


Effect of Chicken Manure, Compost and Cow Dung on the Growth and Yield of Sweet Potato [*Ipomoea batatas* (L.) Lam.] under Guinea Savannah Agroecological Zone of Ghana

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Abstract

Twelve percent (12%) of Ghanaians are food insecure, and climate-smart crops like sweet potatoes are required to help end poverty. Small-scale farmers in Ghana who produce low-technology, subsistence crops, such as sweet potatoes, are more food secure than those who do not. This study was initiated to investigate the effect of chicken manure, compost, and cow dung on the growth and yield of “apomuden”, “SARI-Nyoriberigu”, “SARI-Nan” and “kufour” sweet potato under the Guinea Savannah agroecological zone of Ghana. Organic fertilizer increased leaf chlorophyll content and leaf area index. The application of cow dung, chicken manure and compost in 2015 significantly increased total storage root yield by 38%, 55% and 98%, 62%, 45% and 37%, 52%, 61% and 44%, and 33%, 36% and 28% for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively, when compared to the untreated check. In 2016, and in comparison with the untreated check, the application of cow dung, chicken manure and compost increased total storage root yield by 42%, 61% and 93%, 69%, 49% and 41%, 57%, 67% and 48%, and 36%, 39% and 30% for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively. Hence, the application of organic fertilizers will increase sweet potato yield, give higher returns to resource-poor smallholder farmers and contribute to enhancing food and nutrition security.

Keywords

Sweet Potato, Food Security, Storage Roots, Organic Fertilizer, Chicken

1. Introduction

Sweet potato [*Ipomoea batatas* (L.) Lam.] is the fourth most important root and tuber crop in Ghana, with a 2020 production of 139,439 tonnes (t) from 73,940 ha as compared to cassava (21.8 t from 1.0 m ha), yam (8.5 t from 468,433 ha) and cocoyam (1.3 t from 191,553 ha) [1] [2]. It's an important, versatile, and underutilised food security crop [3] [4]. In Ghana, 12% of the population is food insecure and climate-smart crops are required to help meet Sustainable Development Goal (SDG) 1, which aims to end poverty in all its forms everywhere [2]. Sweet potato can be grown in all agroecological zones of Ghana, and it's a drought-tolerant crop with a short maturity period of 3 - 4 months. Small-scale farmers in Ghana who produce low-technology, subsistence crops, like sweet potatoes, are more food secure than those who do not [5]. With a sequential planting regime, harvesting can provide a continuous supply, thereby ensuring food and nutrition security. With all these potentials to minimize hunger and malnutrition, sweet potato production and yield in Ghana remain very low due to constraints such as low soil fertility and low adoption of good agronomic practices.

There are large stocks of farmyard manure around cattle kraals and other livestock farms in the country, with its attendant negative effects on the environment. At the moment, there is a lack of a developed technology for manure use in crop cultivation [6]. The use of farmyard manure in the cultivation of crops appears to be the best manure disposal strategy. Organic fertilizer is a fertilizer whose basic ingredients are taken from nature with the amount and type of nutrients that occur naturally [7] [8]. Organic fertilizers include manure, compost, green manure, ash, agricultural waste, industrial waste and others [9]. Nutrient requirements of sweet potato cultivation can be met by the application of organic fertilizers.

The utilization of organic fertilizers improves the quality or health of soil. Soil fertility is promoted by the accumulation of nitrogen, hence increasing the nitrogen mineralization potential and, consequently, improving its availability to the crop [10] [11]. The application of organic fertilizers improves soil physical and biological conditions such as soil tilth, water-holding capacity, aeration, beneficial organisms, and minimizes erosion. It also reduces the small-scale farmers' dependence on industrial inputs and makes the plant resistant or tolerant to pests and diseases [11]-[14]. The high cost of inorganic fertilizers and the demand for sustainable crop production calls for locally available low-cost organic sources such as animal manure (cow dung, chicken manure, guano, sheep manure, etc), green manure and compost. Cow dung, which is a mixture of faeces and urine (3:1) is the undigested residue of consumed feed material being excreted by herbivorous bovine animal species such as domestic cattle (*Bos taurus*). It mainly consists of lignin, cellulose and hemicelluloses as well as minerals like nitrogen

and potassium, along with trace amounts of sulphur, iron, magnesium, copper, cobalt and manganese [15]. Cow dung hosts a wide variety of microorganisms varying in individual properties and the exploitation of its microflora can contribute significantly to sustainable agriculture and energy requirements [15]. Harti *et al.* [16] recommend the adoption of 15 t·ha⁻¹ cow manure and 20 cm mound height for the cultivation of sweet potatoes. In another study, Zhang *et al.* [17] reported that the application of 15 t·ha⁻¹ of cow dung increased sweet potato number of shoots, storage root length and yield. In 2020, Ghana's national cattle population was 2,109,000, thus a potential cow dung production of about 53779.5 t·day⁻¹ nationwide [18]. So, if this can be organized and well managed as organic fertilizer, crop production can be enhanced significantly.

Chicken (*Gallus domesticus*) manure is made up of litter material, mainly wood chips or sawdust, and the accumulated faecal matter, feathers and spilled feed from an entire production batch [19]. It is the most accessible organic manure in the country because it is produced in high quantities across the country. It's a cheap and reliable means of improving production among smallholders. Chicken manure provides plant nutrients at low cost and increases soil bacterial activity. In 2020, Ghana's national chicken population was 81,769,000, resulting in an estimated chicken manure production potential of about 1797 t·day⁻¹ nationwide [18]. Chicken manure application increased the productivity of sweet potatoes [20]. Compost is a stable, humus-like product made from controlled aerobic biological decomposition of organic matter [21]. Good compost has less odor, flies, reduced weed seeds and pathogens. Compost improves soil, and increases crop yields and crop height, particularly during the initial stages of growth and during times of drought [21]. In a study in Burkina Faso, Zongo *et al.* [22] reported high orange-fleshed sweet potato (Jewel) storage root yield with a combined application of compost and wood ash. In Nigeria, the application of composted manure and cow dung increased sweet potato storage root yield [23] [24]. In spite of the potential of chicken manure, cow dung, and compost to improve the productivity of sweet potato, there is little information on their impact on sweet potato production in the Guinea savannah agroecological zone of Ghana. The objective was, therefore, to investigate the effect of chicken manure, compost, and cow dung on the growth and yield of sweet potatoes under the Guinea Savannah agroecological zone of Ghana.

2. Materials and Methods

2.1. Location, Treatments and Experimental Design

The experiment was conducted in the field at Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (9°24'N, 0°59'W) Nyankpala, Ghana, in 2015 and 2016. **Table 1** shows the experimental sites weather data collected during the growing period. The experiment was established in a factorial arrangement of treatments in a randomized complete block design with four replications. The first factor was four varieties of sweet potato, and the second factor was four organic fertilizer treatments (Untreated Check, Compost, Chicken manure

and Cow dung). The compost was a local commercial product, chicken manure obtained from a poultry farm, and cow dung collected from a kraal. The organic fertilizers were applied and incorporated at a rate of 10 t·ha⁻¹ two weeks before planting in both years. Field-grown planting materials (slips) were transplanted into four row plots (4 × 6 m) at a spacing of 30 × 100 cm to obtain a plant population of 33,333 plants·ha⁻¹. The test varieties were three orange-fleshed (Apo-muden, SARI-Nan and Kufour) and one white-fleshed (SARI-Nyoriberigu). Each slip had four nodes, with two nodes buried underground and the other two nodes above the soil surface.

2.2. Soil and Organic Fertilizer Sampling, and Analysis

After land preparation, soil samples were randomly collected with an auger at depths of 0 - 15 cm and 15 - 30 cm. These samples were thoroughly mixed to create a composite sample for analysis. Similarly, composite samples were prepared from thoroughly mixed organic fertilizer compost, cow dung, and chicken manure. These samples were analyzed to determine their pre-planting physico-chemical properties. The same organic fertilizer materials were used consistently for both years of the study. The soil and organic fertilizer samples were air-dried, ground, and sieved with 2 mm mesh before being analyzed at CSIR-SARI's Soil Chemistry laboratory. Soil total nitrogen was determined by Kjeldhal method [25], available P by Bray I procedure [26], and exchangeable K and magnesium by ammonium acetate extraction determined by Atomic Absorption Spectrophotometry (AAS) [27]. Soil pH was measured in a 0.01 M CaCl₂ solution at a 1:2.5 soil solution ratio, and soil organic carbon was determined using the Walkley-Black method [28].

2.3. Measurements and Statistical Analysis

Plant population at establishment (PPAE) was taken four weeks after planting. The length of branches was measured, and the number of leaves on each branch was counted from four tagged plants in each plot. Leaf area index was measured with the aid of a portable light meter (Sunfleck Ceptometer, Decagon Devices, Pullman, WA, USA). At 90 days after planting, leaf chlorophyll content was taken with a portable chlorophyll meter (SPAD-502, Minolta Camera Co. Ltd., Japan) from ten plants per plot on the third unfolded leaf of each plant. The trial was harvested 125 and 120 days after planting in 2015 and 2016, respectively. At harvest, the final length of vine branches was measured, and the leaf number was counted on all tagged plants. Plant component parts were separated and oven-dried at 80°C for over 72 h and then weighed for dry matter determination. Fresh storage roots (SR) were separated into marketable and non-marketable lots, counted and weighed.

A SR was considered marketable based on shape quality (not so curved, crooked, constricted or misshapen) and size (diameter was not less than 2.5 cm and length not less than 5 cm).

The experimental data were subjected to analysis of variance using the General Linear Model procedure of the Statistical Analysis System [29] to determine main factor effects and treatment interactions. Means were separated by Fisher's protected LSD test at the 0.05 level of probability. Best-fit equations were determined using the coefficient of variation and root mean square error. Graphical analyses were carried out using SigmaPlot 11.0 [30]. Storage root numbers per plant data were subjected to square-root transformation. To facilitate the interpretation of results, back-transformed (de-transformed) values for storage root numbers per plant are presented.

Table 1. Monthly precipitation, mean daily temperatures (T_{ave}) and mean daily relative humidity at the trial sites in 2015 and 2016.

Month	Rainfall	T_{ave}	Relative Humidity	Rainfall	T_{ave}	Relative Humidity
	Mm	°C	%	mm	°C	%
	2015			2016		
July	146.4	27.5	75	362	26.2	82
August	180.5	27.4	80	189.9	26.4	81
September	227.5	27.4	83	295	26.5	80
October	124.3	28.5	80	137	29.7	59

2.4. Partial Budget Analysis

The partial budget analysis used the average for 2015 and 2016 marketable storage root yield (MSRY). The analysis is used to assess the benefit as a result of the application of the treatments (cow dung, chicken manure and compost) against the untreated check/control. The analysis is to look at the economic viability of the use of organic fertilizer treatments. We used the prevailing market prices of the various treatments and labour costs in 2016. The assumption is that all other costs were constant except the costs of the treatments that vary. Hence, when calculating the input costs, we used the variable cost. Also, we used the difference between yields of treated plots and non-treated plots (called yield increase). Using the output values in 2016, the value of increased yields as a result of treatment was calculated as follows:

Value of increased yield as a result of treatment = Price \times increased yield

$$v_{\text{yielddiff}} = p_{\text{mkt}2016} \times (q_{\text{treated}} - q_{\text{nontreated}})$$

where $p_{\text{mkt}2016}$ are the 2016 market prices of sweet potato storage roots prices in Ghana cedi per tonne (GHC/t), q_{treated} is the yield for the treated plot (t/ha) and $q_{\text{nontreated}}$ is the yield of non-treated plots (control) (t/ha).

The total variable cost of the treatments and their application is calculated as:

$$tvc_{\text{treatment}} = (p_{\text{treatment}} \times y_{\text{treatment}}) + l_{\text{treatmentapp}}$$

where $tvc_{\text{treatment}}$ is the cost of treatment (cow dung, chicken manure and compost) in GHC/ha, $p_{\text{treatment}}$ is the price of treatments (GHC/ha), $y_{\text{treatment}}$ is the

quantity of treatment applied (Kg/ha) and $l_{\text{treatmentapp}}$ is the labour cost for the application of the treatment GHC/ha).

The net benefit per treatment was calculated as follows:

$$\text{Netbenefit per treatment} = \left[p_{\text{mkt2016}} \times (q_{\text{treated}} - q_{\text{nontreated}}) \right] - \left[(p_{\text{treatment}} \times y_{\text{treatment}}) + l_{\text{treatmentapp}} \right]$$

The returns to the application of the treatment were calculated using the following:

$$\text{Returns to treatment} = v_{\text{yielddiff}} / (tvc_{\text{treatment}})$$

3. Results and Discussion

3.1. Soil Characteristics

Based on soil test results, the trial site's soil texture in both seasons was sandy clay loam, with soil extractable macronutrient levels before the study being medium for magnesium and very low for P, N and K (**Table 2**). Soil was moderately acidic and organic matter was 0.3%. Soil acidity slightly increased while soil organic matter values remained the same. The values of these macronutrients in the compost, cow dung and chicken manure were higher than those of the soil (**Table 2**). Among the three organic fertilizers, chicken manure was highest in total N, P and exchangeable Ca, cow dung was highest in exchangeable K content and compost was highest in exchangeable Mg content.

Table 2. Physico-chemical composition of the trial site initial soil, cow dung, chicken manure and compost.

Soil/Material	pH (0.01 M CaCl ₂)	Sand	Silt	Clay	Org. C	Total N	Bray I P	Exch K	Exch Ca	Exch Mg
		%			mg·kg ⁻¹			Cmol + kg ⁻¹		
Soil 0 - 15 cm (2015)	6.12	61.48	6.4	32.12	0.156	0.013	3.693	39	1.64	1.16
Soil 15 - 30 cm (2015)	6.21	67.48	2.4	30.12	0.195	0.016	11.333	36	1.76	1.08
Chicken manure	---	---	---	---	---	1.889	9788.5	25,300	3.16	1.64
Cow dung	---	---	---	---	---	0.982	1579.5	36,000	1.28	0.76
Compost	---	---	---	---	---	1.154	2482.3	30,529	2.44	0.98
Soil 0 - 15 cm (2016)	5.94	62.28	6.6	31.12	0.148	0.012	4.578	38	1.55	1.17
Soil 15 - 30 cm (2016)	5.98	67.87	3.5	28.63	0.187	0.016	10.88	36	1.75	1.12

3.2. Plant Population at Establishment, Leaf Chlorophyll Content and Leaf Area Index

There was no significant difference between the two years for plant population at establishment (PPAE), leaf chlorophyll content (CC) and leaf area index (LAI); therefore, the data were combined for years and analyzed as a function of organic fertilizer treatment and variety (**Table 3**). Application of organic fertilizer treatments had no significant effect ($p = 0.6039$) on PPAE among any of the four varieties. However, the varieties differed significantly ($p < 0.0001$) on PPAE (**Table 3** and **Table 4**). The plant population at establishment ranged from 40.13 - 84.06%. This

is probably due to the drought encountered in July when slips were yet to sprout, as well as differences in the variety of responses to transplanted slip establishment. Only 40.13% of the transplanted slips of variety Kufour sprouted and established after transplanting, which was significantly less than that of Apomuden (84.06%), SARI-Nyoriberigu (83.13%) and SARI-Nan (82.19%).

Table 3. Analysis of variance of the effect of organic fertilizer application on plant population at establishment (PPAE), chlorophyll content (CC), leaf area index (LAI), leaf dry matter (LDM), stem dry matter (SDM), root dry matter (RDM), total dry matter (TDM), storage root number per plant, marketable storage root yield (MSRY), total storage root yield (TSRY) at Nyankpala.

Source of variation	Measured parameters									
	PPAE	CC	LAI	LDM	SDM	RDM	TDM	SR#plant ⁻¹	MSRY	TSRY
Year (Y)	Ns	ns	ns	ns	ns	ns	ns	ns	*	*
Variety (V)	***	***	*	**	***	***	**	***	***	***
Fertilizer (F)	ns	***	***	***	***	***	***	ns	***	***
Y*V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Y*F	ns	ns	ns	ns	ns	ns	ns	ns	*	*
V*F	ns	**	ns	*	***	ns	ns	**	**	**
Y*V*F	ns	ns	ns	ns	ns	ns	ns	ns	*	*

Table 4. Plant population at establishment (PPAE), leaf area index (LAI), total dry matter per plant (TDM).

Treatments	PPAE (%)	LAI	TDM
Untreated check	72.50a	2.136d	167.48b
Cow dung	73.44a	2.484c	297.56a
Chicken manure	73.75a	3.223a	297.13a
Compost	70.00a	2.765b	298.38a
SARI-Nyoriberigu	83.13a	3.021a	250.07b
SARI-Nan	82.19a	2.588b	314.31a
Kufour	40.31b	2.123c	286.62ab
Apomuden	84.06a	2.56b	209.55c
CV (%)	11.9	17.4	26.1

Leaf chlorophyll content, as one indicator of photosynthetic activity, may directly influence the photosynthetic capacity of plants to some extent [31] [32] and it is also positively influenced by N application [33]. There was significant variety by organic fertilizer treatment interaction on leaf chlorophyll content ($p = 0.0047$). Leaf chlorophyll content differed significantly among varieties ($p = 0.0002$) as well as among organic fertilizer treatments ($p < 0.0001$) (Table 3 and Figure 1). Leaf chlorophyll contents of Apomuden, SARI-Nan and SARI-Nyoriberigu were significantly greater when treated with chicken manure than with cow dung and compost (Figure 1). This could probably be so because of the high nitrogen content

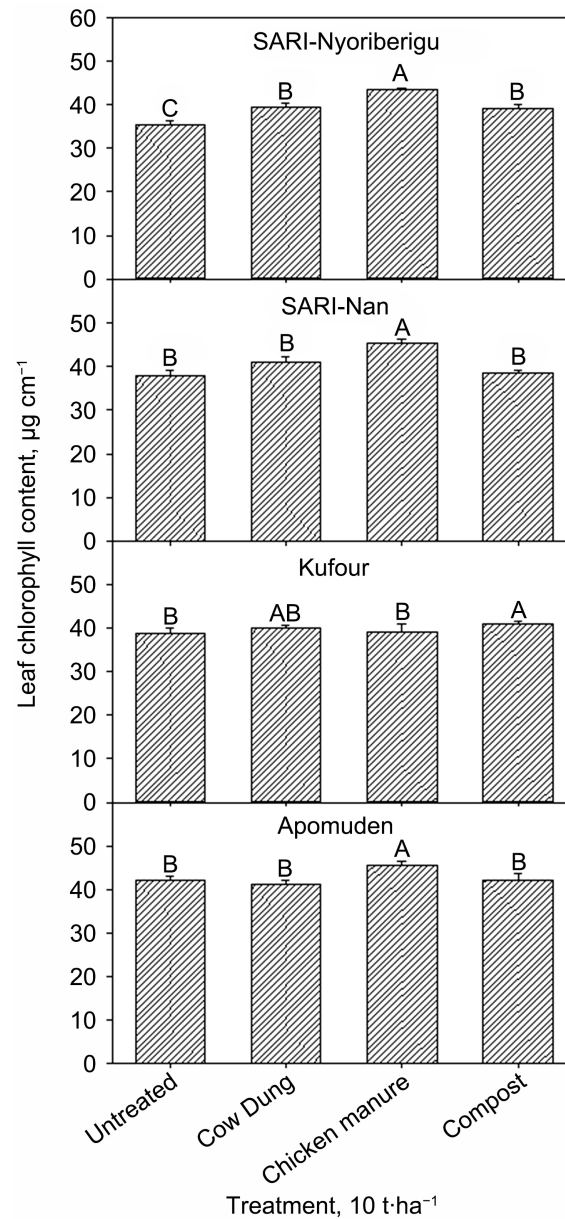


Figure 1. Effect of compost, chicken manure (C Manure) and cow dung on leaf chlorophyll content of four sweet potato varieties grown in the field in 2015 and 2016 at Nyankpala, Ghana.

of the chicken manure (Table 2). This finding is similar to reports of previous studies. Purbajanti *et al.* [34] reported increased chlorophyll content of *Brachiaria* (*Brachiaria brizantha* Stapf) due to the application of 150 kg·N·ha⁻¹ and Pangaribuan *et al.* [35] noted increased sweet corn (*Zea mays convar. Saccharata var. rugosa*) chlorophyll content with application of 15 t·ha⁻¹ chicken compost (mature chicken manure). Similarly, increased sweet potato and corn leaf chlorophyll contents were observed with the application of chicken manure and animal manure, respectively [36] [37]. With SARI-Nyoriberigu, the untreated check had significantly less leaf chlorophyll content than when treated with cow dung, chicken

manure and compost. With SARI-Nan and Apomuden, only the application of chicken manure resulted in a significantly greater leaf chlorophyll content in comparison with the untreated check (**Figure 1**). The application of compost increased Kufour leaf chlorophyll content when compared with the untreated check. Comparing the untreated checks among the four varieties, Apomuden had greater leaf chlorophyll content than SARI-Nyoriberigu, SARI-Nan and Kufour. This is consistent with other studies. Darko *et al.* [38] in a study, found that Apomuden recorded the highest chlorophyll content among several sweet potato varieties. The application of organic fertilizer treatments in this study increased leaf chlorophyll content, and farmers should be encouraged to adopt them since chlorophyll content is an indirect indicator of the health and nutritional status of the plant [39].

Leaf area index (LAI) is an estimate of the plant's ability to capture light energy and, therefore, a critical variable in physiological processes such as photosynthesis and respiration [40]-[43]. There was no variety by organic fertilizer treatment ($p = 0.1423$) interaction for the leaf area index. However, there were significant differences among the four variety means and among organic fertilizer treatment means. SARI-Nyoriberigu had a significantly greater leaf area index, followed by SARI-Nan and Apomuden. Kufour had significantly less leaf area index than the other three varieties (**Table 2**). This is probably due to the low crop establishment after transplanting of this variety (**Table 4**). With organic fertilizer treatments, LAI ranged from 3.223 to 2.136 (**Table 4**). Chicken manure produced the highest LAI, followed by compost and then cow dung. LAI of the untreated check was significantly less. In another study, Pangaribuan *et al.* [33] noted that the sweet corn (*Zea mays convar. Saccharata var. rugosa*) leaf area index increased with the application of 15 t·ha⁻¹ chicken compost (mature chicken manure).

3.3. Plant Component Dry Matter

Similar to PPAE, CC and LAI, there was no significant difference between the two years for leaf dry matter (LDM), stem dry matter (SDM), root dry matter (RDM), and total dry matter (TDM). Therefore, the data were combined for years and analyzed as a function of organic fertilizer treatment and variety (**Table 3**). The application of chicken manure, compost and cow dung led to the partitioning of 69.2%, 69.6% and 74.55%, and 72.9%, 67.5% and 67.4% of photosynthates to the root system as compared to the control/untreated check, for SARI-Nyoriberigu and SARI-Nan, respectively. However, the application of chicken manure, compost and cow dung led to 23.2%, 34% and 34.4%, and 30.5%, 33.4% and 41.7% of photosynthates partitioned to the stems as compared to the control/untreated check, for Apomuden and Kufour, respectively (**Figure 2**). Total biomass yield for treatments receiving chicken manure, compost and cow dung were significantly higher than the control/untreated check across the four varieties except for SARI-Nyoriberigu, where total biomass yield between the control/untreated check and chicken manure treated plots was not significantly different. Across the four treatments, SARI-Nan produced the highest total biomass, followed by Kufour, SARI-

Nyoriberigu and then Apomuden. SARI-Nan and Kufour were the most responsive to chicken manure, compost, and cow dung applications in terms of total biomass yield. Our finding is similar to an earlier study. The application of 6 t ha⁻¹ of chicken manure increased sweet potato dry matter in comparison with the untreated check [44]. The application of cow dung led to the partitioning of the highest percentage of photosynthates to the roots across all four varieties (Figure 2). For Apomuden and Kufour, chicken manure application induced the partitioning of the highest proportion of photosynthates to vines and leaves. In general, Apomuden produced the lowest total dry matter across treatments in this study.

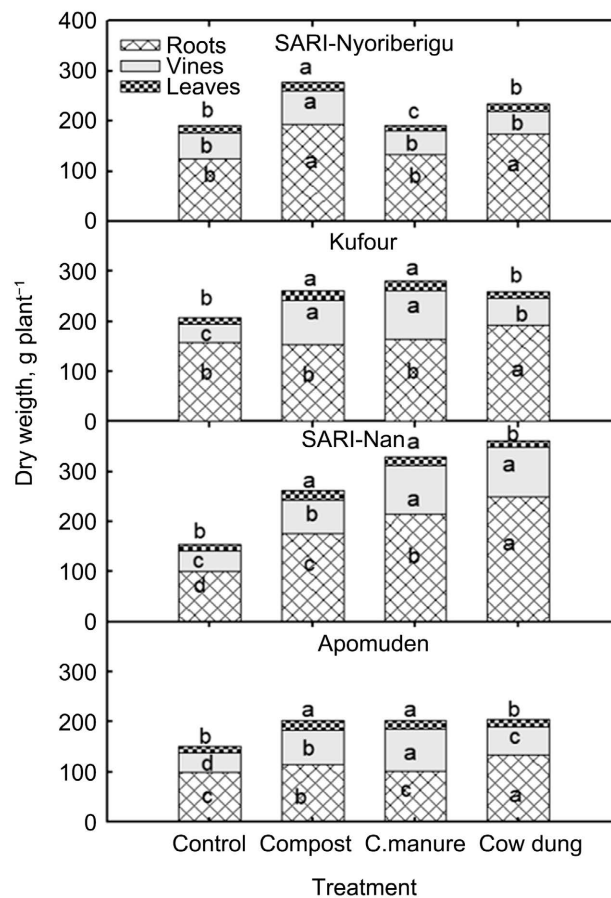


Figure 2. Effect of compost, chicken manure (C Manure) and cow dung on the partitioning of photosynthates of field grown sweet potato in 2015 and 2016 in Nyankpala, Ghana.

3.4. Number of Storage Roots Per Plant, Mean Storage Root Weight, Marketable and Total Storage Root Yields

Like PPAE, CC, LAI, LDM, SDM, RDM and TDM, there was no significant difference between the two years for storage root number per plant and mean storage root weight; therefore, the data were combined for years and analyzed as a function of organic fertilizer treatment and variety (Table 3). There was variety by organic fertilizer treatment interaction for a number of storage roots per plant ($p = 0.0052$) and mean storage root weight ($p = 0.0022$) (Table 1). The application

of chicken manure and compost increased a number of storage roots per plant when compared to the untreated check for SARI-Nyoriberigu, SARI-Nan and Apomuden (Figure 1). In a similar study conducted in Brazil, Chicken manure application increased storage root number [43]. With Kufour, the application of cow dung increased the number of storage roots per plant compared with the untreated check. The application of compost, however, appears to have had a deleterious effect on the variety Kufour's number of storage roots per plant. Mean storage root weight of Kufour was significantly greater than that of the other three varieties with or without organic fertilizer application (Figure 3(B), Figure 3(D), Figure 3(F) and Figure 3(H)).

Unlike PPAE, CC, LAI, LDM, SDM, SR number per plant and TDM, there was variety by organic fertilizer treatment by year interaction ($p = 0.04889$) for MSRY ($p = 0.04889$) and TSRY ($p = 0.04107$) (Table 3).

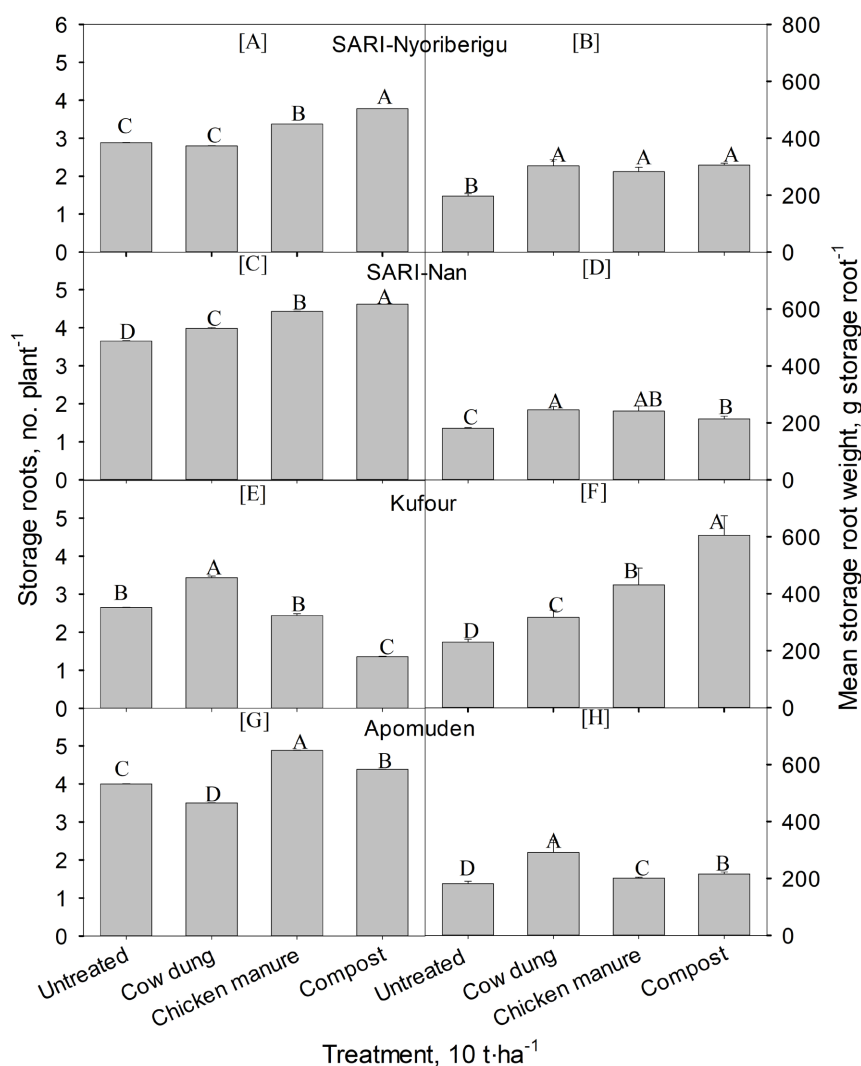


Figure 3. Effect of compost, chicken manure and cow dung on a number of storage roots per plant ((A), (C), (E) and (G)) and mean storage root weight ((B), (D), (F) and (H)) of four sweet potato varieties grown in the field in 2015 and 2016 at Nyankpala, Ghana.

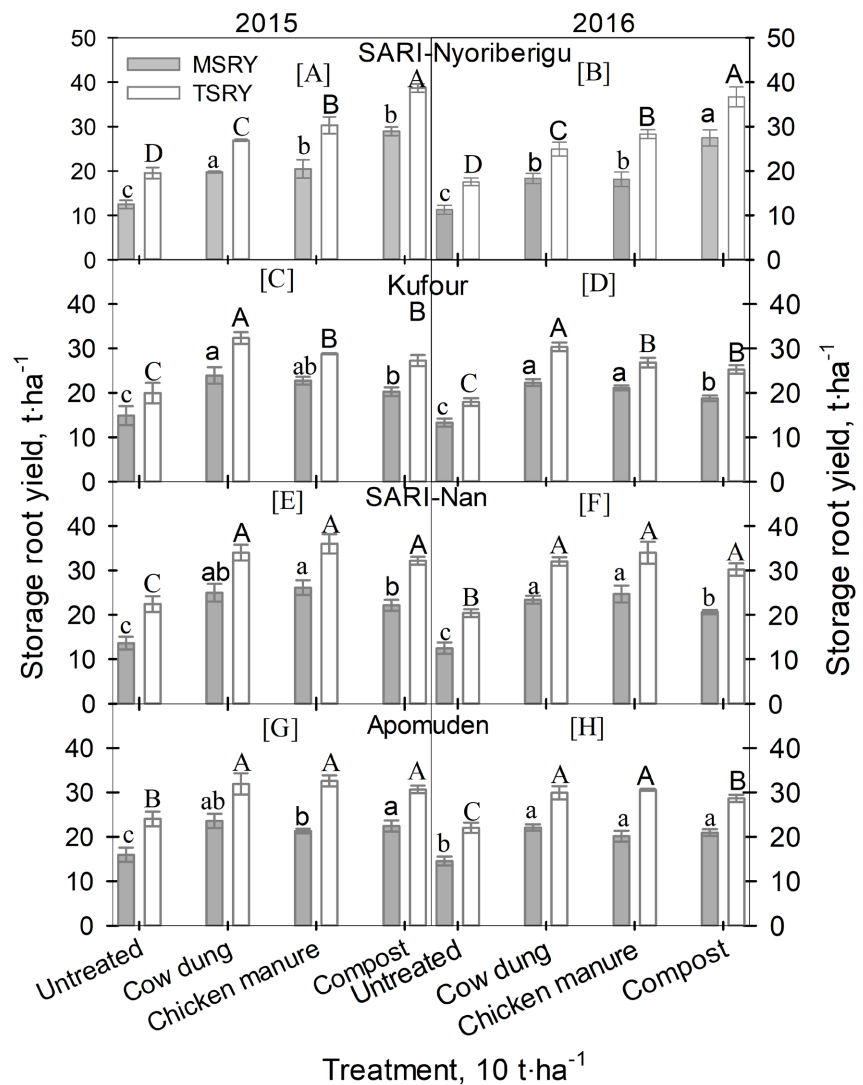


Figure 4. Field-grown sweet potato marketable storage root yield (MSRY) and total storage root yield (TSRY) of sweet potato var SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden as influenced by compost, chicken manure (C manure) and cow dung in 2015 and 2016 at Nyankpala, Ghana. Columns represent the means and the error bars are \pm SE of the mean. Columns with different letters are significantly different at the 5% level by Fisher's least significant difference.

TSRY ranged from 19.5 to 38.7, 19.9 to 32.4, 22.4 to 36.0 and 24.0 to 32.6 $\text{t}\cdot\text{ha}^{-1}$ for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively, in 2015 and from 17.5 to 33.9, 17.9 to 30.4, 20.4 to 34 and 22.0 to 30.6 $\text{t}\cdot\text{ha}^{-1}$ for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively, in 2016 (Figure 4). The application of cow dung, chicken manure and compost in 2015 significantly increased TSRY by 38%, 55%, and 98%, 62%, 45% and 37%, 52%, 61% and 44%, and 33%, 36% and 28% for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively when compared to the untreated check. In 2016, and in comparison with the untreated check, the application of cow dung, chicken manure and compost increased TSRY by 42%, 61% and 93%, 69%, 49% and 41%, 57%, 67% and

48%, and 36%, 39% and 30% for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively. Our findings are similar to previous studies. Adeyeye *et al.* [45] reported increased storage root yield with the application of poultry manure and cow dung when compared to the untreated check. Similarly, storage root yield increased with the application of chicken manure in comparison with the untreated check [46] [47]. Further, Abdulraheem *et al.* [48] reported that the application of 5 t cow dung ha⁻¹ significantly increased storage root yield in comparison with the untreated check in a study conducted in Nigeria. Also, Zongo *et al.* [22], in a study in Burkina Faso, concluded that the application of 6.4 t·ha⁻¹ of compost combined with wood ash increased orange-fleshed sweet potato (var. Jewel) storage root yield.

MSRY in 2015 ranged from 12.5 to 28.9, 14.9 to 23.9, 13.6 to 26.1 and 16 to 23.6 t·ha⁻¹ for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively, and from 11.3 to 27.4, 13.3 to 22.3, 12.5 to 24.7 and 14.6 to 22.1 t·ha⁻¹ for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively, in 2016 (Figure 4). In 2015, cow dung, chicken manure and compost application significantly increased MSRY by 58%, 64% and 132%, 61%, 53% and 36%, 83%, 92% and 62% and 48%, 33% and 41% for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively in comparison with the untreated check. In 2016, the application of cow dung, chicken manure and compost increased MSRY by 62%, 61% and 144%, 68%, 59% and 41%, 88%, 98% and 65%, and 52%, 38% and 44% when compared to the untreated check for SARI-Nyoriberigu, Kufour, SARI-Nan and Apomuden, respectively. Similarly, Boru *et al.* [49] reported increased marketable and unmarketable storage root yields with the application of 15 t farmyard manure ha⁻¹ when compared to the untreated check. Yeng *et al.* [44], in another study, reported increased marketable and storage root yield with the application of 6 t·ha⁻¹ of chicken manure when compared with the untreated check in their Wa location in Ghana.

SARI-Nyoriberigu produced the highest MSRY and TSRY with the application of compost over the two seasons when compared to the other varieties. The application of compost, cow dung and chicken manure resulted in significantly greater MSRY and TSRY in comparison with the untreated check (control) over the two seasons across the four varieties (Figure 4). As observed with the partitioning of photosynthates to roots, cow dung application resulted in the production of the highest storage root yield per hectare among the three orange flesh varieties (Apomuden, SARI-Nan and Kufour). This is probably because of its high content of potassium (Table 2). For the white flesh variety, SARI-Nyoriberigu, the highest storage root production, was obtained with the application of compost (Figure 1).

3.5. Partial Budget Analysis

Figure 5 depicts the net benefit of the soil amendments in MSRY compared to the control. The results gave a positive value for yield increase for each of the soil amendment treatments compared to the control. The net benefit due for each soil amendment is positive, implying that it is profitable to produce sweet potatoes with soil amendments compared to the status quo (control).

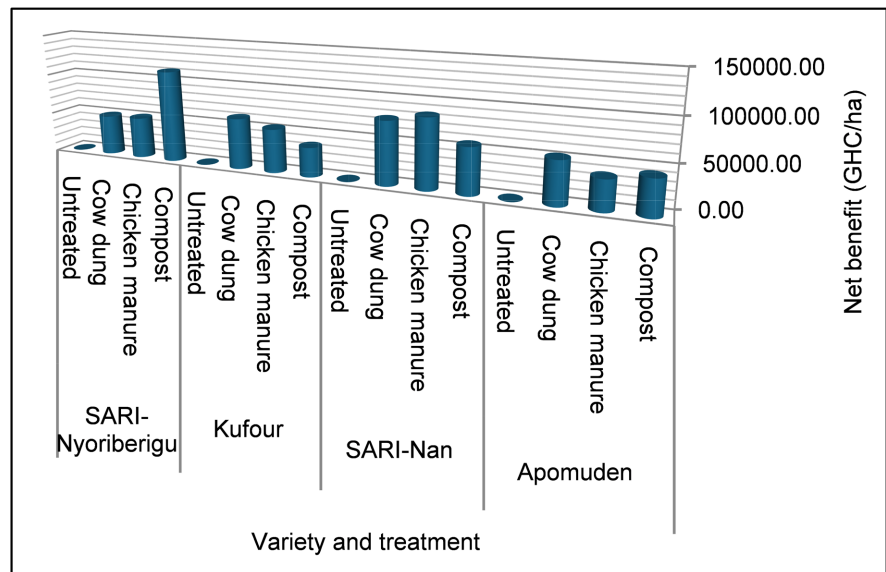


Figure 5. Net benefit for treatments by variety.

Table 5. Partial budget analysis.

Variety	Treatment	Output			Input			Net benefit due to treatment (GHC ha ⁻¹)	Net returns to treatment
		Mean MSRY (t-ha ⁻¹)	Increased MSRY due to treatment (t-ha ⁻¹)	Value of increased MSRY (GHC ha ⁻¹)	Cost of manure (GHC ha ⁻¹)	Labor cost of manure application (GHC ha ⁻¹)	Total Cost (GHC ha ⁻¹)		
SARI-Nyoriberigu	Untreated	11.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cow dung	19.02	7.15	50039.50	1000.00	300.00	1300.00	48739.50	38.49
	Chicken manure	19.28	7.41	51835.00	1500.00	300.00	1800.00	50035.00	28.80
	Compost	28.19	16.31	114187.50	1800.00	300.00	2100.00	112087.50	54.38
Kufour	Untreated	14.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cow dung	23.11	9.02	63140.00	1000.00	300.00	1300.00	61840.00	48.57
	Chicken manure	21.93	7.84	54880.00	1500.00	300.00	1800.00	53080.00	30.49
	Compost	19.51	5.42	37929.50	1800.00	300.00	2100.00	35829.50	18.06
SARI-Nan	Untreated	13.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cow dung	24.20	11.14	77976.50	1000.00	300.00	1300.00	76676.50	59.98
	Chicken manure	25.41	12.35	86439.50	1500.00	300.00	1800.00	84639.50	48.02
	Compost	21.39	8.32	58247.00	1800.00	300.00	2100.00	56147.00	27.74
Apomuden	Untreated	15.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cow dung	22.86	7.59	53158.00	1000.00	300.00	1300.00	51858.00	40.89
	Chicken manure	20.73	5.47	38255.00	1500.00	300.00	1800.00	36455.00	21.25
	Compost	21.70	6.44	45045.00	1800.00	300.00	2100.00	42945.00	21.45

Further analysis from the report comparing the investment to the revenue indicates that, for every cedi invested in the soil amendments, the investor makes a minimum of more than 18 times the investments as shown in **Table 5**.

The net returns for SARI-Nyoriberigu treated with cow dung, chicken manure, and compost were GHC 38.49, GHC 28.80 and GHC 54.28 times, respectively, for every GHC 1.00 invested. In the case of Kufour, the net returns for cow dung, chicken manure and compost were GHC 48.57, GHC 30.49 and GHC 18.06, respectively, for every GHC 1.00 cedi invested in the treatments. SARI-Nan had net returns of GHC 59.98, GHC 48.02 and GHC 27.27, respectively, for every GHC 1.00 invested in cow dung, chicken manure and compost. Apomuden gave net returns of GHC 40.89, GHC 21.25 and GHC 21.45, respectively, for every GHC 1.00 invested in cow dung, chicken manure and compost.

The general analysis of the above results indicates that, in terms of economic returns, SARI-Nan responded very well to the application of cow dung, chicken manure and compost in comparison with the other varieties. The results also generally say that farmers tend to benefit economically when they invest in productivity-improving soil amendments (cow dung, chicken manure, and compost).

4. Conclusions

The application of 10 t·ha⁻¹ cow dung, chicken manure and compost increased MSRY and TSRY of SARI-Nyoriberigu, Apomuden, Kuffour and SARI-Nan. For storage root production, cow dung application led to the highest yield with the orange-fleshed varieties (Apomuden, Kufour and SARI-Nan) and compost application led to the highest yield for the white-fleshed variety (SARI-Nyoriberigu). For shoot production, chicken manure application led to the highest yield across all four varieties. Kufour had the highest mean storage root weight of the other three varieties but had the lowest establishment after planting. These four organic amendments showed great potential for being incorporated into organic sweet potato production practices. Economic analysis of the application of soil amendments indicates high economic returns as productivity is improved. We found that an investment of GHC 1.00 on cow dung, chicken manure and compost gave a net return of a minimum of GHC 18.00. Hence, based on the partial budget analysis, we recommend that farmers should adopt the use of organic amendments in sweet potato production as it has the potential to give high returns. This can generate income for resource-poor farmers in rural areas and improve their livelihood while contributing to enhancing food and nutrition security.

However, since there is an interaction between variety and organic fertilizers, further studies are needed to determine the optimum levels that will maximize yield.

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Data Availability

The authors state that all data generated or analysed during this study are included in this article.

Authors' Contributions

IAA, EEC, and PEA conceived the research. IAA, ETC, PA and KA set up the experiment. IAA, KA and IY collected, analyzed the data and drafted the manuscript. KA, JA-D, IY, JY, GYM, IS, AA, MA and AS edited, revised, and made significant contributions.

Funding Acquisition

IAA, KA, ETC and PA.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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