce the amount of soil that will be transported to the market place. Consequently, soil loss due to crop harvesting should be considered in soil erosion control strategies, and for better post harvest procedures.

Keywords: Soil Properties; Soil loss; Yam, staked, unstaked

Introduction

On arable land, the three most frequently studied soil erosion processes are soil loss by water, wind, and tillage. (Ruysschaert *et al*., 2004). Significant amounts of soil may be lost when crops such as sugar beets, potatoes, chicory roots, and carrots are harvested. (Ruysschaert *et al*., 2004). Soil adhering to crops is transferred from the harvesting field to areas such as headlands, farmsteads, and crop-processing facilities. This process of soil mobility is known as soil loss due to crop harvesting (SLCH). (Ruysschaert *et al*., 2004). The amount of fertile top soil that may be used for food production decreases due to soil loss caused by crop harvesting. Since more than 99% of the world's food is produced on land, it is crucial to comprehend how soil loss occurs and to be able to foresee its effects in order to protect both the natural environment and the availability of food for humans. (Charles, *et al*., 2012). Soil erosion is the separation and movement of soil particles caused by various forces such as water, wind, or tillage. (Poesen and Govers, 1994). One of the main factors contributing to soil degradation is soil erosion. (Oldeman and van Lynden, 1998). Water and wind erosion, mass movements, and, more recently, tillage erosion are regarded to be the most major soil erosion processes. As a result, these processes are the most often researched.

Soil erosion induced by tillage techniques such as mouldboard and chisel operations redistributes soil particles inside a specified field parcel, while material displaced by wind or water is either deposited inside or removed from arable land. Poesen *et al.* (2001) focused on soil erosion caused by agricultural harvesting, a process that is frequently overlooked yet appears to be substantial. (The aforementioned kind of soil degradation is caused by the harvest of root and tuber crops such as (fodder and sugar beet (Beta vulgaris L.), carrot (*Daucus carota* L.), chicory (*Cichorium intybus* L.), cassava (*Manihot spp.*), potato (*Solanum tuberosum* L.), sweet potato (*Ipomoea batatas* (L.) Lam.), yam (*Dioscorea spp.*), bulb crops such as onion (*Allium cepa* L.), groundnut (*Arachis hypogaea* L.) and vegetables (leek (*Allium porrum* L.), asparagus (*Asparagus officinalis* L.), celeriac (*Apium graveolens* L.). The crops are "harvested" from the field along with loose dirt, rock fragments, and soil that has adhered to the crop. The term "soil erosion by crop harvesting" refers to the transfer of soil from the crop's growing area to other locations such as headlands, farmsteads, and processing facilities." This process of soil erosion is known as Soil Lost caused by Crop Harvesting. (SLCH). Rarely has the SLCH been taken into account in studies of soil erosion, and it has never been acknowledged as a global human mechanism for soil deterioration. (Oldeman and van Lynden, 1998; UNEP, 2000). However, Poesen *et al.* (2001) found that soil loss from harvesting chicory and sugar beet roots ranged from just a few to hundreds of Mg per ha every harvest. In 2000, over 88 million hectares of crops were grown worldwide for SLCH research (FAO, 2002), with Belgium accounting for more than 190,000 ha of that total. (NIS, 2000).

There are around 600 species of yam, a tropical crop belonging to the genus *Dioscorea*, in the world. Of those, 50 to 60 are cultivated or harvested for food or medicinal, although only 10 are economically significant as food plants. (Lebot, 2009). While *D. dumenturum* (bitter yam), *D. bulbifera* (bulbil yam), and *D. esculenta* (lesser yam) were minor yams, the three primary food yams include *D. rotundata* (white yam), *D. alata* (water yam), and *D. cayenesis* (yellow yam). (Lebot 2009). There are many varieties of yam in the tropics, but there are very few in the world's temperate climate. Yam is the third largest tropical root crop when it comes to production, after cassava (Manihot esculenta Crantz) and sweet potato. (Ipomea batata Lam). (Scott *et al.*, 2000).

At the conclusion of the dry season (November/December) or the start of the rainy season (February/March), yam is typically planted on mounds or ridges. Yam is typically planted in West Africa as the first crop following clearing since it demands fertile soil. (Scott *et al*., 2000). Over 60 million people in West and Central Africa eat yams (*Dioscorea* spp.), which are a key staple tuber crop. (Nweke *et al.,* 1991). 95 percent of the yearly global output of 301 million metric tonnes of yam is produced in the West African Yam Belt. 75 percent of the world's entire yam production comes from Nigeria alone. (FAO, 1998).

In shifting agricultural systems, yam is usually always planted first in the cropping cycle, right after the fallow is cleared. Yams are less commonly planted in locations where fallow length has been reduced owing to land pressure because the soil is deemed inadequately rich for them. (FAO, 1998). When grown on fertile soil, yields in the main West African producing nations are around 11 t ha-1. According to FAO, 48.7 million tons of yams were grown globally in 2010, with Sub-Saharan Africa accounting for 97% of the total. (2010). Nigeria is the largest producer in West Africa, with a total of 34 million tons, next to Côte d'Ivoire (5 million), Ghana (3.9 million), and Benin. (2.1 million). (IITA, 2010). Benin (364 Kcal), Cote d'Ivoire (342 Kcal), Ghana (296 Kcal), and Nigeria (258 Kcal) have the highest per capita yam consumption. (IITA, 2010). The number of root hairs on yam tubers varies by yam species. Different *Dioscorea* species have different levels of tuber hairiness, which may trap soil on the surface of the tubers during harvest. The number of soil particles that may be retained by tuber hairs may also be significantly influenced by soil texture. Despite the fact that yam is a significant staple food consumed, produced, and present in many parts of Nigeria, the soil loss due to crop harvesting (SLCH) with regards to yam tubers has not been estimated globally, and little is known about the relationship between soil loss due to harvesting of yam tubers as well as soil properties.

Materials and Methods

Site description

The experiment was conducted at the Teaching and Research Farm of the University of Ibadan, Oyo state (latitude 07^0 27'44.17" to 07˚27'44.26" N, longitude 03^0 53'28.004" to 03˚53'28.14" E), Ibadan, Nigeria. The annual rainfall is 1250 mm with a bimodal pattern and has a minimum temperature of 21.90C and a maximum temperature of 35.50C (U.I 2020).

Experimental design and treatment

The experiment was laid out in a 3 x 2 factorial in a Randomized Complete Block Design (RCBD) with three replicates. Three cultivars of yam (Tropical *Dioscorea rotundata* TDr 95/18544 and Tropical *Dioscorea alata* TDa 00/00194 and Tropical *Dioscorea alata* TDa 00/00006*)* and two cultural practices (staked and unstaked) were the treatments used. Staking was done with the aid of bamboo of about 3 m long. About 50 cm of the pole was buried in the soil for firmness and stability. Out of 12 mounds per experimental unit, six yam vines from six mounds were staked while six yam vines were left unstaked.

Soil sampling, preparation, and analysis

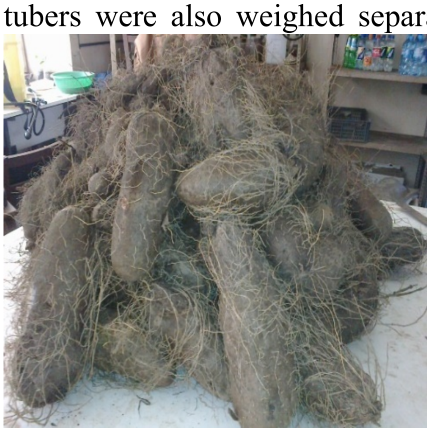
Before planting, soil samples were collected randomly from 0-10cm topsoil from the experimental plots which were analyzed for physical and chemical properties. Before collecting the soil samples, soil surface plant litter was carefully removed. The soil samples collected were packed into well-labeled polythene bags and sealed for transportation to the laboratory to determine; bulk density by core-sampling method (Baruah and Barthakur, 1997), particle size distribution using hydrometer method (Bouyoucos, 1962), saturated hydraulic conductivity by core-sampling method (Soil Science Society of America, 2002; Oshunsanya, 2016), soil pH using pH meter (Udo and Ogunwale, 1986), organic carbon using Walkley Black wet oxidation method (Udo and Ogunwale, 1986), total nitrogen using khadjahl method (Kjeldahl, 1883; Fenton, *et. al*., 2016), available phosphorus with a spectrophotometer using Mehlich 111 as extractant (Mehlich, 1984) method, exchangeable bases (K, Ca, Na, and Mg) with atomic absorption spectrometer, exchangeable acidity and extractable Micronutrient (Fe, Mn, Cu, and Zn) with atomic absorption spectrometer. Post-planting soil was also collected as done before planting to determine the post-planting soil analysis after harvesting.

Sample protocol

Soil samples from the yam fields were taken in the morning during the harvesting of the yams from the heaps. Yam tubers were carefully excavated from the heaps using small cutlasses and hands after cutting off the yam stems. The tubers were hand rubbed as to remove the soil attached or soil adhering to the tubers. The soils were weighed and yam tubers were also weighed separately using a weighing balance. The soil samples collected were then loaded into polythene bags and secured for transportation to the laboratory for further investigation.

Land preparation and crop establishment

The field was cleared manually with cutlass and hoe. Yam setts with an average weight of 260 g were cut from yam tubers using knife. Each yam sett was planted directly at the centre of each mound at a spacing of 1m x 1m. Yam setts were planted at a depth of 15cm. Weeding was done manually as and when due on the field. Data were collected on weight of freshly harvested tubers (WFHT) (kg/ha) using weighed balance at eight months after planting, root hairs (RH) was removed from the tubers using razor blade and weighed using sensitive measuring scale, and total soil loss (TSL) from the soil attached to the harvested yam (i.e. the soils attached to the surface of the freshly harvested tubers were rubbed off with bare hand, weighed using measuring scale and bagged separately.was weighed using measuring scale.



TDa00/00194 (*D. alata*) **TDa00/00006 (*D. alata*)** **TDr95/18544 (*D. rotundata*)**

Plate 1: A comparison of the degree of hairiness of the three cultivars of yam investigated

Statistical Analysis

Data collected were analyzed statistically using the Genstat Statistical Software package. Means were separated using the Least significant difference (LSD) at a 5% level of significance.

Results and Discussion

Pre-planting soil physical and chemical properties of the experimental site is as presented in table 1. The result reveals that the soils are moderate in zinc and phosphorous (1.26 and 20 mg/kg), high in potassium, Organic carbon and total nitrogen (0.71 cmol kg^{-1}, 25.0 and 3.8 g kg^{-1}) respectively which is above the critical range (Adeoye and Agboola, 1985). The pH of the soil was nearly neutral. This implies that the soil is suitable for yam production. The extractable Mn and Fe contents of the soil are high with 302 and 265 mg kg^{-1}, respectively. The experimental site was classified as an Alfisol (Smyth and Montgomery, 1962) with its distinctive characteristics. The soil bulk density was 1.2 g cm^{-3} with sandy loam texture indicating a well drained and a range of fine texture soil i.e. the soil is not compacted. Saturated hydraulic conductivity was 12.84 cm hr^{-1} indicating a well drained soil suitable for growing yam.

Table 1: Pre-planting soil physical and chemical properties of the experimental site

Soil parameters	Content in soil
pH (H_2O)	6.9
Organic carbon (g kg^{-1})	25.0
Total nitrogen (g kg^{-1})	3.8
Available phosphorus(mg kg^{-1})	20.0
Exchangeable cations (cmol kg^{-1})	
Ca	1.86
Mg	0.53
K	0.71
Na	0.81
Extractable micronutrient (mg kg^{-1})	
Mn	302.0
Fe	265.0
Cu	3.39
Zn	1.26
Exchangeable Acidity (cmol kg^{-1})	0.40
Particle size distribution (g kg^{-1})	
Sand	838
Silt	54
Clay	108
Textural class	Sandy loam
Bulk density (g cm^{-3})	1.2
Saturated hydraulic conductivity (cm hr^{-1})	12.84

Soil loss due to harvesting of yam tubers

Soil loss due to yam harvesting is as presented in Table 2. Study of soil loss due to harvesting of yam tubers showed that TDa00/00006 had the highest value of soil loss due to hand rubbing followed by TDa00/00194, and least by TDr95/18544 under staked while under unstaked the order was TDa00/00194 > TDa00/00006 > TDr95/18544. In terms of root-hair density, there was significant difference among the cultivars which was in order of TDa00/00194 (14.10 kg ha^{-1}) > TDa00/00006 (11.02 kg ha^{-1}) > TDr95/18544 (7.11 kg ha^{-1}) under staked while TDa00/00194 had the highest value of (15.40 kg/ha) followed by TDa00/00006 (9.66 kg ha^{-1}) and least by TDr95/18544 (6.41 kg ha^{-1}) under unstaked cultural practice. The differences among the varieties could be due to differences in the hairiness of the tubers. Visual observation showed that *Dioscorea alata* had higher tuber hairs and rougher tuber skin than *Dioscorea rotundata*. These tuber hairs trap soil particles to the tubers during harvesting. There was significant difference (P<0.05) between the cultivars in the soils losses due to harvesting of yam tuber. While Poesen *et al.,* (2011) observed that mean soil loss are 11.8 t ha^{-1} harvest for witloof chicory root, 8.1 t ha^{-1} harvest for sugar beet. In Russia, average soil losses caused by potato harvest appeared to be 2.5 Mg ha^{-1}harvest^{-1} on the basis of some field measurements in 1985 and 0.6 Mg ha^{-1} harvest^{-1} on the basis of factory measurements in 1985 and 1986. The minimum and maximum soil loss in the study ranged between 0.1 and 3.4 Mg ha^{-1} harvest^{-1}(Belotserkovsky and Larionov, 1988). Some measurements of stored potatoes in Germany revealed a soil loss of 0.06 to 0.49 Mg ha^{-1} harvest^{-1} (Auerswald *et al.,* 1997).

Table 2: Soil loss due to yam harvesting

Cultural practice	Yam cultivar	WFHT	SLHR	TSL	RH
			kg ha^{-1}		
Staked	TDr95/18544	11544	102.0	119.9	7.11
	TDa00/00194	13278	194.6	222	14.10
	TDa00/00006	17189	212.3	253.4	11.02
	$\overline{X}$	14003.7	169.6	198.4	10.7
Unstaked	TDr95/18544	10844	80.4	115	6.41
	TDa00/00194	20433	202.5	229	15.40
	TDa00/00006	18878	165.5	194	9.66
	$\overline{X}$	16718.3	149.5	179.3	10.5
LSD (p≤0.05) Cultivar		8809.8*	37.39*	43.6*	3.43*
LSD (p≤0.05) Cultural practice		Ns	45.79*	ns	4.20**
LSD (p≤0.05) Cultural practice x cultivar		Ns	Ns	ns	Ns

x=Interaction, *=P≤0.05, **=P≤0.01 ns = not significantly different,
CP = cultural practices, WFHT= Weight of freshly harvested tubers (kg ha^{-1}),
TSL= Total soil loss (kg ha^{-1}), RH = Root hairs (kg ha^{-1}),

Nutrient losses in the soil removed by yam tubers

Nutrients loss due to hand rubbing of yam tubers is presented in Table 3. Among the nutrients analysed from soil loss, only manganese had significant difference between the cultural practices. However, the cultivar had no significant effect. The nutrient loss from harvesting was relatively high with respect to other crops like carrot, cassava and onion as reported by (Mwango *et al.,* 2015; Isabirye *et al.* 2007).

Table 3: Nutrient losses in the soil removed by yam tubers

Cultural practice	Yam cultivar	Ph	O.C	TN	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn	Ex. Acidity
			(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-1})	(cmol kg^{-1})			(mg kg^{-1})				(cmol kg^{-1})
Staked	TDr95/18544	6.8	33.6	3.74	25.0	0.92	2.76	0.31	0.74	205	223.7	3.58	1.34	0.43
	TDa00/00194	6.8	39.3	4.00	20.7	0.48	1.75	0.26	0.56	214	180.0	3.03	1.03	0.33
	TDa00/00006	6.6	33.9	3.70	17.3	0.41	3.71	0.28	0.59	280	242.0	3.65	1.23	0.32
Unstaked	TDr95/18544	6.8	38.7	4.03	26.0	0.39	1.45	0.27	0.70	178	170.3	1.42	1.15	0.45
	TDa00/00194	6.8	34.3	3.77	18.0	0.93	0.96	0.34	0.60	167	208.7	2.35	1.39	0.42
	TDa00/00006	6.7	30.1	4.04	19.0	1.61	1.06	0.24	0.56	206	215.0	3.32	1.12	0.32
LSD ($p \leq 0.05$) Cultural practice		Ns	Ns	Ns	ns	Ns	ns	ns	Ns	44.2*	Ns	ns	ns	ns
LSD ($p \leq 0.05$) Cultivar		Ns	Ns	Ns	ns	Ns	ns	ns	Ns	ns	Ns	ns	ns	ns
LSD ($p \leq 0.05$) Cultural Practice x cultivar		Ns	Ns	Ns	ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns

CP = cultural practices, ns = not significantly different, x = Interaction,

Post-harvest soil physical properties of the experimental site

The post-harvest soil physical properties of the experimental site are as presented in table 4. Gravimetric moisture content, saturated hydraulic conductivity, sand silt, clay and total porosity had significant difference in the interaction between cultural practices and yam cultivars. While, bulk density did not significantly different in the interaction between cultural practices and cultivars used in the post harvest. Among the three cultivars, TDa00/00194 (1.40 g cm^{-3}) had the highest bulk density and least by TDr95/18544 (1.23 g cm^{-3}) under staked. While, TDa00/00006 (1.30 g cm^{-1}) had the highest bulk density and least by TDa00/00194 (1.18 g cm^{-3}) under unstaked cultural practices. TDa00/00006 (11.57 %) had the highest gravimetric moisture content and least by TDr95/18544 (10.66 %) under staked. While, TDr95/18544 (13.60 %) had the highest gravimetric moisture content and least by TDa00/00006 (11.88 %) under unstaked cultural practices. TDa00/00006 (13.73 cm hr^{-1}) had the highest saturated hydraulic conductivity and least by TDa00/00194 (11.78 cm hr^{-1}) under staked while TDa00/00006 (17.33 cm hr^{-1}) had the highest saturated hydraulic conductivity and least by TDa00/00194 (1.91 cm hr^{-1}) under unstaked cultural practices. The textural class of the soil was sandy loam and TDa00/00194 (55.47 %) had the highest total porosity and least by TDa00/00006 (50.94 %) under staked however, TDr95/18544 (53.58 %) had the highest total porosity and least by TDa00/00194 (47.17 %). The result of this study agrees with the reports established by Li *et al*., (2006) and Ruysschaert *et al*. (2006) where soil moisture content had significant difference, linear and exponential relationship with soil loss parameters.

Table 4: Post-harvest soil physical properties of the experimental site

Cultural practice	Yam cultivar	Sand	Silt ($g\ kg^{-1}$)	Clay	T. C	BD ($g\ cm^{-3}$)	SHC ($cm\ hr^{-1}$)	TP (%)	G.M.C (%)
Staked	TDr95/18544	650	230	120	S.L	1.23	12.06	53.58	10.66
	TDa00/00194	620	290	90	S.L	1.40	11.78	47.17	11.50
	TDa00/00006	740	190	70	S.L	1.34	13.73	49.43	11.57
Unstaked	TDr95/18544	800	50	150	S.L	1.28	15.45	51.70	13.60
	TDa00/00194	750	90	160	S.L	1.18	12.91	55.47	12.13
	TDa00/00006	710	130	160	S.L	1.30	17.33	50.94	11.88
LSD ($p \leq 0.05$) Cultural practice		**	**	**		Ns	**	**	**
LSD ($p \leq 0.05$) Cultivar		**	**	**		Ns	**	**	Ns
LSD ($p \leq 0.05$) Cultural Practice x cultivar		**	**	**		Ns	**	**	**

S.H.C = Saturated hydraulic conductivity, B.D = Bulk density, T.C = Textural class,
S.L. = Sandy loam

Relationships among root hair (RH), tuber yield (TY), and total soil loss (TSL)

The correlation coefficient among root hair (RH), tuber yield (TY), and total soil loss (TSL) is presented in Table 4, fig. 1 and fig. 2. Mass of root hairs was low and positively correlated to the weight of freshly harvested tubers (0.305 kg ha^{-1}) which implies that an increase in yield will lead to an increase in root hair. Also, root-hair was significantly ($p \leq 0.05$) correlated with the total soil loss due to harvesting of yam tubers (0.656 kg ha^{-1}). Total soil loss due to harvesting of yam was low and positively correlated to the weight of freshly harvested tubers (0.101 kg ha^{-1}) which means that the increase in the weight of freshly harvested tubers will lead to increase in soil loss due to harvesting of yam. The literature reports that root hairs are agents used for trapping sediment and exporting nutrients from the field during crop harvesting (Oshunsanya, 2022).

Table 5: Correlation matrix among root hair (RH), weight of freshly harvested tubers (WFHT), and total soil loss (TSL) due to harvesting of yam tubers

Parameters	RH	WFHT	TSL
		kg ha^{-1}	
RH (kg ha^{-1})	1	0.305	0.656**
WFHT (kg ha^{-1})		1	0.101
TSL (kg ha^{-1})			1

* = P ≤ 0.05, Correlation is significant at 5%, ** Correlation is significant at the 0.01 level.

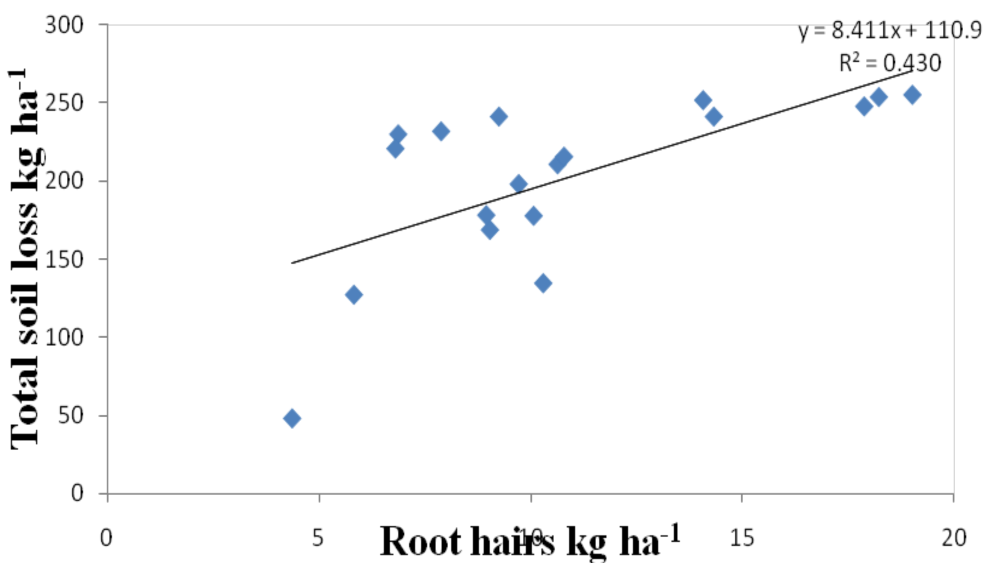


Figure 1: Relationship between total soil loss due to harvesting of yam and yam root-hairs (kg ha^{-1})

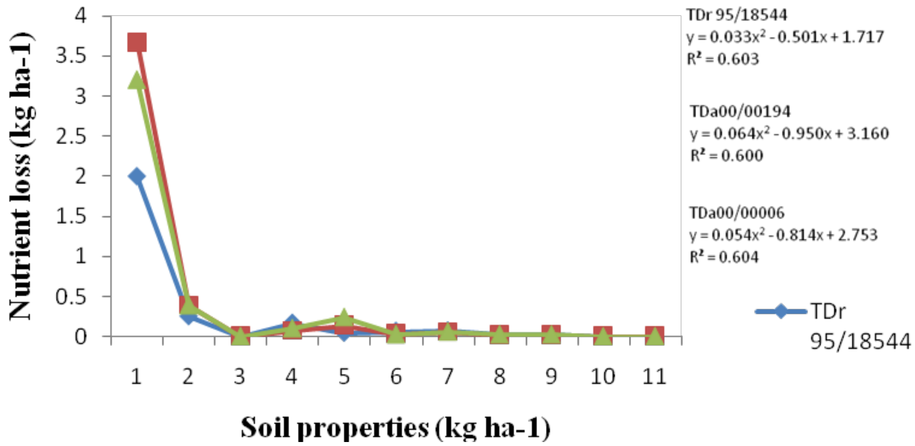


Figure 2: Relationship between field soil properties and soil loss due to harvesting of yam under different cultivars

Conclusion and Recommendation

Soil loss due to harvesting of yam was quantified and soil properties that influence the huge amount of soil loss were investigated. *Dioscorea alata* characterized by skin roughness and tuber hairs had more quantity of soil tare as compared with *Dioscorea rotundata* which is characterized with a smooth skin and less tuber hairs. Hairiness of Yam tuber significantly accounted for 65% of soil loss due to harvesting. It can be concluded that a significant amount of soil is lost from manual yam harvesting especially when the soils have high clay content. It can be recommended that farmers should take considerable measures such as cleaning up harvested root and tuber crops such as yam in the field so as to reduce the amount of soil lost to crop harvesting. Farmers should grow yam cultivars with less root-hair in order to reduce the amount of soil adhere to the yam tubers that will be transported to the market place.

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