Effect of Live Mulch Conservation Practices on Crop Yields: A study of Sweet potato in Southwest Nigeria.

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Authors' contributions

This work was carried out in collaboration between all authors. Author OSO and APA designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author OGE managed the analyses of the study. Author AO and CEA managed the literature searches. All authors read and approved the final manuscript.

Abstract

Live mulch can reduce land degradation by protecting the surface soil from direct impacts of rain drops and consequently increasing crop yields. To compare the potential biomass production of sweet potato for soil conservation, two farmlands with different degradation potentials were selected to plant ten commonly grown cultivars of sweet potato of Africa. Soil degradation rate (SDR) and vulnerability potential (Vp) of the two farms were also compared using selected soil properties as assessment tools. Results indicated that Farm A with higher total biomass slightly degraded with low vulnerability potential (SDR/Vp ≈ 2/4) while the Farm B with lower biomass severely degraded with high vulnerability potential (SDR/Vp ≈ 4/2). Correlation between biomass and yields was not significant for both the farms, indicating that biomass alone cannot determine the yields of sweet potato. On a slightly degraded soil, Benue, Akinima, TIS 87/0087 and Arrow tip cultivars had the highest tuber production (100 - 70)%, followed by Ex-Igbaraiam, Eruwa, Shaba, Ishiayi and TIS 8441 (69 - 50)% and least by Akwide (<50%). While on a severely degraded soil, Ex-Igbaraiam cultivar had the highest yield production (100 - 70) %, followed by Shaba, TIS 87/0087, Benue and TIS 8441 (69 - 50)% and least by Akwide, Eruwa, Ishiayi, Akinima and Arrow tip (<50%). The trend of the result reflects the ability of potato cultivars to cope with degraded soils. In terms of biomass production, TIS 87/0087, Ex-Igbaraiam, TIS 8441 and Benue was highest followed by Shaba and Akwide and least by Arrow-tip and Ishiayi. The results indicates that TIS 87/0087 cultivar can perform well under severely degraded soil while Ex-Igbaraiam and TIS 8441 with high biomass potential are better used as folders especially on a degraded soil.

Keywords: Sweet potato, soil degradation, vulnerability potential, yields.

1. Introduction

Sweet potato (*Ipomea batatas* L. Lam.) belongs to the family *Convolvulaceae*, and has a long history to stave off famine – especially as a cheap source of calories (1). Globally, sweet potato is a very important food crop and the total world potato production is estimated at 381,682,000 tonnes in 2014 (2). It is a major food and industrial root crop in Nigeria with an estimated annual production of 2.52 million tons (3). In terms of world's most important food crop, it ranked fourth, after rice, wheat and corn (4). According to (5), sweet potato is ranked third in the world's root and tuber crops, after Irish potato and cassava.

Sweet potato has a high yield potential that may be realised within a relatively short growing season and adapt to a wide range of ecological conditions (6). According to Tewe *et al*. (7), sweet potato is the only crop among the root and tuber crops that had a positive per capita annual rate of increase in production in Sub Saharan Africa. (8) also reported that Nigeria is the largest producer of sweet potato in Africa and the second largest in the world after China. Despite its importance, sweet potato cultivation is still restricted to few states in Nigeria and its production is mainly by small scale farmers for home consumption (6). For example, Benue State of Nigeria produced a mean yield of 9.80 t ha^{-1} sweet potato from approximately 212,840 ha of land in 2008 (8).

Although, estimates of sweet potato yields from different parts of Nigeria vary widely over the years. The Presidential Task Force Report on alternate formulation of livestock feeds (9), revealed a national sweet potato output of 530,000 tonnes for 1990, while FAO estimated that 143,000 tonnes of sweet potato were produced in 1990. FAO statistic, though lower, did show a major increase in the production of sweet potato in the 1990s, with output growing by nearly ten times over the decade (7). Despite the fact that FAO (10) further reported an increase in sweet potato output from 143,000 tonnes in 1990 to 2,468,000 tonnes in 2000, it was however attributed to the increase in area under cultivation from 13,000 ha to 381,000 ha, as yield was also reported to decrease from 11 to 6.8 t ha^{-1} over the same period. (11) reported that sweet potato variety commonly cultivated by farmers in the Southern Guinea Savannah Zone of Nigeria, which has a low soil fertility status, often produces low yields of 3 to 9 t ha^{-1}. Similarly, (12) reported that a mean yield of 3 to 7 t ha^{-1} on farmer's field is considered low. Poor sweet potato productivity in Sub-Saharan Africa has been traced to poor soil fertility status (13).

Another factor contributing to a decline in food production in upland farming systems, especially in Nigeria, has often been attributed to farmer's inability to replenish nutrients lost in continuous cultivation (14). This may partly be due to the intense farming pressure on the land in order to meet the food demand of the ever-growing population, consequently leading to soil degradation (15). Now, using satellite imagery for the years between 1981 and 2003, the FAO researchers estimate that 24 percent of all land surface area is depleted. Despite the world undergoing a crisis of food supply shortages, funding and research dedicated to global land degradation is sparse.

A recent study by (16), using an overlay of cropland areas and GLASOD data, showed that degraded agricultural land area has increased to about 16% of the world's agricultural land. (17) reported that since 1960, one-third of the world's arable land has been lost through erosion and other degradation processes that disrupt soil physical, chemical and biological activities, leading to reduction crop productivity over time. Out of three billion hectares of arable land in tropical Africa, only 14.7% is considered to be free of physical or chemical constraints, with one third (32.2%) having physical constraints, 13.2% having limited nutrient retention capacity, 16.9% having high soil acidity, and 6.8% having high phosphorus (P) fixation (18).

Due to the high cost of procuring fertilizers by peasant farmers in rural communities for improving crop yield coupled with the challenge of slow rate of mineralization of organic soil amendments, comparing coping potential of commonly grown sweet potato cultivars on degraded soils is evident. We aimed to (on-farm studies were conducted to) (i) assess the growth and yield performance of ten (10) sweet potato cultivars on a degraded soil and (ii) rate the soil degradation and its vulnerability potential in two farms.

2. Materials and methods

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2.1 Site description

The experiment was conducted at the Teaching and Research Farm, University of Ibadan. It lies between Latitude 07° 27′ 08.3″ N and Longitude 03° 53′ 29.7″ E with an elevation of 200 m above sea level. According to (19), Ibadan has a tropical wet and dry season, with a lengthy wet season and moderately varied temperatures throughout the year. Two farms were used for the study. Farm A and farm B have been continuously cultivated for 7 years and 10 years, respectively.

The field was laid out in a randomized complete block design (RCBD) for 2 farms with ten treatments replicated four times. The treatments consisted of sweet potato cultivars such as Arrow tip, Shaba, Ishiayi, TIS 8441, Akwide, Ex-Igbaraiam, Benue, Akinima, TIS 87/0087 and Eruwa. Each replicate occupied 3 m ×x 4 m area of land, which contained 15 mounds spaced at 1 m apart. This arrangement gave a total land area of 300 m^2 with a total plant population of 300 plants for farm A and 300 plants for plant B.

The mounds were averagely 38 cm in height with a circumference of 213 cm at the base. The 30 cm long vine cuttings were planted at the centre of the mound at an angle of 45° such that two-third (2/3) of the vine length was buried in the soil.

2.4 Soil sampling

Undisturbed and disturbed soil samples were randomly collected at 0-40 cm soil depth with the aid of soil cores and an auger, respectively. This was done prior to field preparation for laboratory analysis. The disturbed soil samples collected were bulked and thoroughly mixed to form a composite sample from which sub-samples were obtained for analysis. The sub samples were air-dried, and passed through 2 mm and 0.5 mm sieve respectively for various soil physical and chemical analysis.

Comment [AL2]: how long, time

2.5 Soil analysis

Soil physico-chemical parameters such as soil pH was determined using a glass-electrode pH meter in a 1:1 soil and water mixture (20); organic carbon was determined using the Walkley-Black wet-oxidation method (21). Total nitrogen was determined using the macro-kjeldahl digestion-distillation apparatus (22), while ascorbic acid molybdate blue method was used in the colorimetric determination of available phosphorus in water and soil extracts (23). The exchangeable bases and micronutrient analyses were carried out using ammonium acetate and

Comment [AL3]: mass or volume?

0.01N HCl procedure (24). Value for sodium was read with the aid of a flame photometer while the respective values for other elements were read using the atomic absorption spectrometer. Particle size distribution was determined using the Bouyoucos hydrometer method, with calgon as the dispersant (25). Bulk density was determined by core method while saturated hydraulic conductivity was determined using the constant-head steady state permeability method (26).

2.6 Data collection

Data on growth indicators such as the number of leaves was obtained by counting, while vine length was obtained by measuring the length of sweet potato vines with the aid of a metre rule. Data on both parameters were collected at two (2) weeks interval from five (5) to eleven (11) weeks after planting (WAP). Yield parameters such as weight of harvested tubers and total biomass (on fresh weight basis) were determined on the field by weighing the tubers and all agronomic components of the sweet potato varieties, respectively. Furthermore, the harvest index and percentage yield production for each sweet potato variety were determined as follows:

$$HI = \frac{TW}{TBW} \quad (1)$$

Where HI = harvest index, TW = weight of harvested tuber, TBW = weight of total biomass.

$$\%YP = \frac{MY}{TM} \times 100 \quad (2)$$

Where %YP = percentage yield production, MY = mounds with yield, TM = total mounds planted to sweet potato.

2.7 Soil degradation rating (SDR) and vulnerability potential (Vp) assessment

Degradation and vulnerability ratings were carried out using the rating scheme for soil degradation developed by (27) and (28) for soil physical and chemical properties such as texture, pH (H_2O), organic carbon, total nitrogen, and available phosphorus. These parameters were selected because they have been considered as important measures of soil quality that determine soil productivity (29). The critical levels of soil quality were weighted on a scale of 1 to 5. For the SDR, the weighting sequence was as follows: 1 = no degradation, 2 = slightly degraded, 3 = moderately degraded, 4 = severely degraded, and 5 = extremely degraded. Thus, good soils have the lowest SDR and poor soils the highest value. However, the reverse of the weighting order was the case for vulnerability potential where 5 = no vulnerability, 4 = low vulnerability, 3 = moderate vulnerability, 2 = high vulnerability, and 1 = very high vulnerability. Determination of SDR of the selected soil parameters was based on the established critical levels of soil elements from various literatures (30; 31; 27; 32).

2.8 Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) using GenStat Statistical package 8th edition. Means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability.

3. Results

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2.13.1 Soil physical and chemical properties of experimental site

Table 1 presents the results of the soil physical and chemical properties of the study site for both Farms A and B respectively. The soils of the experimental sites were slightly acidic. In Farm A, the soil had a pH value of 5.7. The org. C content was 26.04 g/kg, while the TN, available phosphorus and potassium contents were 2.69 g/kg, 17.71 mg/kg and 0.49 cmol/kg, respectively. The site had a bulk density and saturated hydraulic conductivity values of 1.39 g/cm^3 and 1.38 cm/hr, respectively.

However, Farm B has soil pH of 5.6, while its organic carbon reduced to 4.58 g/kg. The total nitrogen was 0.91 g/kg with available phosphorus of 8.88 mg/kg and potassium of 0.05 cmol/kg. Its bulk density and hydraulic conductivity values were 1.53 g/cm^3 and 4.20 cm/hr respectively. Texturally, both farms are loamy sand.

Table 1: Soil properties of degraded soils planted to sweet potato varieties

Parameter	Value	
	Farm A	Farm B
pH (1:1 H_2O)	5.7	5.6
Organic carbon (g/kg)	26.04	4.58
Total nitrogen (g/kg)	2.69	0.91
Available phosphorus (mg/kg)	17.71	8.88
K (cmol/kg)	0.49	0.05
Ca (cmol/kg)	9.81	0.39
Mg (cmol/kg)	0.77	0.77
Na (cmol/kg)	0.65	0.84
Mn (mg/kg)	166	26.8
Cu (mg/kg)	0.59	1.90
Fe (mg/kg)	94.1	269.0
Zn (mg/kg)	3.48	18.3
Bulk density (Mg m^{-3})	1.39	1.53
Saturated hydraulic conductivity (cm hr^{-1})	1.38	4.20
Particle size distribution (g kg^{-1})		
Sand	872	874
Silt	55	80
Clay	73	46
Textural class	Loamy sand	Loamy sand

2.23.2 Soil degradation rating (SDR)/vulnerability potential (Vp)

Soil degradation rating (SDR) and vulnerability potential (Vp) of the two farms are presented in Table 2. According to SDR, farms A and B are moderately degraded in terms of soil pH. However, farms A and B are moderately and extremely degraded respectively in terms of organic C content of the soils. In terms of total N, farms A and B revealed no degradation and severely degraded, respectively. Farm A was slightly degraded as per phosphorus content while farm B was severely degraded as per phosphorus content. Bulk density and saturated hydraulic conductivity values revealed that farm A was slightly degraded while farm B was severely degraded. However, farms A and B were severely degraded in terms of soil texture (loamy sand). On the average of aforementioned soil properties, farm A is slightly degraded while farm B contains moderately to severely degraded soil.

Vulnerability potential (Vp) of farms A and B indicated that the two farms had moderate vulnerability in terms of soil pH. Computed vulnerability potential values using organic C content showed that farm A is moderately vulnerable while farm B is very highly vulnerable to water erosion. However, total N content of the farms A and B indicated no vulnerability and high vulnerability, respectively. Vulnerability potential computed using available P revealed that farms A and B are low vulnerability and high vulnerability, respectively. Bulk density and saturated hydraulic conductivity values showed that vulnerability of farm A to water erosion is low. However, farm B had low vulnerability and no vulnerability for bulk density and saturated hydraulic conductivity. However, both farms are highly vulnerable to water erosion in terms of soil texture. Overall, soil properties assessment revealed that farm A had a low vulnerability potential while farm B had a high vulnerability potential to water erosion.

Table 2: Soil degradation rates (SDR) and vulnerability potential (Vp) of selected soil properties of farms A and B

Parameter	Farm A		Farm B	
	Mean value	SDR/Vp	Mean value	SDR/Vp
pH	5.7	3/3	5.6	3/3
Organic carbon (%)	26.04	3/3	4.58	5/1
Total nitrogen (%)	2.69	1/5	0.91	4/2
Available phosphorus (mg/kg)	17.71	2/4	8.8	4/2
Bulk density (Mg/m$^{3)}$	1.39	2/4	1.53	4/2
Saturated hydraulic conductivity (cm/hr)	1.38	2/4	4.20	1/5
Texture	Loamy sand	4/2	Loamy sand	4/2
Mean		≈ 2/4		≈ 4/2

For SDR, 1 = no degradation, 2 = slightly degraded, 3 = moderately degraded, 4 = severely degraded, 5 = extremely degraded.
For Vp, 1 = very high vulnerability, 2 = high vulnerability, 3 = moderate vulnerability, 4 = low vulnerability, 5 = no vulnerability.

2.33.3 Yield indicators

Yield components of sweet potato varieties grown on a degraded soil are presented in Table 3.

Total biomass

Total biomass which was determined on fresh weight basis by weighing all agronomic parameters of sweet potato plants showed significant ($p \leq 0.05$) differences among the sweet potato varieties in farms A and B (Table 3). In farm A, TIS 87/0087 had the highest total biomass of 26000 kg ha^{-1}, followed by Akinima, Benue, Eruwa and Ex-Igbaraiam (24250 and 14,250 kg ha^{-1}), and least by Shaba, TIS 8441, Akwide, Arrow tip and Ishiayi (4,725 and 3,775 kg ha^{-1}). Howver, Ex-Igbaraiam had the highest total biomass of 7,867 kg ha^{-1} from farm B, followed by TIS 87/0087, TIS 8441, Eruwa and Benue (7,050 and 4,300 kg ha^{-1}), and least by Ishiayi, Shaba and Akinima, Arrow tip and Akwide (3,150 and 1,617 kg ha^{-1}).

Tuber weight

There were significant ($p \leq 0.05$) differences in the weight of harvested sweet potato tubers among the varieties grown to slightly degraded farm A and severally degraded farm B, respectively. On farm A, Arrow tip had the highest tuber weight of 1890.5 kg ha^{-1}, followed by TIS 87/0087, Benue, TIS 8441, Ex-Igbaraiam and Shaba, with a range of tuber weights between 1725 kg ha^{-1} and 1047.5 kg ha^{-1}, and least by Akinima, Eruwa, Ishiayi and Akwide with a range of tuber weight between 835.3 kg ha^{-1} and 215.8 kg ha^{-1}.

In farm B, TIS 87/0087 had the highest tuber weight of 2814 kg ha^{-1}, followed by TIS 8441, Ishiayi, Ex-Igbaraiam and Benue, with a range of tuber weights between 2317 kg ha^{-1} and 756 kg ha^{-1}, and least by Eruwa, Shaba, Arrow tip and Akwide with a range of tuber weight between 685 kg ha^{-1} and 132 kg ha^{-1}.

Harvest index

Harvest index showed significant ($p \leq 0.05$) differences among the sweet potato varieties from farms A and B (Table 3). In farm A, Arrow tip had the highest harvest index of 0.54, followed by

TIS 8441, Shaba, Ishiayi and Benue, with a range of harvest index between 0.39 and 0.11, and least by Akwide, Ex-Igbaraiam, TIS 87/0087, Akinima and Eruwa, with a range of harvest index between 0.07 and 0.03.

In farm B, TIS 8441 had the highest harvest index of 0.41, followed by Ishiayi, TIS 87/0087, Benue, Eruwa and Ex-Igbaraiam, with a range of harvest index between 0.25 and 0.11, and least by Akinima, Shaba, Akwide and Arrow tip, with a range of harvest index between 0.09 and 0.07.

Percentage yield production

This index of the yield potentials of sweet potato varieties grown on a degraded soil was found to vary significantly ($p \leq 0.05$) among the varieties in farms A and B, respectively. In farm A, Benue had the highest percentage yield production of 85%, followed by Arrow tip, TIS 87/0087, Akinima and TIS 8441, with a range of percentage yield production between 82.5% and 67.5%, and least by Ex-Igbaraiam, Eruwa, Shaba, Ishiayi and Akwide, with a range of percentage yield production between 62.5% and 12.5%.

In farm B, Ex-Igbaraiam had the highest percentage yield production of 76.7%, followed by TIS 87/0087, Shaba, TIS 8441, and Benue with a range of percentage yield production between 66.7% and 61.7%, and least by Ishiayi, Arrow tip, Eruwa, Akwide and Akinima, with a range of percentage yield production between 46.7% and 23.3%.

Table 3: Yield indicators of sweet potato varieties grown on a degraded soil

Variety	Weight of tuber	Total Biomass	Harvest index	yield production
	Kkg ha^{-1}			%
Farm A				
Ex-Igbaraiam	1075.5ab	14,350ab	0.06c	62.5b
Benue	1662.0a	24,000a	0.11c	85a
Akinima	771.0ab	24,250a	0.03c	72.5ab
TIS 87/0087	1725.0a	26,000a	0.06c	80a
Eruwa	810.8ab	22,250a	0.03c	62.5b
Arrow tip	1890.5a	3,800b	0.52a	82.5a
Shaba	1047.5ab	4,725b	0.21b	62.5b
Ishiayi	835.3ab	3,775b	0.21b	55b
TIS 8441	1774.8a	4,175b	0.43a	67.5b
Akwide	214.8b	4,025b	0.06c	12.5c
CV (%)	28.6	19.8	9.7	75.2
Farm B				
Ex-Igbaraiam	7867.0a	823.0b	0.11ab	76.7a
Benue	4300.0cd	756.0b	0.17a	61.7abc
Akinima	1822.0e	152.0b	0.09bc	23.3c
TIS 87/0087	7050.0ab	2814.0a	0.21abc	66.7a
Eruwa	5067.0c	685.0b	0.11abc	40bc
Arrow tip	1617.0e	150.0b	0.07c	43.3abc
Shaba	2650.0de	207.0b	0.08bc	65ab
Ishiayi	3150.0cde	961.0b	0.25bc	46.7abc
TIS 8441	5083.0bc	2317.0a	0.41abc	63.3ab
Akwide	1617.0e	132.0b	0.08c	35c
CV (%)	24.8	66.4	33.7	16.9

Note: Means with the same letter(s) within a column are not significantly different at p=0.05

2.43.4 Vine length and number of leaves

Figure 1 depicts the number of leaves of sweet potato varieties grown on a degraded soil. Number of leaves was found to highest at 11 WAP with significant ($p \leq 0.05$) variations among the varieties in farms A and B respectively. In farm A, Benue had the highest number followed by Ex-Igbaraiam, Eruwa and TIS 87/0087, and least by Akinima, Arrow tip, Shaba, TIS 8441, Akwide and Ishiayi. However, farm B had a reduction in the number of leaves when compared with farm A at 11 WAP. Eruwa had the highest number of leaves followed by TIS 87/0087, TIS 8441, Ex-Igbaraiam and Ishiayi and least by Benue, Arrow tip, Akinima, Shaba and Akwide.

Figure 2 illustrates the vine length of sweet potato varieties grown on a degraded soil. The figure shows significant ($p \leq 0.05$) differences in the vine length among sweet potato varieties in farms A and B respectively. In farm A, Benue had the highest vine length value of 98.4 cm, followed by TIS 87/0087, Ex-Igbaraiam, Eruwa, TIS 8441, Arrow tip and Shaba with respective vine lengths of 81.9 cm, 71.3 cm, 66.4 cm, 54.8 cm, 53.8 and 52.8 cm, and least by Ishiayi, Akwide and Akinima with vine lengths of 34.4 cm, 39.8 cm and 22.8 cm respectively.

Contrary to the trend in number of leaves, vine length was found to increase among the sweet potato varieties in farm B. Eruwa had the highest value (674 cm) followed by TIS 87/0087, Ex-Igbaraiam, TIS 8441, Ishiayi and Benue with respective vine length values of 489 cm, 439 cm, 397 cm, 330 cm and 304 cm, and least by Shaba (195 cm), Arrow tip (176 cm), Akinima (82 cm) and Akwide (69 cm).

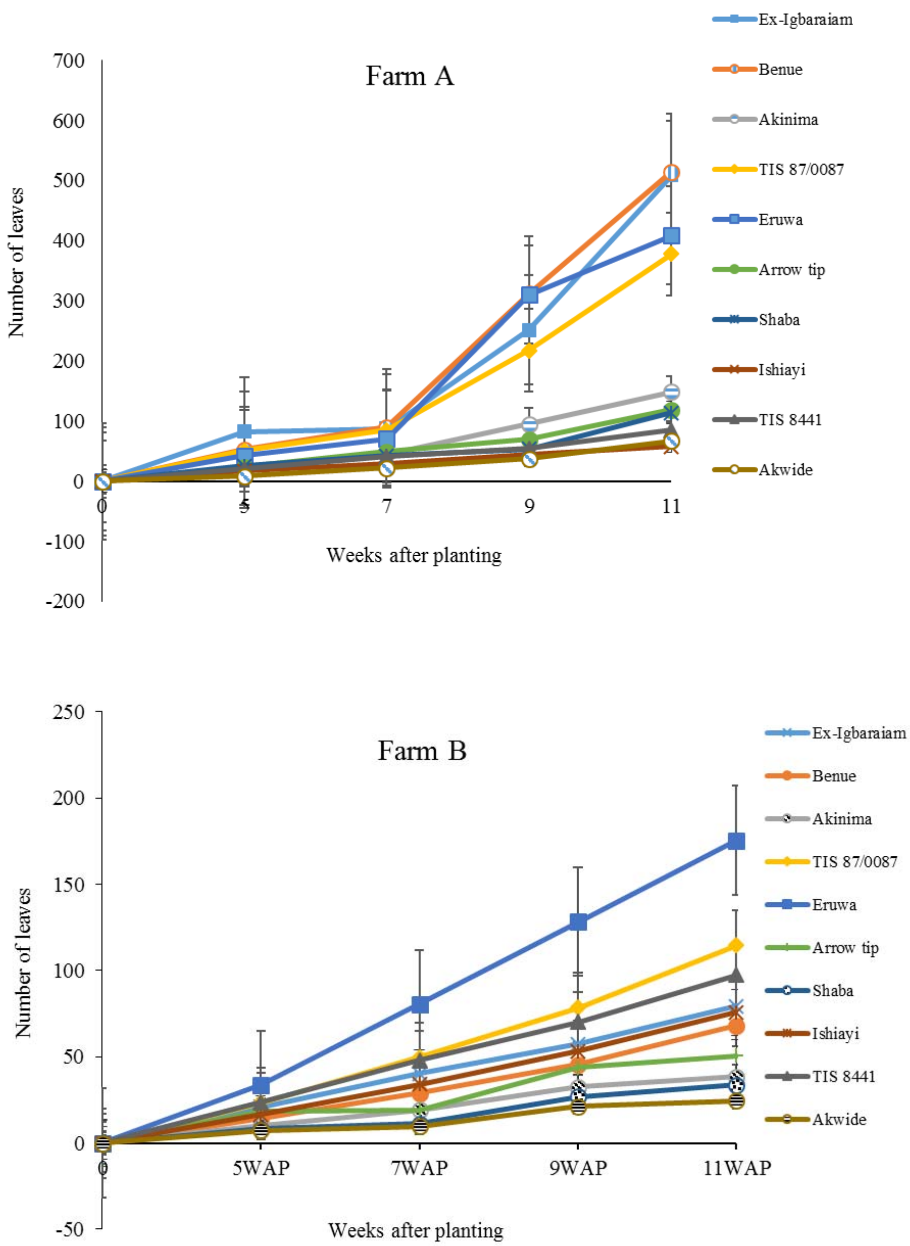
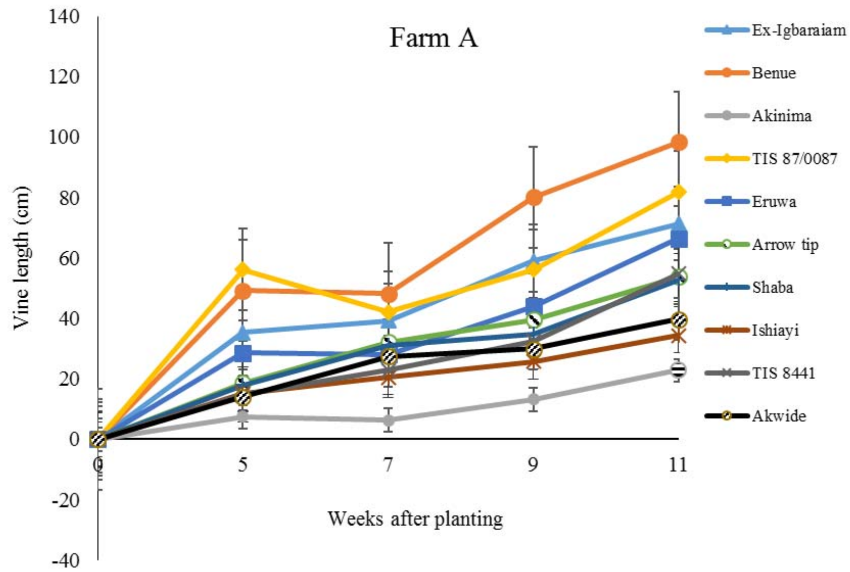


Figure 1: Number of leaves of sweet potato varieties grown on a degraded soil



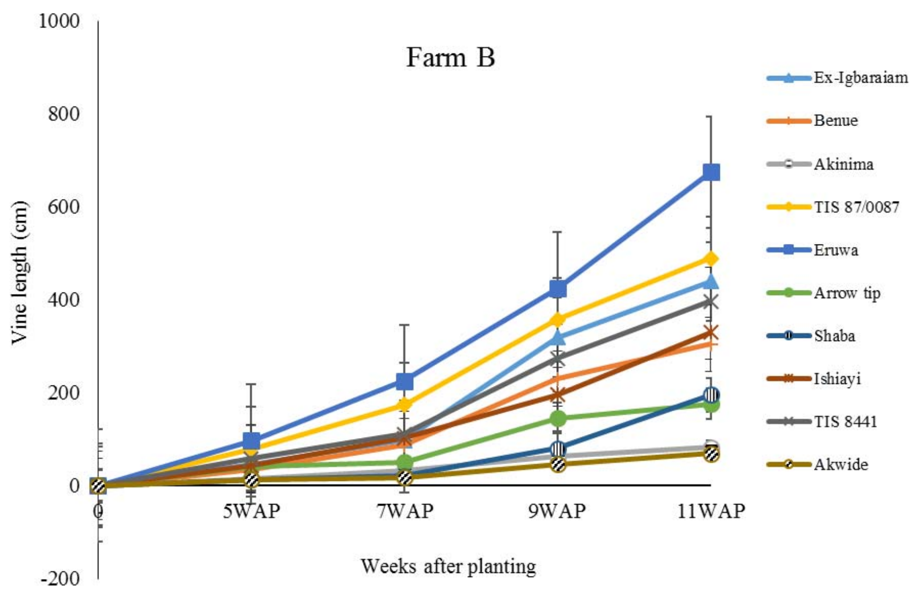


Figure 2: Vine length of sweet potato varieties grown on a degraded soil

3.4. Discussion

The soil in the study area is characterised by high sand content (loamy sand), which is responsible for soil degradation rate (SDR) and vulnerability potential (Vp) value of 4/2 in both farms. This is an indication that the farms were severely degraded with high vulnerability potential for further degradation. (33) and (28) reported that loamy sand lack adsorption capacity for basic plant nutrients and water. The soil pH values in both farms is low, indicating an acidic condition. (27) reported that optimum pH for most agricultural crops falls between 6.0 and 7.0 and nutrients are readily available at pH of about 6.5. This low value of pH may be due to leaching which is a peculiar characteristics of a coarse textured soil (loamy sand). According to (34), low pH values could be due to the amount of materials removed at previous harvests, amount and type of fertilizer used to crop. The SDR/Vp of 3/3 for soil pH showed that the soil from both farms had been moderately degraded and would moderately be vulnerable to further degradation if conservation measures are not put in place.

The soil organic carbon in farm B was at a threshold (2% C) according to the (35), which is an indication of a major decline in soil quality. (36) reported that continuous cropping of Alfisols, Ultisols and Oxisols in the tropics has resulted in a rapid decline in soil organic matter in the surface soil during the first few years following land clearing. Similar values were reported by (28) who noted that values of org. C below 15.00 g kg^{-1} are rated low and may not sustain intensive cropping system (31). Total nitrogen value is also rated low when compared with the critical (0.15% or 1.5 g kg^{-1}) and optimum (4.50 g kg^{-1}) for tropical soils (31). The low level of nitrogen may be due to intensive farming carried out in the study area with significant nutrient mining impact. (31) reported that low levels of nitrogen in soils may be related to intense leaching and erosion due to rainfall. The SDR/Vp of 1/5 for nitrogen indicates a soil that is not degraded in farm A, while the SDR/Vp of 4/2 shows that the soil had been severely degraded with a high vulnerability for further degradation. The SDR/Vp in farms A and B are similar to the reports of (28) and (39) for different soils in Southern Nigeria, respectively.

The soil available phosphorus in farm A is high, exceeding 15 mg kg^{-1} regarded as productive soils zone (40). However, available phosphorus was low in farm B when compared with the critical range (8 to 12 mg kg^{-1}) reported for tropical soils (31). This low P value in farm B could be attributed to continuous nutrient mining from continuous cropping in the previous years. In comparison to the critical values of 2.0 and 0.20 cmol kg^{-1} reported by (37) and (32) for calcium and potassium, respectively, mean values of calcium and potassium of the soil in study area were low, especially farm B.

Soil physical assessment showed that the high bulk density values may be attributed to effects of seasonal erosion which leads to crusting and compaction (38). The increase in saturated hydraulic conductivity value from 1.38 cm hr^{-1} to 4.20 cm hr^{-1} indicates that the soil had slight conductivity of water in farm A compared to farm B which had a moderate water flow. This increase in hydraulic conductivity may be due to increases in bioturbation such as root movement in soil. (39) reported increases in bioturbation results to higher bio-pores and cross-sectional areas that contribute to hydraulic flow in soils.

The significant differences observed in the results of the various sweet potato parameters assessed in this study may be due to their genetic variations as opposed to the planting environment (41). TIS 87/0087 with the highest yield has the capacity of consistently converting most of its photosynthetic products into carbohydrates stored in tuber in a degraded soil. TIS 87/0087 was also the highest yielding variety across the farms while Akwide was consistently the lowest yielding variety followed by Akinima. The difference in tuber yield under the prevailing soil conditions could be attributed to the genetic variations among the varieties in partitioning photosynthates. Differences in yield due to the genetic make-up among varieties have also been reported in other sweet potato trials (42; 43).

Akwide and Akinima were among the three varieties with the lowest vine length in both farms whereas TIS 87/0087 was among the two varieties with the longest vine length, being second to Benue and Eruwa in farms A and B, respectively. This indicates that apart from tuber yield benefits obtained from TIS 87/0087 planted on a degraded soil, sweet potato vines could be used as forage to raise animals. Sweet potato vines have been included in livestock feed because it contains high protein and mineral contents that are needed for growth and development of ruminants (44; 45; 46; 47). From this study, it showed that some cultivars are good producer of vines on a degraded soil while some cultivars could cope with degraded soils by producing high tuber yields. For example, Akinima (farm A) was next to TIS 87/0087 in terms of total biomass, indicating that Akinima is able to convert most of its photosynthetic products into carbohydrates stored in various agronomic components of the plant.

Also, Benue and Eruwa had the highest number of leaves and vine length in farms A and B, respectively with reduced quantity of tubers indicating their poor ability to convert most of the photosynthetic products into carbohydrates and store them in the tubers (48). On the other hand, the low tuber yield by Akwide may be attributed to its low number of leaves, which could have been responsible for its consistent low tuber yield. (49), (44) and (50) explained that a genotype with large leaf area and number of leaves can easily trap sunlight for photosynthesis than those with small leaf area or number of leaves.

On the average, higher yields were obtained from farm A than farm B and this could be attributed to the decline in soil quality after the first cropping season. This is in line with (51) who attributed low crop yields to a decline in soil fertility in Kenya. However, (42) and (43) reported that number of leaves per plant and stand count strongly affected the number and size of the tubers.

5. Conclusions

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Soil degradation rates (SDR) and vulnerability potential (Vp) of farms A and B using chemical (pH, C, N, and P) and physical (texture, bulk density and saturated hydraulic conductivity) showed that farm A is slightly degraded with low vulnerability (SDR/Vp ≈ 2/4) while farm B is severely degraded with high vulnerability to water erosion (SDR/Vp ≈ 4/2). Severely degraded soil of farm B could have been responsible for lower total biomass of sweet potato than farm A. However, cultivars of sweet potato responded differently to severely degraded soils in terms of biomass and tuber yields. Akinima and Akwide could not thrive well on a degraded soil condition while Benue and Eruwa cultivars produced high vine length with high number of leaves, indicating that forage farmers could grow Benue and Eruwa purposely for feeding livestock animals.

However, Arrow tip and TIS 8441 cultivars had highest tuber yield on both farms, indicating that farmers interested in sweet potato tubers could grow Arrow tip and TIS 8441 on a slightly to severely degraded soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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