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Improvement in Yield and Chemical Composition of Sweet Potato for Livestock Feeding Through Tillage and Fertilizer Application

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Abstract: The effects of soil tillage and fertilizer application on yield and chemical composition of sweet potato (Ipomoea batatas (L) Lam) grown for livestock feeding during the dry season was investigated. The experiment was conducted at the Teaching and Research Farm, University of Ibadan. A split plot design was used with tillage as the main plot factor and fertilizer application as sub plot factor. The four treatments namely; Tilled, Fertilized (TF); Tilled, Not Fertilized (TNF); Not Tilled, Fertilized (NTF); Not Tilled, Not Fertilized (NTNF, control) was replicated three times. Yield and chemical composition of the root was determined. Residual forage and biomass production were also measured. There were significant differences ($p<0.05$) in dry matter yield of the root, residual forage and biomass production of sweet potato (SP) among treatments. Root yield was 7.8, 4.4, 4.4 and 3.4 t ha^{-1}; residual forage, 7.5, 5.1, 5.9 and 4.3 t ha^{-1}; and biomass production, 15.3, 9.5, 10.3 and 7.6t ha^{-1} for TF, TNF, NTF and NTNF, respectively. The treatments had no significant ($p>0.05$) effect on chemical composition of SP root although there was a slight improvement in crude protein (CP) content and a reduction in fibre components of the root with fertilizer application. Tillage and fertilizer application had equal influence on root yield of SP but when forage yield is considered, fertilizer application seemed to be more beneficial to the crop than tillage. The best economic returns from SP grown for livestock feeding were realized when both cultural practices were combined.

Key words: Sweet potato, root crop, tillage, fertilizer, livestock feeds, dry matter, biomass, chemical composition

INTRODUCTION

Sweet potato root is a valuable source of energy in livestock feeds[1,2]. Sweet potato root meal has been used extensively to replace maize in poultry and pig diets as a means of reducing the costs of feeding these livestock species[3-5]. Although sweet potato root was found to be inferior in nutritive value to maize, these workers suggested it could replace part of the maize in livestock diets without adverse effects on health and growth of these animals. Sweet potato root has also been found to be a useful source of energy in rabbit diets[6]. Dried sweet potato roots have successfully replaced maize in ruminant diets. It has been demonstrated by Massey and Kariuki[7,8] that increased weight gain and high milk production can be achieved when sweet potato roots are fed to cattle.

A common problem encountered in the use of raw sweet potato root, as a feedstuff for monogastric animals is the presence of antinutritional factors (trypsin inhibitors and alpha-amylase inhibitors[9-12]; this has a negative implication for the digestibility and utilization of sweet potato root. Heat treatment and ensilage have been employed to improve the digestibility and utilization of sweet potato root by livestock species[9,11].

The high cost of sweet potato roots relative to maize is a major constraint to its use as livestock feed in Nigeria[13]. This is due mainly to the low yield of sweet potato from farmers' plots[14] and the high demand for the roots as human food. Higher yields from individual farmer's plot will ensure an increased supply of sweet potato roots for human food and animal feeds at much reduced costs. Tillage and fertilizer application are two management practices that can be employed to improve yield of sweet potato roots from farmer's plot.

The aim of this study was to evaluate the effects of tillage and fertilizer application on yield and chemical composition of sweet potato roots for feeding sheep during the dry season when forage is very scarce.

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MATERIALS AND METHODS

The experiment was conducted at the Teaching and Research Farm of the University of Ibadan, Nigeria between April and September 2004, on a field that had been left to fallow for a year after several years of cultivation to maize and cassava. The experimental site received a total 1570 mm rainfall in 2004. Average mean daily temperature was 27.4°C while the relative humidity was about 81.4% during this period. Samples of soil in the top 30 cm were taken from the experimental area before the commencement of the experiment and bulked for laboratory analysis. Available nutrients were determined using standard chemical methods[15].

A dual-purpose variety of sweet potato (TIS-Ex-Igbariam) collected from the National Root Crops Research Institute (NRCRI), Umudike, Nigeria was used in this study. The vines were cut into 30 cm pieces with a minimum of 4 nodes. The plot size in this experiment was 24 m^2. The plots were arranged along the contour of the field in such a way that the longer part was at right angles with the slope of the land. A space of 2 m was maintained between the plots and trailing vines were regularly re-directed to their respective plots to prevent mingling. A planting distance of 50 cm within the row and 80 cm between rows was adopted in this study, giving rise to a population of 60 plants plot $^{-1}$ (25,000 plants ha^{-1}).

A split plot design was used for the experiment with tillage as main plot and fertilizer application as subplot factor. The treatments were Tilled, Fertilized (TF); Tilled, Not Fertilized (TNF); Not Tilled, Fertilized (NTF); Not Tilled, Not Fertilized (NTNF, control). Fertilizer was applied as 300 kg ha^{-1} of NPK -15-15-15 at planting and 150 kg ha^{-1} of urea at 0 and 90 Days After Planting (DAP), respectively. Each treatment was replicated three times. Tilled plots were ridged while untilled plots were cleared using a cutlass. Weeding was done manually with a hoe. Tilled plots were weeded two times before harvest while untilled plots were weeded three times. Sweet potato roots were harvested from each plot at 150 DAP and residual forage yield after root has been harvested was also determined. Biomass production was determined by simple addition of forage and root yields.

Samples of sweet potato roots were taken from the plots during harvest and dried in the oven at 65°C to constant weight. Dried samples from each plot were analyzed for chemical composition. Proximate and detergent fibre composition of samples was determined by methods of AOAC and Van Soest[15,16], respectively. Gross energy content of the top was calculated from the organic matter components using the relationship described by Nehring[17] as follows:

Gross energy, kcal/100 g = 5.72 (crude protein, percent) +9.5 (ether extract, percent) +4.79 (crude fibre, percent) +4.03 (nitrogen-free extract, percent).

All data obtained were subjected to generalized linear model to obtain an ANOVA and significant means were separated by Duncan's multiple range tests and standard error using the procedures of[18].

RESULTS AND DISCUSSION

The chemical properties of the soil in the study area are shown in Table 1. A striking feature of this soil is its inherently low fertility as expressed in the low levels of organic carbon, total nitrogen, available phosphorus and potassium. This low fertility status will guarantee a response of sweet potato to fertilizer application.

Root yield: Root yield differed significantly ($p<0.05$) among the treatments when sweet potato plots were subjected to tillage and fertilizer application. The highest root yield was recorded for TF while the least yield was recorded for control (Table 2). Root yield increased by 133% when sweet potato plots were Tilled and Fertilized (TF), however, when the plots were only tilled (TNF) or fertilized (NTF), root yield increased by only 31%. Since there was no significant difference among TNF, NTF and control, it may be inferred that tillage or fertilizer application had little influence on root yield of sweet potato when applied separately, however when these treatments were combined, a significant improvement in root yield was enhanced. Tillage has been reported by Ndaeyo[19] to induce higher yields in maize and cassava in the southwest of Nigeria. He however noted that tillage practices also resulted in a rapid loss of soil nutrients and a sharp decline in soil fertility. He recommended a minimum tillage practice for maximum economic returns from arable crop production in this part of Nigeria.

Table 1: Chemical analysis of soil at the experimental site within 30 cm depth before commencement of the experiment

Soil properties	Value
pH (H_2O)	5.80
Organic carbon (%)	1.28
Organic matter (%)	2.02
Total N (%)	0.07
C/N ratio	18.00
Avail. P (mg kg^{-1})	5.48
Ca (cmol kg^{-1})	3.05
Mg (cmol kg^{-1})	1.58
K (cmol kg^{-1})	0.11
Mn (mg kg^{-1})	40.22
Fe (mg kg^{-1})	24.96
Zn (mg kg^{-1})	2.87
Cu (mg kg^{-1})	0.59

Table 2: Root and residual forage yields (t ha^{-1}) of sweet potato under tillage and fertilizer treatments

	Treatments					
DM yield	TF	TNF	NTF	NTNF	Mean	SEM
Root yield	7.80^{a}	4.40^{b}	4.38^{b}	3.35^{b}	4.98	0.53
Forage yield	7.51^{a}	5.13^{bc}	5.91^{b}	4.26^{c}	5.70	0.48
Total biomass	15.31^{a}	9.51^{b}	10.30^{b}	7.60^{c}	10.68	1.38

Means with same letter within the row are not significantly different (p>0.05) by DMRT

Table 3: Carrying capacity of sweet potato crop grown for sheep feeding under tillage and fertilizer treatments

	Treatments			
Measurements	TF	TNF	NTF	NINF
Intake/animal (g day^{-1}, DM)	450	450	450	450
Root yield (kg ha^{-1}, DM) 7800	4400	4380	3350	
Biomass yield^{a} (kg ha^{-1}, DM)	15310	9510	10300	7600
Carrying capacity 1^{b} (animals ha^{-1})	144.4	81.5	81.1	62.0
Carrying capacity 2^{c} (animals ha^{-1})	284.5	170.1	190.7	140.7

a: determined as root yield+residual forage yield, b: calculated from root yield and daily intake per animal for 120 days, c: calculated from biomass yield and daily intake per animal for 120 days, DM: dry matter

The root dry matter yields obtained in this experiment were slightly higher than root yields of 1.9 to 6.6 t ha^{-1} reported by Shittu[20] for sweet potato planted on different soil types in a valley bottom during the dry season. Fresh root yields of 0 - 15.4 t ha^{-1} (0- 4.7 t ha^{-1}, DM) have also been reported by Egeonu[21] for 35 accessions of sweet potato planted without fertilizer application in the southwest of Nigeria. This is comparable to yields obtained in this study when fertilizer was not applied to the plots. The availability of moisture has been demonstrated by Chowdhury[22] to influence N and K uptake and therefore favoured more vegetative growth and tuber yield. Nonetheless, too much of moisture reduces soil aeration. Improvement in soil aeration could increase ATP content and ATPase activity in functional leaves and tubers. It also accelerated the translocation of 14C-photosynthate from the leaves to the tubers with a consequent increase in yield[23]. In this study, moisture was available in a moderate quantity to guarantee a crop of sweet potato.

Forage yield: Residual forage yield after root had been harvested ranged from 4.3-7.5 t ha^{-1}. There was an improvement of 20.4 and 38.7%, respectively in forage yield when tillage or fertilizer was applied to the plots separately, however, when these treatments were combined, residual forage yield improved by 77.7%.

Biomass production: Total biomass yield followed a similar trend with forage yield. When tillage or fertilizer was applied to sweet potato plots biomass production increased by 25.1 and 35.5%, respectively (Table 2), however, when these management practices were combined, biomass production increased by 101.4%.

These results suggest that maximum benefits from additional input of tillage or fertilizer in sweet potato cultivation can be derived when these inputs are combined.

Biomass yield from this study ranged from 7.6-15.3 t ha^{-1}, DM. This is comparable to 5.2-13.5 t ha^{-1}, 10.1-15.3 t ha^{-1} and 8.2-20 t ha^{-1} DM reported for Cynodon sp., Panicum maximum and pennisetum purpureum, respectively under similar environmental conditions[24,25].

Carrying capacity: The dry season which lasts for about 4 months in the southwest of Nigeria is a critical period of feed scarcity for ruminant animals. On a hypothetical farm, a 15 kg West African dwarf sheep consuming biomass of about 3% of its body weight would require 450 g of sweet potato (DM) on a daily basis. The number of animals that can be supported by one hectare of sweet potato (carrying capacity) grown for dry season feeding of sheep can be calculated from the DM yield and average intake of sheep in 120 days. Table 3 presents the calculated carrying capacity of one hectare of sweet potato crop under the various treatments using the hypothetical figures above.

The projected number of animals supported by one hectare of sweet potato root increased from 62 to 81 animals ha^{-1}, when the plots were either tilled or fertilized, however, when both treatments were combined, carrying capacity increased to 144 animals ha^{-1}. Combining tillage and fertilizer application on sweet potato plots supported the highest number of animals per hectare of sweet potato crop. The carrying capacity of sweet potato crop will approximately double when the total biomass produced forms the basis of feeding sheep. This suggests that the best economic return from sweet potato cultivation is derived when both forage and roots of sweet potato are fed to ruminant animals.

Chemical composition: The chemical composition of sweet potato root under different tillage and fertilizer treatments are given in Table 4. Analysis of variance shows that there were no significant differences (p>0.05) among the treatments for DM, Crude Protein (CP), Ether Extract (EE), Crude Fibre (CF), ash, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and gross energy content of sweet potato roots under the various treatments. However, the CP content increased slightly when fertilizer was applied to sweet potato plots while fibre components reduced.

The CP content of sweet potato root in this study ranged from 4.3 to 5.6%. This is comparable to 5.3% CP obtained by Ladokun[4] and within the range of 1.4 to 8.6%

Table 4: Chemical composition of sweet potato root under tillage and fertilizer treatments

	Treatments				
Components (%)	TF	TNF	NTF	NTNF	SEM
Dry matter	30.80	29.50	29.90	29.20	0.78
Crude protein	5.60	4.25	5.10	4.34	0.46
Ether extract	1.06	1.38	1.18	1.30	0.08
Crude fibre	3.01	3.88	3.28	4.01	0.12
Nitrogen free extract	87.27	86.91	87.44	86.39	2.85
Ash	3.06	3.58	3.00	3.96	0.29
Neutral detergent fibre	8.00	9.40	9.00	9.50	0.58
Acid detergent fibre	3.00	4.00	3.50	4.00	0.31
Gross energy (kcal/g)	4.08	4.06	4.09	4.05	0.41

CP reported by Tewe[26]. The CF content ranged from 3.0 to 4.0% which is close to the range of 3.5 to 5.9% CF reported by Tewe[26]. The average gross energy value of 4.1 kcal g^{-1} of root obtained in this study is higher than 3.9 kcal g^{-1} obtained by Ladokun[4] but within the range of 2.9-5.5 kcal g^{-1} reported by Tewe[26]. Result from this study suggests that tillage and fertilizer application had little influence on the chemical composition of sweet potato root.

CONCLUSION

Tillage and fertilizer application had equal influence on root yield of sweet potato (31% improvement) however, when they were combined, root yield improved by 133%. This supports the idea that tillage plays a complementary role to fertilizer application in sweet potato production. The estimated carrying capacity of sweet potato crop increased significantly when tillage or fertilizer was applied to the crop. Both treatments however had no significant influence on chemical composition of the root.

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