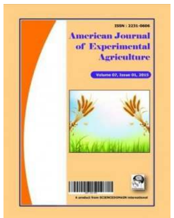

American Journal of Experimental Agriculture
11(2): 1-19, 2016, Article no.AJEA.22446
ISSN: 2231-0606

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Yield and Root Quality of Two Sweetpotato (*Ipomoea batatas* [L.] Lam) Varieties as Influenced by Chicken Manure, Inorganic Fertilizer and Storage Methods

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Authors' contributions

This work was carried out in collaboration between all authors. Author HKD designed the study, wrote the protocol and identified the plants. Author MEE was involved in the design of the study, carried out the field work, managed the analyses of the study and wrote the first draft of the manuscript. Authors JOA and ETB reviewed the experimental design and all drafts of the manuscript. Author JCN critically reviewed the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2016/22446
Editor(s):
(1) Mirza Hasanuzzaman, Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh.
Reviewers:
(1) Adelia Bovell-Benjamin, Tuskegee University, USA.
(2) Chagonda Ignatius, Midlands Satte University, Zimbabwe.
(3) Olubode, Olusegun Olufemi, Federal University of Agriculture, Nigeria.
(4) Tran Dang Xuan, Hiroshima University, Japan.
Complete Peer review History: http://sciencedomain.org/review-history/12764

Original Research Article

Received 1st October 2015
Accepted 2nd December 2015
Published 22nd December 2015

ABSTRACT

Two field experiments were conducted at two seasons at the University of Education, Winneba, Mampong-Ashanti campus to investigate the responses of the yield and root quality of two varieties of sweetpotato (*Apomuden* and *Okumkom*) to chicken manure and inorganic fertilizers and storage methods. The experimental design used for the experiment was a 2 x 8 factorial arranged in randomized complete block design with four replicates in both seasons. The application of 15-15-15 kg/ha NPK+ 5t/ha CM and 15-30-30 kg/ha NPK + 5t/ha CM to *Apomuden* produced thicker vine diameter and dry matter accumulation respectively during the major season while *Okumkom* grown

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on 30-30-30 kg/ha NPK gave longer vine length in the same season. However, the application of amended treatments to both varieties decreased root quality (root crack) during the major season and increased pest infested roots during the minor season. *Okumkom* grown on 15-15-15 kg/ha NPK+ 5t/ha CM plot produced higher forked roots at harvest in both seasons. *Okumkom* grown on 30-45-45 kg/ha NPK and 30-60-60 kg/ha NPK plots had increased root sugar and starch content at harvest during the major season. Both varieties, whether treated or untreated had decreased starch content at 12 weeks in storage than at harvest in both seasons. Pit storage showed the most effective storage method in terms of root starch and sugar content in both seasons followed by ash and grass storage methods.

Keywords: Sweetpotato; Apomuden; Okumkom; root starch; root sugar.

1. INTRODUCTION

Sweetpotato (*Ipomoea batatas* [L.] Lam) is an important root crop grown in the tropics, sub-tropics and warm temperate regions of the world. It is commonly referred to as subsistence food security or famine relief crop and income earner in the Southern Africa. Sweetpotato is grown, especially by women for daily family consumption and for sale by the poorest among African communities [1,2]. Sweetpotato is an important crop with an annual global production of 106.6 Mt and grown in over 115 countries. The world leading producer country is China with 81.7 Mt in 2010. Africa contributes up to 14% of global production with more than 14.2 Mt [3]. The sweetpotato has been reported to have numerous health benefits, which have been attributed to its phytochemical constituents. The orange-fleshed sweetpotato contains β-carotene, responsible for conferring pro-vitamin A activity that contributes to the prevention of cataract and age-related macular degeneration [4]. Beta carotene is known to be a precursor of Vitamin A (or a provitamin A carotenoid) in humans. Vitamin A plays crucial roles in vision, cellular differentiation and morphogenesis, haemopoiesis, skeletal growth and fertility in humans [5]. Despite its importance, the yields are low in Ghana which can be attributed to among others the low fertility of the soil. The production of sweetpotato however in Ghana is low. Sweetpotato appears to be the least recognized by both farmers and consumers probably because the crop is considered poor man's food and also as a dessert rather than as a staple food even though it is comparable to the other root crops in yield and quality. Sweetpotato responds to phosphorus and potassium application under most conditions though the response rate and optimum dose varies with the cultivar and soil types. The inherent poor soil fertility of most soils in the tropics and subtropics constitute a major constraint in sustainable smallholder crop production in the sub-Saharan Africa [6]. Increase in population which has resulted in land shortages has led to reduction in traditional methods of maintaining soil fertility. Technologies based on combinations of organic and inorganic sources of fertilizer would produce higher and more sustainable yields than either organic or inorganic fertilizer alone [7]. Chemical fertilizers have been the conventional way to supplying nutrients to the crop. However, with the increasing cost of fertilizers following the removal of government subsidy on the commodity, farmers are looking for alternative but sustainable methods of cultivating the crop. Applying chicken manure in combination with inorganic fertilizers provides a favourable condition for both high and stable yields of various varieties of crops [8]. Poultry manure has been found to improve upon both the physical and chemical properties of the soil when applied appropriately. Physically, [9] reported that poultry manure improves the physical condition of both light and heavy soils. Improved physical conditions, enhance aeration, ease of seed bed preparation, seed germination, water holding capacity, soil microbial activity, water infiltration and structural stability of the soil.

Poultry litter incorporation also increased organic carbon and N to the depth of 15 and 30 cm respectively [10]. However, sweetpotato yields declined with increased levels of chicken manure [11]. This study was carried out to investigate the responses of yield and root quality of two varieties of sweetpotato (*Apomuden* and *Okumkom*) to chicken manure and inorganic mineral fertilizers.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Two field experiments were conducted at two seasons at the Multipurpose crop nursery of the University of Education, Winneba, Mampong-Ashanti campus during the minor and major rainy seasons from September, 2011 to January, 2012 and April to July, 2012 respectively.

The weather conditions during the experimental periods show that differences in climatic factors (rainfall, temperature and relative humidity) were observed between both cropping seasons. The total monthly rainfall in the minor season was 429.8 mm and it occurred from September, 2011 to January, 2012 with the peak in September and October. The mean monthly temperature of the area for the minor season ranged between 23℃ to 31.9℃ with the highest daily of 33.7℃ occurring in January, 2012. The mean monthly relative humidity ranged from 54 to 93.4% with the peak occurring between September and November. The bimodal rainfall pattern of Mampong-Ashanti gave the area two seasons; the major season occurred between March and July and the minor from September to November with one month drought spell in August [12]. In the major rainy season (2012), the total monthly rainfall was 1,042.3 mm and it occurred from April to August, 2012 with the peak in May and July. The mean monthly temperature of the site for the major season ranged between 22.5℃ to 30.1℃, with the highest daily of 33.3℃ occurring in April. The mean monthly relative humidity ranged from 67.4 to 93.4% with the peak occurring between April and June. Similarly, the bimodal rainfall pattern of Mampong-Ashanti gave the area two seasons, the major rainy season occurred between March and July and the minor season, 2011 from September to November with one month dry spell in August [13].

The soil has been classified by FAO/UNESCO **(**Food and Agricultural Organization/United Nations Educational Scientific and Cultural Organization) [14] legend as Chronic Luvisol and locally as the Bediesi series with a pH range of 4.0-6.5 and is good for root, cereal, vegetable and legume crop production [15].

2.2 Soil and Manure Analysis

The chicken manure used for the research project for both seasons was four months old (20.0% moisture content) and was obtained from the poultry farm of the College of Agriculture, University of Education, Winneba, Mampong-Ashanti campus and heaped under shade to dry before use. Sub-samples of the dried manure were taken for nutrient analysis. Soil samples were taken prior to and after application of organic manure and fertilizers from the top 0-20 cm of plots for physico-chemical analyses. Soil samples and manure analyses were carried out at the soil research institute of CSIR laboratory, Kumasi. The characteristics analyzed for included particle size, pH in 1:1 soil: water ratio 1:2 soil: 0.01 $CaCl_2$, Organic matter was determined by the Walkey and Black method [16] and total nitrogen was determined by the micro Kjeldahl method [17]. The available phosphorus was extracted by the Bray's method [18]. In this method specific coloured compounds (0.03 M NH_4F in 0.025 M HCl) are formed with the addition of appropriate reagents in the solution: dissolve 2.22 g NH_4 in 200 ml distilled water, filter, and add to the filtrate and 1.8 liters of water containing 4 ml of concentrated HCl. The intensity of which is proportional to the concentration of the element being estimated. The colour intensity was measured spectrophotometrically.

Exchangeable cations were determined by flame emission photometry [18]. Extraction is carried out by shaking the soil-extract mixture, followed by filtration or centrifugation. Ca and Mg are determined using an atomic absorption or spectrometry (AAS) after the removal of ammonium acetate and organic matter at pH 7.0. The water–soluble cations are estimated in the 1:2 soil-water extract and deducted from ammonium acetate extractable Ca and Mg in order to obtain exchangeable Ca and Mg. The content of exchangeable cations is determined in extract by flame photometry.

2.3 Experimental Design and Treatments

The experimental design was a 2 x 8 factorial arranged in randomized complete block design (RCBD) with four replicates. The factors were two sweetpotato varieties (*Okumkom* and *Apomuden*) and seven organic and inorganic fertilizer rates and control (no amendment). Treatment combinations and nutrient levels are as indicated in Table 1.

2.4 Storage Studies

Seven clean roots (without bruises or signs of insect pest attack) were randomly selected from each treatment for each of the storage methods (pit, ash and grass) from the field experiment after harvest and stored for 12 weeks. In each pit or basket used for the ash and grass storage methods, there were a total of 112 roots that were monitored for 12 weeks. The pit storage method consisted of a circular pit of size 0.5 m diameter x 0.5 m wide x 0.5 m depth. The size of the pit was chosen to suit local climatic conditions and is a modification of the traditional pits. The pit was lined with dry plantain leaves before the sweetpotato roots were stored in them. Layers of tubers as per treatment were separated with about 1.0 kg dry spear grass (*Imperata cylindrica*). The sweetpotato roots were finally covered with dry spear grass before covering them with 2.0 kg of soil. The grass acted as an insulating material and ensured cool condition in the pit (17℃, RH 95-100%). The pit was constructed under a shade to prevent rain water from entering the storage pit.

The ash storage method consisted of wood ash packed in a basket of size 50 cm x 50 cm x 70 cm lined with a layer of dry plantain leaves The tubers as per treatment were thoroughly coated with wood ash by mixing them with 2 kg of wood ash. The tubers were then alternated with 1.0 kg of dry spear grass. The ash acted as an absorbent to moisture and has a repelling effect on pests. Wood ash has alkaline properties, which are not conducive for the development of diseases.

The grass storage method consisted of grass packed in a basket of size 50 cm x 50 cm x70 cm lined with dry plantain leaves with tubers alternating with layers of grass and finally covered with a grass. Layers of tubers as per treatment were separated with about 1.0 kg dry spear grass (*Imperata cylindrica*). The sweet potatoes were then finally covered with dry spear grass at the top.

2.5 Land Preparation, Fertilization and Planting

The total field size of 64.0 m x 18.0 m (1152 m^2) was cleared followed by ploughing and harrowing as there were no stumps. Chicken manure was applied and worked into the soil two weeks before planting of vines. Inorganic mineral fertilizer, NPK (15:15:15), Triple super phosphate and muriate of potash were applied two weeks after planting of vines at appropriate rates as per treatments. Each treatment plot measured 4.0 m x 3.0 m. Ridges were constructed 1.0 m between rows and planted at 0.3 m within row plants. Vine cuttings of two sweetpotato varieties *Apomuden* and *Okumkom* of length 0.3 m topmost apical sections and other actively growing sections were planted two weeks after chicken manure application.

2.6 Data Collection and Analyses

2.6.1 Vegetative data

Percentage crop establishment was measured on eighteen plants from the two central rows at 4 weeks after planting (WAP). Vine length and vine girth, were measured on three plants from the two central rows with meter rule and vernier caliper respectively. Fresh vine weight gain and dry matter accumulation were measured on three plants at four weeks after planting and at two weeks interval. Plants were destructively sampled and weighed for fresh vine weight accumulation at 2 weeks interval from 4 WAP to 12 WAP using an electronic weighing scale. After destructive sampling for fresh vine weight gain, 200 g samples per plot were oven-dried at 72℃ for 72 hours to remove all moisture. Dried samples were then weighed using an electronic weighing scale.

Table 1. Treatment combinations and nutrient levels

Treatments	Inorganic fertilizer (NPK 15-15-15)	Triple Super phosphate	Muriate of potash	Chicken manure (CM)
15-30-30 kg/ha NPK+ 5 t/ha CM	100 kg/ha	65 kg/ha	24 kg/ha	5 t/ha
15-23-23 kg/ha NPK+ 5 t/ha CM	100 kg/ha	32.5 kg/ha	12 kg/ha	5 t/ha
15-15-15 kg/ha NPK+ 5 t/ha CM	100 kg/ha	-	-	5 t/ha
30-60-60 kg/ha NPK	200 kg/ha	130 kg/ha	48 kg/ha	-
30-45-45 kg/ha NPK	200 kg/ha	65 kg/ha	24 kg/ha	-
30-30-30 kg/ha NPK	200 kg/ha	-	-	-
10 t/ha CM	-	-	-	10 t/ha
No fertilizer (control)	-	-	-	-

2.6.2 Yield and yield components and root qualities

Marketable and unmarketable root weight per plot, yield and yield components including weight per root and marketable and unmarketable root diameter were estimated. Root diameter of less than 3 cm was considered unmarketable and those with diameter more than 3 cm as marketable [19]. Root market quality including root cracks, forked root and pest infestation were also determined. The roots harvested from eighteen plants of each plot were sorted into five categories using the recommended scale [19]. Each attribute was scored by relating the number of affected roots to the total number of roots per treatment plot. Rating Scale: None ....1, ii.Slight.....2, iii. Moderate ......3, iv. Severe.........4, v. Very Severe ....5.

2.7 Proximate Analysis

The freshly harvested sweetpotato samples (from each variety and fertilizer combinations) were washed with clean water, packaged in aluminum foil, labeled and stored at -4℃ for starch and sugar analysis using Abbe Refractometer, model, 98-440 (Novex-Holland). Additionally, sweetpotato roots were randomly selected after three months storage from each of the storage methods (pit, grass and ash) for similar analysis. The samples were shredded later and made to pass through a 0.2 mm mesh. 10.0 g of each sample was placed in a cheese cloth and a few drops of the sap squeezed out slowly onto the lens of the refractometer and closed with the cover. The eye piece was immediately focused to clearly see the graduation. The sugar content of each sample in Degrees Brix (°Bx) was quickly recorded. This was repeated for the other treatments using new cheese cloth. For the determination of starch, the refractive indices obtained from the samples were compared with an International Scale of refractive index [20] to obtain accurate values that is the percentage mass of the starch was read from a chart corresponding to the value of refractive index. Precautionary measures such as cleaning of lens with a soft damp cloth after every reading and allowing sap to rest on the lens for at least 30 seconds before taking a reading were taken.

Data Analysis was done using RCBD ANOVA and GenStat statistical package [21]. Least Significant Difference (LSD) was used to separate the means at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Soil Nutrients Levels after Application of Chicken Manure and Inorganic Fertilizers in Both Studies during the Minor season, 2011 and the Major Season, 2012

Initial effects of manure application on some soil physical and chemical properties at the minor and major seasons experimental sites are shown in Table 2. Both the no-fertilizer soil and manured supplemented soils were within the sandy loam textural range. 10 t/ha chicken manure supplemented soil had higher levels of organic matter, exchangeable Ca, Mg and effective cation exchange capacity than the other manured soil and control. Both the untreated soil and manured soil had an acidic pH; however, 10 t/ha CM supplemented soil had a slightly acidic pH. The application of chicken manure increased organic matter content, water holding capacity of the soil, the soil pH and bulk density. The inorganic fertilizer supplemented plots improved only the chemical properties of the soil, but not the soil physical properties, such as, soil structure, bulk density and water holding capacity.

3.2 Growth Performance

3.2.1 Percentage crop establishment

The percentage crop establishment during the minor and major growing seasons for the two sweetpotato varieties (*Apomuden* and *Okumkom*) ranged from (59.2 – 78.8) and (53.5 – 85.5), respectively (Table 3). The healthy and actively growing parts of vines used as planting materials might have accounted for the high percentage crop establishment. According to [22,23] there is the need to use healthy and actively growing portions of planting material (vines) and appropriate spacing as well as reduction in weed competition for good plant growth later during the seasons. There was a significant difference between *Apomuden* and *Okumkom* in percentage crop establishment during the minor season (Table 3). This might be due to differences in variety. Organic and inorganic fertilization either singly or in combination did not significantly influence crop establishment across both growing seasons. *Okumkom* grown on amended plots during the major season produced higher percentage crop establishment than those in the minor season. The initial high rainfall experienced during the major growing season as compared with the minor season coupled with cultivar differences might have contributed to such high percentage crop establishment.

3.3 Vine Diameter

Vine diameter of both sweetpotato cultivars (*Okumkom* and *Apomuden*) grown under amended plots were significantly thicker than the control during the major season (Table 4). This might be due to differences in soil fertility status through increased availability of nitrogen on manured plots. The results at both sites and growing seasons were similar to the findings of [24] that in sweetpotato high nitrogen may cause luxuriant growth of the vines at the expense of storage root yield and that excessive N rates stimulate vine and root growth and delay root bulking and maturation. *Apomuden* and *Okumkom* grown on amended and control plots during the major season produced thicker vine diameter than those grown under the same treatments during the minor season at 12 weeks after planting. The differences in sweetpotato growth observed in the two seasons might be attributed to initial high rainfall and low temperature experienced during the major season coupled with slow and effective release of nutrients from manure applied during the major season. The moderate temperature affected carbohydrate metabolism through increased in leaf starch levels which in turn resulted in thicker vine diameter. [25,26] reported that sweet potato response to nutrient input was greatly affected by other factors such as rainfall and number of cropping seasons. There was a significant difference between *Apomuden* grown under 15-15-15 kg/ha NPK + 5 t/ha CM and the control in vine diameter during the major season. This might be due to differences in soil fertility and the initial slow release of N in chicken manure.

3.4 Vine Length

There was a significant difference between *Okumkom* and *Apomuden* in vine length in both seasons (Table 4). This might be due to differences in variety and their response to soil nutrient. Significant increase in vine length occurred with application of 30-30-30 kg/ha NPK to *Okumkom* than the control during the major season. *Apomuden* grown under 15-30-30 kg/ha NPK +5 t/ha CM differed significantly from 30-30-30 kg/ha NPK in vine length in the same growing season. The significant difference between the two varieties grown under amended and the control plot might be due to differences in genetic characteristics of the varieties and their response to soil nutrients. This result however contradicts those found by [27] that the application of organic and inorganic fertilizer to two cultivars of sweetpotato resulted in insignificant changes in vine growth due to differences in genetic composition of the sweetpotato varieties. *Apomuden* and *Okumkom* grown under amended and the control plots during the major season produced longer vine length than those grown on the same treatments during the minor season, 2011 at 12 WAP (Table 4). This might be due to good climatic conditions coupled with slow and effective release of nutrients, especially potassium from the manure applied during the major season. [28] reported that vine length and growth habit of sweetpotato depend on cultivar and environment, particularly, the climate of the growing area available to the plant and the plant's nutrition.

3.5 Yield and Yield Components of Sweetpotato

3.5.1 Marketable root weight (kg/ha)

There was a significant difference between *Apomuden* and *Okumkom* in marketable root weight in both growing seasons (Table 5). The significant difference between the two sweetpotato varieties might be due to differences in variety. The two sweetpotato varieties produced higher marketable root weight during the major season than in the minor season. This might be due to the genetic characteristics of the varieties and their response to different climatic conditions. The poor climatic conditions due to long periods of drought and high temperature experienced during tuber bulking stage might explain the low weight of marketable roots during the minor season. [25] reported that rainfall can affect sweetpotato response to nutrient input. According to [22] regular irrigation of sweetpotato is required, especially during the tuber formation stage. This result is similar to those found by [2] that relatively small increase in soil temperature can have a direct effect on tuber quality.

Table 2. Physico-Chemical properties of soil and soil plus manure Ap horizon at 0-20 cm depth for the minor season, 2011 and the major season, 2012

Property	Value							
	Minor season (2011)				Major season (2012)			
	Untreated soil (control)	Inorganic fertilizer + Soil	10t/ha Chicken manure + Soil	5t/ha Chicken manure + Inorganic fertilizer +Soil	Untreated soil (control)	Inorganic fertilizer + Soil	10t/ha Chicken manure + Soil	5t/ha Chicken manure + Inorganic fertilizer +Soil
Sand (%)	66.49	68.78	66.86	65.93	75.80	59.90	70.80	66.90
Silt (%)	27.51	27.22	25.14	26.07	15.20	31.30	22.00	26.60
Clay (%)	6.00	4.00	8.00	8.00	9.00	8.80	7.20	6.50
Organic carbon (%)	1.06	1.07	1.26	1.14	1.21	1.00	0.92	1.07
Total nitrogen (%)	0.13	0.14	0.17	0.15	0.13	0.21	0.32	0.16
Organic matter (%)	1.83	1.84	2.17	1.97	2.09	1.72	1.59	1.85
pH (1:1 H_2O)	5.44	5.44	6.45	5.77	6.73	5.42	6.19	6.02
Available P (ppm)	38.02	1018.78	334.04	436.10	153.87	439.29	285.42	692.82
Available K (ppm)	73.65	503.78	113.83	177.44	43.96	74.40	71.01	87.92
Bulk density (g/cm^3)	1.49	1.51	1.67	1.51	1.51	1.49	1.49	1.49
Exchangeable cations								
Ca^{2+} (mg/100g)	2.49	2.97	12.80	6.14	5.34	3.47	4.54	5.07
Mg^{2+}(mg/100g)	2.94	2.94	6.74	2.14	2.67	2.67	0.80	0.53
K^+ (mg/100g)	0.35	1.34	0.48	0.67	0.50	0.66	0.62	0.80
Na^+ (mg/100g)	0.13	0.13	0.17	0.18	0.17	0.22	0.21	0.25
Total Exchangeable bases	6.36	7.38	20.19	9.13	0.10	0.80	0.10	0.80
Effective Cation Exchange Capacity(E.C.E.C)me/100g	7.11	8.13	20.34	9.58	8.78	7.82	6.27	7.45

Table 3. Percentage crop establishment as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

	Percentage crop establishment (%)-minor season		Mean	Percentage crop establishment (%) -major season		Mean
	Apomd.	Okumk.		Apomd.	Okumk.	
Fertilizer rate						
10t/ha CM	66.1	60.6	63.3	53.5	75.5	64.5
15-15-15 kg/ha NPK + 5 t/ha CM	75.2	63.7	69.5	73.9	63.2	68.6
15-23-23 kg/ha NPK+ 5 t/ha CM	71.3	68.7	70.0	76.1	69.6	72.8
15-30-30 kg/ha NPK + 5 t/ha CM	59.2	70.6	64.9	63.5	75.5	69.5
30-30-30 kg/ha NPK	72.9	70.9	71.9	53.5	61.1	57.3

	Percentage crop establishment (%)-minor season		Mean	Percentage crop establishment (%) -major season		Mean
	Apomd.	**Okumk.**		**Apomd.**	**Okumk.**	
30-45-45 kg/ha NPK	71.3	59.8	65.5	85.5	61.1	73.3
30-60-60 kg/ha NPK	66.9	64.5	65.7	75.0	71.5	73.3
No fertilizer	78.8	69.2	74.0	80.6	72.6	76.6
Mean	70.2	66.0		70.2	68.8	
LSD (0.05) Variety	7.7*			NS		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety x Fertilizer	NS			NS		
CV (%)	22.5			25.5		

= significant at 5% probability level, NS= not significant

Table 4. Vine diameter and vine length as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

Fertilize	Vine diameter (cm) minor season		Mean	Vine diameter (cm) major season		Mean	Vine length (cm) minor season		Mean	Vine length (cm) major season		Mean
	Apom.	**Okum.**		**Apom.**	**Okum.**		**Apom.**	**Okum.**		**Apom.**	**Okum.**	
10t/ha CM	0.62	0.89	0.75	1.19	1.51	1.4	77.1	101.5	89.3	155.6	177.3	166.5
15-15-15 kg/ha NPK + 5 t/ha CM	0.80	0.98	0.89	1.73	1.26	1.5	89.2	104.5	96.9	128.4	158.1	143.3
15-23-23 kg/ha NPK + 5 t/ha CM	0.75	0.94	0.85	1.52	1.45	1.5	96.1	108.0	102.1	149.9	181.2	165.5
15-30-30 kg/ha NPK + 5 t/ha CM	1.14	0.99	1.07	1.13	1.43	1.3	101.4	110.9	106.2	164.8	183.2	174.0
30-30-30 kg/ha NPK	0.76	0.99	0.87	0.89	1.59	1.3	81.0	122.5	101.8	122.6	183.5	153.1
30-45-45 kg/ha NPK	0.75	1.05	0.88	1.00	1.42	1.2	100.4	125.3	112.9	127.8	169.0	148.4
30-60-60 kg/ha NPK	0.73	1.04	0.89	1.06	1.55	1.3	81.7	100.4	91.1	142.1	178.5	160.3
No fertilizer	0.69	0.92	0.81	0.77	1.25	1.0	90.8	117.8	104.3	137.7	130.1	133.9
Mean	0.78	0.97		1.16	1.43		89.7	111.4		141.1	170.1	
LSD (0.05) Variety	0.11*			0.18*			9.62*			19.59*		
LSD(0.05) Fertilizer	NS			0.18*			NS			39.19*		
LSD(0.05) Variety x Fertilizer	NS			NS			NS			55.42*		
CV (%)	25.5			24.2			19.0			21.4		

= significant at 5% probability level, NS= not significant

Table 5. Marketable and unmarketable root weight (kg/ha) as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

Treatments	Weight of marketable roots (kg/ha)		Weight of unmarketable roots (kg/ha)	
	Minor season	Major season	Minor season	Major season
Variety				
Apomuden	2628.4	5965.3	294.1	319.0
Okumkom	2008.1	3469.0	170.4	625.3
LSD (0.05) Variety	539.0*	1116.1*	63.3*	193.2*
Fertilizer rates/types				
10t/ha CM	1573.3	4333.0	184.1	333.4
15-15-15 kg/ha NPK + 5 t/ha CM	2021.0	4847.2	208.0	264.2
15-23-23 kg/ha NPK + 5 t/ha CM	2625.2	5931.1	230.2	778.1
15-30-30 kg/ha NPK + 5 t/ha CM	2406.1	6444.3	169.1	708.1
30-30-30 kg/ha NPK	2135.4	4528.2	322.4	278.0
30-45-45 kg/ha NPK	2729.5	4181.0	256.3	403.3
30-60-60 kg/ha NPK	2542.1	5500.4	253.1	792.2
No fertilizer (control)	2510.3	1972.3	233.2	222.0
LSD (0.05) Fertilizer	NS	2232.2*	NS	386.5*
LSD (0.05) Var. x Fert.	NS	3156.7*	NS	546.6*
CV (%)	41.2	35.1	40.1	39.4

**= significant at 5% probability level, NS= not significant*

There was no significant difference between amended and the control plots in marketable root weight during the minor season (Table 5). There was a significant difference between amended and the control plots in marketable root weight during the major season. The significant difference between amended and the control plots might be due to differences in soil fertility. The application of 15-30-30 kg/ha NPK + 5 t/ha CM differed significantly from the control in marketable root weight during the major season. This might be due to differences in soil fertility. This result is similar to those found by [29] that when the soil nitrogen level is zero or low increasing nitrogen fertilization is beneficial to yield and that nitrogen affects the number and weight of tuberous roots. [27] reported that addition of organic matter in combination with fertilizer can create a beneficial interaction. Application of amended treatments during the major season produced higher marketable root weight than in the minor season. The higher marketable root weight during the major season compared with the minor season might be due to early release of available nutrient from the manure coupled with the initial high rainfall. Variety by fertilizer interaction did not influence the marketable root weight of *Apomuden* in both seasons. However, there was a significant difference between variety by fertilizer interaction in marketable root weight of *Okumkom* in both seasons (Table 5).

3.6 Unmarketable Root Weight (kg/ha)

There was a significant difference between *Apomuden* and *Okumkom* in unmarketable root weight in both growing seasons (Table 5). The significant difference between the two sweetpotato varieties might be due to differences in variety and their response to different climatic conditions. The two sweetpotato varieties produced higher unmarketable root weight during the major season compared with the minor season, 2011. The excessively high rainfall coupled with low temperature experienced during the major season might have affected the root size. This result is similar to those found by [30] and [31] that sweetpotato is intolerant to high rainfall that may result in water logging, especially during tuber initiation, but the crop is at times tolerant to drought. There was no significant difference between the amended and the control plots in unmarketable root weight during the minor season, 2011. However, there was a significant difference between the amended and the control plots in unmarketable root weight during the major season (Table 5). The initial high rainfall coupled with early release of available nutrients from the amended treatments during the major season might explain the significant difference between the fertilizer rates in unmarketable root weight. The application of 30-60- 60 kg/ha NPK differed significantly from the control in unmarketable root weight during the major season. This might be due to differences in soil fertility. [32] reported that rich, heavy soils produce high yields of low quality roots. The amended plots except 30-30-30 kg/ha NPK plot produced higher unmarketable root weight during the major season compared with the minor season. This might be due to differences in soil fertility and climatic conditions. Variety by fertilizer interaction did not influence the marketable root weight per plot during the minor season. However, there was a significant difference between variety by fertilizer interaction in marketable root weight during the major season (Table 5).

3.7 Average Weight per Root

There was a significant difference between *Apomuden* and *Okumkom* in average root weight in both growing seasons (Table 6). The significant difference might be due to differences in cultivar. There was a significant difference between chicken manure and inorganic fertilizer applied either singly or in combination and the control in average root weight in both seasons. The significant difference might be due to difference in soil fertility and climatic conditions. The application of 15-30-30 kg/ha NPK+ 5 t/ha CM during the major season produced significantly higher average root weight than the control (Table 6). The application of amended and the control plots during the major season produced higher average root weight than during the minor season. This might be due to differences in soil fertility and climatic condition.

3.8 Total Root Weight per Plant

There was a significant difference between *Apomuden* and *Okumkom* in total root weight per plant in both seasons (Table 6). The significant difference might be due to differences in cultivar. There was no significant difference between the amended and the control plots in total root weight per plant during the minor season. There was a significant difference between the amended and the control plots in total root weight per plant during the major season. This might be due to differences in soil fertility. The application of 15-30-30 kg/ha NPK+ 5 t/ha CM during the major season produced significantly higher total root weight per plant than the control (Table 6). The application of amended treatments during the major season produced higher total root weight per plant than during the minor season. The significant decrease in total root weight during the minor cropping season could be due to high temperature experienced during the growing period. High temperature affects photosynthates availability through enhanced leaf senescence. Differences in vegetative growth and soil fertility experienced during the cropping period might have also decreased total root weight per plant.

3.9 Root Dry Matter Accumulation

There was no significant difference between *Apomuden* and *Okumkom* in root dry matter accumulation in both seasons (Table 7).

Table 6. Average root weight and total root weight as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

Treatments	Average root weight (kg)		Total root weight per plant (kg/ha)	
	Minor season	Major season	Minor season	Major season
Variety				
Apomuden	0.23	0.37	2922.0	6285.2
Okumkom	0.18	0.23	2177.2	4094.3
LSD (0.05) Variety	0.04*	0.06*	546.5*	1198.9*
Fertilizer rates/types				
10t/ha CM	0.19	0.29	1757.2	4667.0
15-15-15 kg/ha NPK+ 5t/ha CM	0.19	0.27	2229.1	5111.2
15-23-23 kg/ha NPK + 5t/ha CM	0.21	0.30	2855.2	6708.0
15-30-30 kg/ha NPK + 5t/ha CM	0.21	0.37	2576.3	7153.0
30-30-30 kg/ha NPK	0.19	0.31	2457.2	4806.3
30-45-45 kg/ha NPK	0.23	0.31	2985.0	4583.2
30-60-60 kg/ha NPK	0.20	0.33	2794.4	6292.4
No fertilizer (control)	0.21	0.23	2743.1	2194.0
LSD (0.05) Fertilizer	0.04*	0.06*	1092.9ns	2397.7*
LSD (0.05) Var. x Fert.	NS	NS	1545.6ns	3390.9*
CV (%)	32.5	31.1	42.6	39.2

**= significant at 5% probability level, NS= Not significant*

The non-significant difference between *Apomuden* and *Okumkom* might be due to the inherent characteristics of the cultivars and their response to climatic condition. There was no significant difference between *Apomuden* and *Okumkom* grown under amended and the control plots in root dry matter accumulation during the minor season. There was a significant difference between *Apomuden* and *Okumkom* grown under amended and the control in root dry matter accumulation during the major season. *Apomuden* grown under 15–30–30 kg/ha NPK +5 t/ha CM differed significantly from the control in dry matter accumulation during the major season. *Okumkom* grown under 15–23–23 kg/ha NPK+5t/ha CM differed significantly from the control in root dry matter accumulation during the major season (Table 7). The relatively high soil fertility status, especially the organic matter in manured plots coupled with initial high rainfall might have accounted for higher dry matter accumulation in cultivars grown on both organic and inorganic fertilizer and during the major season than the control plot. The beneficial effect of organic manure on dry matter accumulation might be due to increase in organic matter rate caused by the generation of carbon dioxide during manure decomposition and improvement of the soil structure conditions which encouraged the plant to have a good root development [33]. This indicates the need for supplementary irrigation at the early growth stage, especially at the root formation stage during drought periods. According to [22] sweetpotatoes need uniform irrigation water per week for normal growth, especially during transplant establishment and root development. [28] also indicated that the growth potential of sweetpotato and for that matter differences in dry weight depend on cultivar and environment. Generally, the high percentage crop establishment coupled with increased vine diameter and vine length in amended plots during the major season compared with the minor season might have contributed to the high root dry matter accumulation.

3.10 Root Quality of Sweetpotato at Harvest

3.10.1 Percentage cracked and forked roots

There was no significant difference between *Apomuden* and *Okumkom* grown under amended and the control plots in root crack in both seasons (Table 8). The non-significant difference between the two varieties might be due to inherent characteristics of the varieties and their response to soil nutrient and climatic conditions. *Apomuden* and *Okumkom* grown on amended and control plots produced higher root crack during the major season than in the minor season (Table 8). This might be due to the slow and effective release of N, especially from amended plots coupled with high total monthly rainfall values during the major cropping period. According to [34] excessive amounts of N may encourage excessive vine growth and result in cracked and poor storage quality. [22] reported that over watering of sweetpotato late in the cropping season may cause the root to crack.

There was a significant difference between *Okumkom* and *Apomuden* grown on amended and control plots in forked roots in both seasons (Table 8). The significant difference between the varieties in forked roots might be due to differences in genetic composition of the sweetpotato varieties. There was no significant difference between the amended and the control plots in forked root in both growing seasons although *Okumkom* grown on 15 – 15 – 15 kg/ha NPK+ 5 t/ha CM had the highest forked roots in both seasons. The organic and inorganic fertilizer input in terms of high N from chicken manure in the soil might have accounted for this result obtained. According to [34], excessive amounts of N may cause excessive vine growth, misshapen roots and poor storage quality. Higher number of forked roots was produced during the minor season by both varieties planted on amended and control plots than during the major season. This might be due to difference in climatic conditions and soil nutrient levels, especially nitrogen [34].

3.10.2 Percentage pest infested root

The level of pest infestation at harvest of *Apomuden* grown on amended and control plots was more severe and differed significantly from *Okumkom* in both seasons (Table 9). This might be due to differences in variety, cultural and environmental adaptation. The level of pest infestation of *Apomuden* and *Okumkom* grown on amended and control plots at harvest during the minor season was higher than during the major season except for *Apomuden* grown on 15 – 30 – 30 kg/ha NPK + 5 t/ha CM plot (Table 9). Although the total monthly rainfall values were high during the initial cropping period during the minor season the intermittent long periods of drought coupled with high temperature during root development might have resulted in high incidence of pest infestation during the minor season. [35] reported that weevil attack is most serious when drought persists for a long time, more especially in the minor season and also wet and warm conditions increase the likelihood of serious pest infestations.

3.10.3 Changes in starch and sugar content in two varieties of sweetpotato roots at harvest

Results in both seasons elicit significant effect of the chicken manure and inorganic fertilizer either alone or in combination on sugar content of root for both varieties at harvest (Table 10). The significant difference in sugar content on both varieties and for the two cropping seasons might be explained in terms of differences in cultivar and climatic variations during the cropping season. *Apomuden* grown on 15-23-23 kg/ha NPK + 5 t/ha CM differed significantly from the control in sugar content of root at harvest during the minor season while in the same season *Okumkom* grown on 10 t/ha CM differed significantly from the control in sugar content of root at harvest. *Apomuden* and *Okumkom* grown on amended and the control plots produced higher sugar content of root at harvest during the minor season than in the major season (Table 10). The relatively high total maximum temperature values during the minor cropping season compared with the major season might have resulted in the high root sugar content at harvest. The high organic carbon content of the soil from the minor season site implies a higher capacity for the synthesis of carbon and subsequently sugar in both varieties.

There was a significant difference between *Okumkom* and *Apomuden* in starch content of root at harvest during the minor season. This might be due to differences in variety. There was no significant difference between *Okumkom* and *Apomuden* grown on amended and the control plots in starch content of root at harvest during the major season. *Okumkom* grown on amended and the control plots produced higher starch content of root at harvest than *Apomuden* in both seasons. This might be due to differences in cultivar and their responses to soil nutrient for the formation of starch during root bulking. *Okumkom* grown on 30-45-45 kg/ha NPK and 30-60-60 kg/ha NPK produced higher sugar and starch contents of root at harvest than the other amended treatments during the major season (Table 10).

Table 7. Root dry matter accumulation at harvest as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

Treatments	Root dry matter accumulation at harvest (kg) minor season		Mean	Root dry matter accumulation at harvest (kg) major season		Mean
	Apom.	Okum.		Apom.	Okum.	
Fertilizer rates						
10t/ha CM	0.74	0.76	0.75	1.71	1.12	1.41
30-30-30 kg/ha NPK	1.11	0.72	0.91	1.28	1.57	1.43
15-15-15 kg/ha NPK + 5 t/ha CM	1.10	0.72	0.91	1.80	0.86	1.33
15-23-23 kg/ha NPK + 5 t/ha CM	1.21	1.36	1.29	1.92	2.63	2.27
15-30-30 kg/ha NPK + 5 t/ha CM	1.09	1.17	1.13	3.08	1.51	2.29
30-45-45 kg/ha NPK	1.21	4.81	3.01	1.83	1.32	1.57
30-60-60 kg/ha NPK	1.11	1.07	1.09	1.53	1.97	1.75
No fertilizer (control)	1.24	1.43	1.34	0.55	0.71	0.63
Mean	1.10	1.51		1.71	1.46	
LSD (0.05) Variety	NS			NS		
LSD (0.05) Fertilizer	NS			0.85*		
LSD (0.05) Variety x Fertilizer	NS			NS		
CV (%)	38.1			34.8		

**= significant at 5% probability level, NS= not significant*

Table 8. Percentage cracked and forked roots as influenced by chicken manure and inorganic fertilizer during the minor season, 2011, 2011 and the major season, 2012

	Percentage cracked roots (%)-minor season		Mean	Percentage cracked root (%) –major season		Mean	Percentage forked roots (%)-minor season		Mean	Percentage forked roots (%)- major season		Mean
	Apom.	Okum.		Apom.	Okum.		Apom.	Okum.		Apom.	Okum.	
Fertilizer rate												
10t/ha CM	4.4	8.1	6.3	13.55	13.59	13.57	14.4	21.4	17.9	0.0	2.99	1.50
30-30-30 kg/ha NPK	2.8	3.0	2.9	14.70	12.04	13.37	14.7	23.0	18.8	0.0	7.73	3.86
15-15-15 kg/ha NPK + 5 t/ha CM	9.7	8.9	9.3	7.51	11.42	9.47	18.7	28.8	23.8	2.30	13.69	8.00
30-45-45 kg/ha NPK	5.8	9.7	7.7	12.44	6.44	9.44	19.2	20.4	19.8	0.0	8.49	4.25
15-23-23 kg/ha NPK + 5 t/ha CM	5.1	5.3	5.2	11.39	7.64	9.52	19.0	23.3	21.1	6.47	8.30	7.38
30-60-60 kg/ha NPK	7.1	2.3	4.7	12.59	9.80	11.19	15.9	26.7	21.3	0.0	4.43	2.21
15-30-30 kg/ha NPK + 5 t/ha CM	3.2	0.0	1.6	16.78	11.76	14.27	17.0	23.3	20.2	3.03	2.84	2.94
No fertilizer (control)	0.0	7.5	3.8	8.66	11.05	9.86	17.5	18.6	18.1	0.0	13.46	6.73
Mean	4.8	5.6		12.20	10.47		17.0	23.2		1.48	7.74	
LSD (0.05) Variety	NS			NS			3.74*			2.95*		
LSD (0.05) Fertilizer	NS			NS			N S			NS		
LSD (0.05) Variety x Fertilizer	NS			NS			NS			NS		
CV (%)	39.4			37.2			36.9			38.4		

**= significant at 5% probability level, NS= not significant*

Table 9. Percentage pest infested roots at harvest as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

	Percentage pest infested root at harvest (%)-minor season		Mean	Percentage pest infested root at harvest (%)-major season		Mean
	Apom.	Okum.		Apom.	Okum.	
Fertilizer rate						
10t/ha CM	24.1	9.7	16.9	14.3	5.3	9.8
15-15-15 kg/ha NPK + 5 t/ha CM	28.3	14.4	21.3	23.8	15.2	19.5
15-23-23 kg/ha NPK + 5 t/ha CM	37.4	17.4	27.4	24.9	9.2	17.0
15-30-30 kg/ha NPK + 5 t/ha CM	20.1	12.1	16.1	25.6	11.5	18.5
30-30-30 kg/ha NPK	29.6	16.0	22.8	14.7	6.1	10.4
30-45-45 kg/ha NPK	30.1	16.9	23.5	21.4	5.8	13.6
30-60-60 kg/ha NPK	27.4	15.7	21.6	21.6	9.6	15.6
No fertilizer (control)	28.8	11.2	20.0	18.2	5.0	11.6
Mean	28.2	14.2		20.6	8.5	

	Percentage pest infested root at harvest (%)-minor season		Mean	Percentage pest infested root at harvest (%)-major season		Mean
	Apom.	Okum.		Apom.	Okum.	
LSD (0.05) Variety	5.94*			5.22*		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety x Fertilizer	NS			NS		
CV (%)	28.7			31.0		

**= significant at 5% probability level, NS= not significant*

Table 10. Percentage sugar and starch content of roots at harvest as influenced by chicken manure and inorganic fertilizers during the minor season, 2011 and the major season, 2012

	Percentage Sugar of root at harvest (%)-minor season		Mean	Percentage Sugar of root at harvest (%)-major season		Mean	Percentage Starch of root at harvest (%)-minor season		Mean	Percentage Starch of root at harvest (%)-major season		Mean
	Apom.	Okum.		Apom.	Okum.		Apom.	Okum.		Apom.	Okum.	
Fertilizer rate												
10t/ha CM	11.7	24.5	18.1	8.0	11.0	9.5	13.3	27.9	20.6	9.6	12.4	11.0
15-15-15 kg/ha NPK + 5t/ha CM	12.1	19.0	15.5	11.0	11.5	11.2	14.3	21.6	17.9	12.0	13.0	12.5
15-23-23 kg/ha NPK + 5t/ha CM	13.5	18.5	16.0	9.7	11.7	10.7	14.9	20.9	17.9	10.8	13.2	12.0
15-30-30 kg/ha NPK + 5t/ha CM	13.0	16.5	14.7	10.7	11.0	10.8	14.9	18.6	16.7	12.0	12.4	12.2
30-30-30 kg/ha NPK	10.5	17.7	14.1	10.0	12.0	11.0	11.9	20.4	16.1	12.0	13.7	12.8
30-45-45 kg/ha NPK	10.0	20.0	15.0	11.7	12.0	11.8	11.2	23.2	17.2	13.2	13.8	13.5
30-60-60 kg/ha NPK	11.0	23.0	17.0	10.0	12.0	11.0	13.2	25.7	19.4	11.0	13.8	12.4
No fertilizer (control)	12.1	17.0	14.5	9.7	11.7	10.7	16.8	19.6	18.2	10.8	13.2	12.0
Mean	11.7	19.5		10.1	11.6		13.8	22.2		11.4	13.1	
LSD (0.05) Variety	0.08*			0.43*			0.17*			NS		
LSD (0.05) Fertilizer	0.17*			0.86*			0.34*			NS		
LSD (0.05) Variety x Fertilizer	0.24*			1.21*			0.48*			NS		
CV (%)	5.1			6.7			5.9			4.7		

**= significant at 5% probability level, NS= not significant*

Table 11. Percentage starch content of roots 12 weeks under pit or ash storage as influenced by chicken manure and inorganic fertilizers during the minor season, 2011 and the major season, 2012

	Percentage Starch of root12 weeks in storage (%)-(Pit)-, minor season		Mean	Percentage starch of root 12 weeks in storage (%)-(Pit)- major season		Mean	Percentage starch of root 12 weeks in storage (%)-(Ash) major season		Mean
	Apom.	**Okum.**		**Apom.**	**Okum.**		**Apom.**	**Okum.**	
Fertilizer rate									
10 t/ha CM	10.8	15.6	13.2	12.0	13.0	12.5	0.0	0.0	0.0
15-15-15 kg/ha NPK + 5 t/ha CM	10.8	12.0	11.4	11.7	13.2	12.4	0.0	0.0	0.0
15-23-23 kg/ha NPK + 5 t/ha CM	9.0	13.6	11.3	11.0	13.4	12.2	11.7	0.0	5.8
15-30-30 kg/ha NPK + 5 t/ha CM	11.5	0.0	5.7	11.0	12.0	11.5	0.0	0.0	0.0
30-30-30 kg/ha NPK	0.0	0.0	0.0	11.0	0.0	5.5	0.0	13.2	6.6
30-45-45 kg/ha NPK	10.4	0.0	5.2	13.2	13.8	13.5	0.0	14.0	7.0
30-60-60 kg/ha NPK	0.0	0.0	0.0	11.0	0.0	5.5	0.0	13.8	6.9
No fertilizer (control)	11.5	0.0	5.7	11.0	12.0	11.5	0.0	0.0	0.0
Mean	8.0	5.1		11.49	9.67		1.46	5.12	
LSD (0.05) Variety	0.60*			0.45*			0.14*		
LSD (0.05) Fertilizer	1.21*			0.91*			0.29*		
LSD (0.05) Variety x Fertilizer	1.72*			1.29*			0.42*		
CV (%)	7.3			4.7			7.7		

**=* *significant at 5% probability level, NS= not significant*

3.10.4 Starch content of roots at 12 weeks under pit, ash or grass storage

Results in both seasons elicit significant effect of the chicken manure and inorganic fertilizer either alone or in combination on starch content of root for both varieties at 12 weeks under pit and ash storage (Table 11). *Apomuden* and *Okumkom grown* under 30- 45-45 kg/ha NPK and stored in pit had the highest root starch content during the major season compared with the minor season (Table 11). The increased starch content in both varieties under 30-45-45 kg/ha NPK and stored in pit during the major season might probably be due to high moisture level coupled with relatively low temperature under the pit during the major season as well as the influenced of P and K in the chicken manure applied during crop cultivation. Starch synthesis increased with increasing K concentration up to an optimum root concentration of 1.8%. [22] indicated that P tends to increase starch synthesis and hasten maturity. *Okumkom* grown on 30-45-45 kg/ha NPK and stored in ash gave higher starch content than the other amended treatments and the *Apomuden* on the same treatment. Generally, *Apomuden* and *Okumkom* stored in pit showed the most effective storage method with regard to its ability to store well followed by ash and grass storage at 12 weeks in storage in both seasons. The inability of root to store well under grass storage conditions might probably be due to high temperatures in the storage conditions during storage. [36] indicated that post-harvest physiological processes that may affect storability include evaporation of water from the product, changes in chemical composition, and damage by extreme temperatures. *Okumkom* and *Apomuden* grown on amended and control plots and stored in pit for 12 weeks for both seasons had a low starch content compared with the starch level at harvest (Tables 10 and 11). The high respiration rate due to long term storage condition for roots of both varieties stored in pit probably might have contributed to this result. Starch content of roots tends to reduce during long term storage as a result of high respiration rate. This is in conformity with [37] who found that respiration and transpiration contribute to weight loss and alteration of internal and external appearance of potatoes, because starch is used as a respiratory substrate, the starch content decreased during storage and subsequent the dry matter also decreased.

3.10.5 Sugar content of roots at 12 weeks under pit, ash or grass storage

Results in both seasons elicit significant effect of the chicken manure and inorganic fertilizer either alone or in combination on sugar content of root for both varieties at 12 weeks under pit and ash storage (Table 12). *Okumkom* grown under 15-23-23 kg/ha NPK + 5t/ha CM and stored in pit had higher sugar content than *Apomuden* grown on amended treatments at 12 weeks in storage during the minor season (Table 12). The significant increase in sugar content in *Okumkom* than *Apomuden* might be due to differences in cultivar and their ability to respond to compositional change based on manure treatment and storage condition. *Okumkom* grown under 30-45-45 kg/ha NPK and stored in pit had higher sugar content during the major season compared with the minor season. The high relative humidity and water content in root coupled with low temperature in the pit during the major season storage period might have accounted for the results obtained. According to [38] higher humidity during long-term storage is likely and that the extent of enzyme amylase activity depends on temperature and root water content. *Okumkom* grown on 30-45-45 kg/ha NPK and stored in ash gave higher sugar content than the other amended treatments and stored in pit although roots stored in ash did not store well at 12 weeks in storage (Table 12). Generally, pit storage was the most effective storage method followed by ash with grass storage being the least in root sugar content for both cultivars at 12 weeks in storage in both seasons. [39] indicated that if quality of the stored crop and weight variation of roots is considered then the use of soil banks (pit) is the most effective compared with ash and grass.

Table 12. Percentage sugar content of roots 12 weeks under pit and ash storage as influenced by chicken manure and inorganic fertilizer during the minor season, 2011 and the major season, 2012

	Percentage sugar of root at12 WAS -(Pit) (minor season)		Mean	Percentage sugar of root at12 WAS- (Pit) (major season)		Mean	Percentage Sugar of root at12 WAS- (Ash)(major season)		Mean
	Apom.	Okum.		Apom	Okum.		Apom	Okum	
Fertilizer rate									
10 t/ha CM	9.6	14.2	11.9	11.0	11.6	11.3	0.0	0.0	0.0
15-15-15 kg/ha NPK + 5 t/ha CM	9.7	11.0	10.3	10.5	11.7	11.1	0.0	0.0	0.0
15-23-23 kg/ha NPK + 5 t/ha CM	8.2	13.0	10.6	10.0	11.8	10.9	0.0	0.0	0.0
15-30-30 kg/ha NPK + 5 t/ha CM	10.0	0.0	5.0	10.0	11.0	10.5	0.0	0.0	0.0
30-30-30 kg/ha NPK	0.0	0.0	0.0	10.0	0.0	5.0	0.0	11.7	5.8
30-45-45 kg/ha NPK	9.3	0.0	4.6	11.7	12.0	11.8	0.0	12.1	6.0
30-60-60 kg/ha NPK	0.0	0.0	0.0	10.0	0.0	5.0	0.0	12.0	6.0
No fertilizer (control)	10.2	0.0	5.1	10.0	11.0	10.5	0.0	0.0	0.0
Mean	7.1	4.7		10.4	8.6		0.0	1.31	
LSD (0.05) Variety	0.58*			0.41*			0.14 *		
LSD (0.05) Fertilizer	1.16*			0.82*			0.29 *		
LSD (0.05) Variety x Fertilizer	1.64*			1.16*			0.42*		
CV (%)	7.4			6.5			8.7		

**= significant at 5% probability level, NS= not significant*

4. CONCLUSION

For farmers to appreciate the benefits of amendment *Apomuden* should be grown on 15-15-15 kg/ha NPK+ 5t/ha CM and 15-30-30 kg/ha NPK + 5 t/ha CM for thicker vine diameter and dry matter accumulation respectively during the major season. For longer vine length *Okumkom* should be grown on 30-30-30 kg/ha NPK during the major season. Farmers should apply 15-30-30 kg/ha NPK+ 5 t/ha CM during the major season for higher sweetpotato average root weight, total root weight per plant and marketable root weight. *Okumkom* grown on 15-15-15 kg/ha NPK+ 5 t/ha CM plot produced higher forked roots at harvest in both seasons. For reduced number of pest infestation on sweetpotato, farmers should grow *Apomuden* and *Okumkom* on amended and control plots during the major season than during the minor season.

For higher sugar content of root at harvest farmers are to grow *Apomuden* on 15-23-23 kg/ha NPK + 5 t/ha CM and *Okumkom* on 10 t/ha CM during the minor season. Farmers are to grow *Okumkom* on 30-45-45 kg/ha NPK and 30-60-60 kg/ha NPK treatments for higher sugar and starch contents of root at harvest during the major season. This suggests the influence of variety and nutrient supply on sugar and starch production in sweetpotato. For higher starch content in root, farmers should grow *Apomuden* and *Okumkom* on 30- 45-45 kg/ha NPK and also store in pit during the major season. For better storage of sweetpotato root with high sugar and starch content farmers should grow *Okumkom* on 15-23-23 kg/ha NPK + 5 t/ha CM and 30-45-45 kg/ha NPK and store roots in pit. In the case of ash storage farmers should grow *Okumkom on* 30-45-45 kg/ha NPK for better storage and also provide high sugar and starch content in root.

ACKNOWLEDGEMENTS

The authors are most grateful to the Management of the University of Education, Winneba, Mampong-Ashanti Campus, Crop research institute and soil research institute of CSIR and Physical Laboratory in the Chemistry Department of the Kwame Nkrumah University of Science and Technology all in Kumasi for the provision of land and chicken manure from the animal farm, planting materials, and analyses of the soil, manure samples and starch and sugar respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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