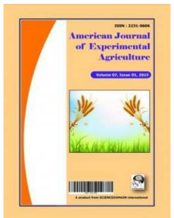

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Growth and Yield of Sweetpotato (*Ipomoea batatas* [L.] Lam) as Influenced by Chicken Manure and Inorganic Fertilizers

M. E. Essilfie[1*], J. Ofosu-Anim[2], K. H. Dapaah[1], J. C. Norman[2] and E. T. Blay[2]

[1]Department of Crop and Soil Sciences Education, Faculty of Agriculture Education, University of Education, Winneba, Mampong-Ashanti, Ghana.
[2]Department of Crop Science, University of Ghana, Legon, Ghana.

Authors' contributions

This work was carried out in collaboration between all authors. Author KHD 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.

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ABSTRACT

Aims: To assess the growth, yield and yield components of two varieties of sweetpotato as influenced by chicken manure and inorganic fertilizers.
Study Design: The experimental design was a 2 x 8 factorial arranged in randomized complete block design with four replicates for both seasons.
Place and Duration of Study: Field experiments were conducted at the multipurpose crop nursery of the University of Education, Winneba, Mampong-Ashanti from September, 2011 to January, 2012 (minor season) and from April to August, 2012 (major season).
Methodology: Two sweetpotato varieties (*Okumkom* and *Apomuden*) and eight fertilizer treatments [(i) 10 t ha^{-1} chicken manure (CM), (ii) 30-30-30 kg/ha NPK, (iii) 15-15-15 kg/ha NPK +

**Corresponding author: E-mail: maggifremp@yahoo.co.uk;*

5 t ha^{-1} CM, (iv) 30-45-45 kg/ha NPK, (v) 15-23-23 kg/ha NPK + 5 t ha^{-1} CM, (vi) 30-60-60 kg/ha NPK, (vii) 15-30-30 kg/ha NPK + 5 t ha^{-1} CM and (viii) No fertilizer (control)] were studied.

Results: *Okumkom* differed significantly from *Apomuden* in number of leaves per plant, number of branches and vine fresh weight in both seasons. *Apomuden* grown on 30 45-45 kg/ha NPK and 30-30-30 kg/ha NPK produced significantly higher number of marketable tubers and total tuber yield during the minor season. Tuber length and number of marketable tubers of *Apomuden* was significantly influenced by the application of 15 – 30 – 30 kg/ha NPK + 5 t ha^{-1} CM during the major season. Correlation analyses in both seasons show that the vegetative characters were significantly and positively correlated. On the other hand, number of leaves per plant was negatively correlated to the total tuber weight, marketable tuber number and marketable tuber weight.

Conclusion: Farmers are encouraged to grow *Apomuden* on 15-30-30 kg/ha NPK + 5 t ha^{-1} CM for high marketable tuber number in both seasons. For high vegetative biomass as fodder for animals farmers are to grow *Okumkom* in both seasons.

Keywords: Sweetpotato; Apomuden; Okumkom; chicken manure; inorganic fertilizer.

1. INTRODUCTION

Sweetpotato (*Ipomoea batatas* [L.] Lam), is an important and popular staple food grown in Ghana and many parts of West and East African countries [1]. Sweetpotato is grown, especially by women for daily family consumption and for sale by the poorest among African communities [2,3]. However, the inherent low soil fertility is a major constraint to its sustainable production. Sweetpotato responds to phosphorus and potassium application under most conditions though the response rate and hence optimum dose varies with the variety and soil types [4]. The use of both organic and mineral fertilizers is often limited and this has resulted in a gradual depletion of soil nutrients in sub-Saharan Africa [4]. Cowdung and chicken manures are the two suitable manures, but it is not possible to meet the nutritional requirements from the organic sources only. The potentialities of organic source are very limited to afford higher crop production due to slow release of plant nutrients from organic matter [5]. This may be a concern for fertility maintenance but is obviously a barrier for higher plant nutrition uptake. To overcome this problem, application of organic manure in combination with inorganic fertilizers can play important role in sweetpotato cultivation. Integrated nutrient use has assumed great significance in vegetable as well as tuber crop production. This practice sustains the productivity of soils under highly intensive cropping systems [6]. Moreover, the application of organic matter as a source of some portion of required nutrients will have positive impact on soil physical and chemical properties which ultimately will increase the productivity.

Chicken manure is a rich source of nitrogen, phosphorus, organic carbon and exchangeable Ca and Mg [7]. Appropriate application of chicken manure improves both the physical and chemical properties of the soil. Physically, it improves the condition of both light and heavy soils which enhance aeration, ease of seed bed preparation, rapid seed germination, better water-holding capacity, soil microbial activity, water infiltration and structural stability of the soil [8]. Chicken manure helps to correct Zn and Fe deficiencies in the soils and supplements NPK fertilizers in crop production. Successful cultivation of sweetpotato depends heavily on the use of fertilizers, organic manure and their efficient management. It is a heavy feeder hence fertilization with the three major nutrients; nitrogen, phosphate and potassium is therefore indispensable [9]. One approach to improve soil fertility, hence increased tuber yield and market quality is to improve the fertility of the soil through good management of potassium and phosphorus and adding organic manure. This study was conducted to verify the effect of chicken manure and inorganic fertilizer either singly or in combination for sweetpotato production.

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 August, 2012, respectively. The soil type is the savanna ochrosol formed from the

Voltaian sandstone of the Afram plains. Texturally, the soil is friable with a thin layer of organic matter and is deep and brown-sandy loam and well-drained. It however has a good water-holding capacity. The soil has been classified by FAO / UNESCO legend as Chronic Luvisol and locally as the Bediesi series with a pH range of 4.0-6.5 [10].

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 during 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 [11]. 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 from September to November with one month dry spell in August [12].

2.2 Soil and Manure Analyses

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. The decomposed and dried chicken manure was applied and worked into the soil two weeks before planting of vines. 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 [13] and total nitrogen was determined by the micro Kjeldahl method [14]. The available phosphorus was extracted by the Bray's method and exchangeable cations were determined by flame emission photometry [15].

2.3 Experimental Design and Planting

The experimental design was a 2 x 8 factorial arranged in randomized complete block design (RCBD) with four replicates made up of eight organic manure and fertilizer rates and two sweetpotato varieties was assigned to each block. The two sweetpotato varieties (*Okumkom* and *Apomuden*) were grown under eight fertilizer treatments [(i) 10 t ha^{-1} chicken manure (CM), (ii) 30-30-30 kg/ha NPK, (iii) 15-15-15 kg/ha NPK + 5 t ha^{-1} CM, (iv) 30-45-45 kg/ha NPK, (v) 15-23-23 kg/ha NPK + 5 t ha^{-1} CM, (vi) 30-60-60 kg/ha NPK, (vii) 15-30-30 kg/ha NPK + 5 t ha^{-1} CM and (viii) No fertilizer (control)]. 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. 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.

2.4 Data Collection and Analysis

Number of leaves per plant and branches were counted on five plants from the two central rows while three plants were randomly sampled for dry matter accumulation and leaf chlorophyll content. The leaf chlorophyll content was measured using a Fieldscout CM 100 chlorophyll meter (Spectrum Technologies Inc.). Data were collected at four weeks after planting and at two weeks interval. Fresh vine weight at harvest, number of marketable and unmarketable tubers, total tuber yield and yield component including tuber length were estimated from the two central rows. Data analysis was done using analysis of variance and GenStat statistical package [16].

Least significant difference (LSD) was used to separate means at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Soil Nutrients Levels after Application of Chicken Manure and Inorganic Fertilizers during the Minor (2011) and Major Rainy Seasons (2012)

Initial effects of manure application on some soil physical and chemical properties at the minor season, 2011 experimental site are shown in Table 1. Both the untreated soil (no- manure) and manure supplemented soils fell within the sandy loam textural range 10 t ha^{-1} chicken manure supplemented soil gave 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 gave an acidic pH (5.44 and 5.77); however, 10 t ha^{-1} chicken manure supplemented soil gave a slightly acidic pH (6.45).

Initial effects of manure application on some soil physical and chemical properties at the major season, 2012 experimental site are shown in Table 2. The soil and manure supplemented soil for initial analysis fell within the sandy loam textural range. The soil analysis for the untreated soil was neutral (6.73), inorganic fertilizer + soil was acidic (5.42) and chicken manure + soil and the manure + inorganic fertilizer + soil was slightly acidic (6.19, 6.02) for the top soil. Organic matter content was low to moderate and the total nitrogen levels were moderate. Exchangeable calcium and magnesium levels were low to moderate at the initial soil nutrient analysis. Application of chicken manure and inorganic fertilizer increased organic manure moderately in the different treatments in both seasons.

Table 1. Physico-chemical properties of soil and soil plus manure Ap horizon at 0-20 cm depth of plots for the minor season (2011)

	Value			
Property	**Untreated soil (control)**	**Inorganic fertilizer + Soil**	**10 t ha^{-1} chicken manure + Soil**	**5 t ha^{-1} chicken manure + Inorganic fertilizer + Soil**
Sand (%)	66.49	68.78	66.86	65.93
Silt (%)	27.51	27.22	25.14	26.07
Clay (%)	6.00	4.00	8.00	8.00
Organic carbon (%)	1.06	1.07	1.26	1.14
Total nitrogen (%)	0.13	0.14	0.17	0.15
Organic matter (%)	1.83	1.84	2.17	1.97
pH (1:1 H_2O)	5.44	5.44	6.45	5.77
Available P (ppm)	38.02	1018.78	334.04	436.10
Available K (ppm)	73.65	503.78	113.83	177.44
Bulk density (g/cm^3)	1.49	1.51	1.67	1.51
Exchangeable cations				
Ca^{2+} (mg/100 g)	2.49	2.97	12.80	6.14
Mg^{2+}(mg/100 g)	2.94	2.94	6.74	2.14
K^+ (mg/100 g)	0.35	1.34	0.48	0.67
Na^+ (mg/100 g)	0.13	0.13	0.17	0.18
Total exchangeable bases	6.36	7.38	20.19	9.13
Effective cation Exchange capacity (E.C.E.C) Me/100 g	7.11	8.13	20.34	9.58
Exchangeable Aluminium (Al^+H)	0.75	0.15	0.15	0.45
Bases Saturation (%)	89.40	90.70	99.26	95.30

Table 2. Physico-chemical properties of soil and soil plus manure Ap horizon at 0-20 cm depth of plots for the major season (2012)

	Value			
Property	**Untreated soil (control)**	**Inorganic fertilizer + Soil**	**10 t ha^{-1} chicken manure +Soil**	**5 t ha^{-1} chicken manure + Inorganic fertilizer + Soil**
Sand (%)	75.80	59.90	70.80	66.90
Silt (%)	15.20	31.30	22.00	26.60
Clay (%)	9.00	8.80	7.20	6.50
Organic carbon (%)	1.21	1.00	0.92	1.07
Total nitrogen (%)	0.13	0.21	0.32	0.16
Organic matter (%)	2.09	1.72	1.59	1.85
pH (1:1 H_2O)	6.73	5.42	6.19	6.02
Available P (ppm)	153.87	439.29	285.42	692.82
Available K (ppm)	43.96	74.40	71.01	87.92
Bulk density (g/cm^3)	1.51	1.49	1.49	1.49
Exchangeable cations				
Ca(mg/100 g)	5.34	3.47	4.54	5.07
Mg	2.67	2.67	0.80	0.53
K	0.50	0.66	0.62	0.80
Na	0.17	0.222	0.21	0.25
Total Exchangeable bases	0.10	0.80	0.10	0.80
Effective cation Exchange capacity (E.C.E.C) Me/100 g	8.78	7.82	6.27	7.45
Exchangeable Aluminium (Al^+H)	8.68	7.02	6.17	6.65
Bases saturation (%)	98.86	89.77	98.41	89.26

Table 3. Mean squares of traits of two sweetpotato varieties as influenced by chicken manure and inorganic fertilizer during the minor season, 2011

Trait	**Mean squares**			
	Variety	**Fertilizer**	**Variety x fertilizer**	**Error**
Number of leaves per plant	1309766.1*	9942.2 (ns)	3905.2 (ns)	8751.3
Number of branches	1291.05*	23.32 (ns)	14.28 (ns)	17.3
Chlorophyll content of leaves	894075.4*	4196.1 (ns)	4343.2 (ns)	11525.0
Root dry weight	44520.3(ns)	9332.1 (ns)	16282.0 (ns)	17505.2
Vine dry weight	3443692.1(*)	230749.2 (ns)	247190.0 (ns)	305250.1
Total tuber weight	12.8*	1.842 (ns)	0.738 (ns)	1.696
Marketable tuber number	232.6*	43.4 (ns)	49.3 (ns)	51.30
Unmarketable tuber number	1040.1*	17.6 (ns)	21.2 (ns)	31.5
Tuber length	202.0*	3.6 (ns)	7.8 (ns)	8.7

3.2 Growth Performance

3.2.1 Number of leaves per plant

Okumkom differed significantly from *Apomuden* in number of leaves per plant for the entire growing period in both growing seasons (Fig. 1). The significant difference between *Okumkom* and *Apomuden* might be due to differences in variety. *Okumkom* can colonize or establish on marginal soils in spite of the prevailing climatic conditions of the growing area. It readily produces adventitious tubers, trailing vines and exhibits aggressive ground cover [17]. *Apomuden* and *Okumkom* grown on amended and the control plots did not differ significantly in number of leaves per plant from 4 to 12 weeks after planting (WAP) in both seasons. *Apomuden* and *Okumkom* grown on 10 t ha^{-1} CM produced the lowest number of leaves per plant from 8 to

12 WAP than the other amended and the control plots during the minor season (Fig. 1). This might be due to relatively low soil fertility status, especially exchangeable Ca and low effective cation exchange capacity (E.C.E.C) in chicken manure during the minor growing season that might have resulted in low plant growth and leaf appearance in 10 t ha^{-1} CM treatment. Calcium functions in plant as an essential part of plant cell structure, provides the normal transport and retention of other elements as well as strength in the plant. Generally, both varieties planted on amended and control plots during the major season produced significantly higher leaf numbers than during the minor season. This might be attributed to high rainfall that resulted in better soil moisture supply coupled with a relatively high soil N, especially at the early planting stage of sweetpotato during the major season leading to better nutrient availability. According to Maynard and Hill [18] excessive rain or nitrogen can lead to vigorous vine growth.

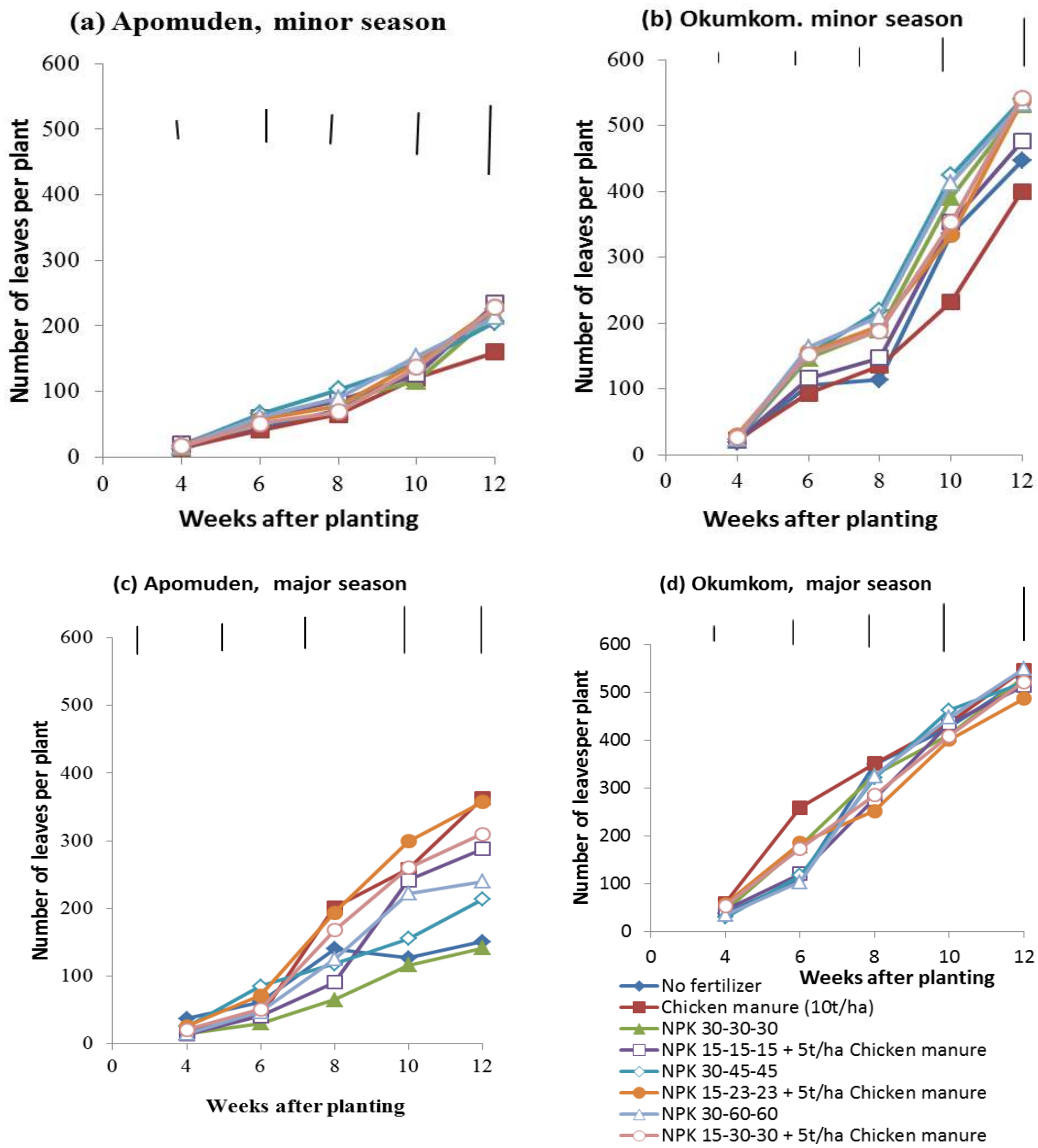

Fig. 1. Number of leaves per plant as influenced by chicken manure and inorganic fertilizer during the minor season (a, b) and major season (b, c)

3.2.2 Number of branches

There was a significant difference between *Okumkom* and *Apomuden* in number of branches from 4 to 12 WAP in both growing seasons (Fig. 2). The significant difference between *Okumkom* and *Apomuden* might be due to differences in variety. This result agrees with CRI [17]. *Apomuden* and *Okumkom* grown on amended and the control plots did not differ significantly in number of branches for the entire growing period in both growing seasons (Fig. 2). *Okumkom* grown on amended and control plots during the major season produced higher number of branches than those grown under the same treatments during the minor season at 12 WAP. This might be due to high rainfall during the major season coupled with slow and effective release of nutrients from the manure applied during the major season. Raemaekers [19] reported that vine growth habit of sweetpotato depends on variety and environment, particularly the climate of the growing area available to the plant and the plant's nutrition. The agrees with Hartemink et al*.* [20] and Hartemink et al*.* [21] that sweetpotato response to nutrient input was greatly affected by rainfall. *Apomuden* grown on 10 t ha^{-1} CM plot produced the lowest number of branches for the entire period during the minor season than those grown on the same treatment during the major season (Fig. 2). In spite of the initial higher rainfall experienced during the minor season compared with the major season, perhaps the initial relatively slow release of N in chicken manure as well as initial competition for nutrients by the soil microorganisms responsible for mineralization might have accounted for the least number of branches of *Apomuden* grown on 10 t ha^{-1} CM during the minor season. This result however, contradicts the report of Rice [22] that the use of well-rotted manure prior to planting and a pre-planting application of complete fertilizer are generally beneficial and required for good plant growth.

3.2.3 Chlorophyll content of sweetpotato leaves

Okumkom differed significantly from *Apomuden* in chlorophyll content of leaves from 8 to 16 WAP during the minor season. There was a significant difference between *Apomuden* and *Okumkom* in chlorophyll content of leaves at 8 and 16 WAP during the major season (Fig. 3). The significant difference between the two sweetpotato varieties in chlorophyll content of leaves might be due to differences in variety and their response to soil fertility and climatic conditions. Mascianica [23] and Walker [24] reported that plants need nitrogen for growth, reproduction and photosynthesis which depend directly on chlorophyll content of leaves. There was no significant difference between amended and the control plots in chlorophyll content of leaves for the entire period in both growing seasons. The non-significant difference between the two varieties in chlorophyll content of leaves might be due to the fact that sweetpotato does not depend on soil fertility but rather on variety. *Apomuden* grown on amended and the control plots at 8 WAP during the major season produced substantially higher chlorophyll content of leaves than those grown on the same treatments at the same period during the minor season (Fig. 3). This might be due to initial high rainfall experienced coupled with slow release of soil nutrients during the major season.

Table 4. Mean squares of traits of two sweetpotato varieties as influenced by chicken manure and inorganic fertilizer during the major season, 2012

Trait	Mean squares			
	Variety	**Fertilizer**	**Variety x fert.**	**Error**
Number of leaves per plant	84.2*	10291.2 (ns)	13043.0 (ns)	10171.1
Number of branches	12128.5*	75.4 (ns)	51.9 (ns)	35.5
Chlorophyll content of leaves	16738.0 (ns)	12256.2 (ns)	7438.1 (ns)	14026.4
Root dry weight	75843.1 (ns)	49148.2 (ns)	79763.4 (ns)	67873.0
Vine dry weight	990079.2*	94923.0 (ns)	103253.3 (ns)	91214.1
Total tuber weight	83.1*	21.2*	15.5*	5.955
Marketable tuber number	1419.2*	116.0 (ns)	132.1 (ns)	156.9
Unmarketable tuber number	808.5*	477.1*	451.5*	177.7
Tuber length	104.5*	5.3 (ns)	8.8*	3.2

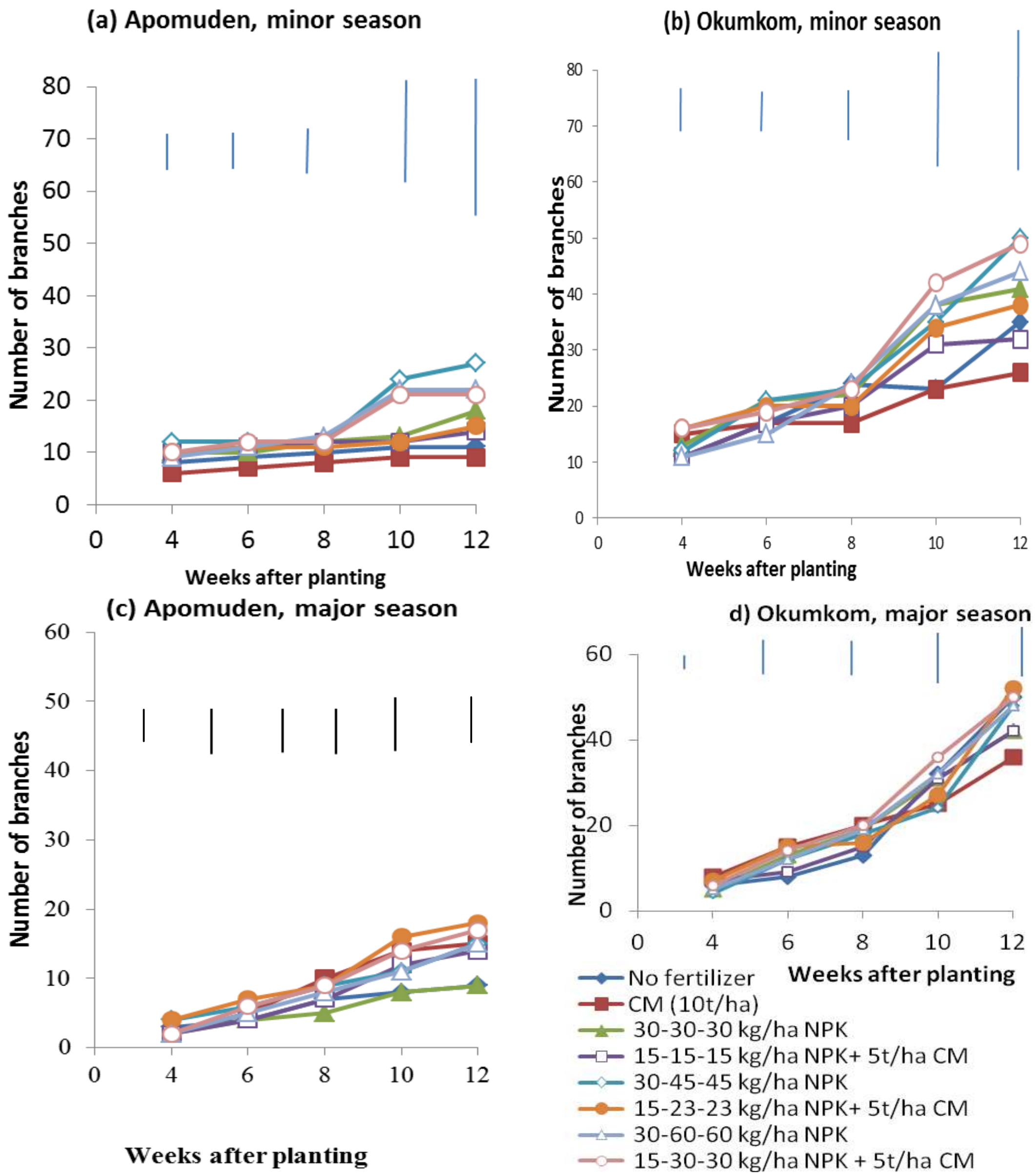

Fig. 2. Number of branches as influenced by chicken manure and inorganic fertilizer during the minor season (a, b) and the major season (c, d)

3.2.4 Mean root and vine dry weight gain

There was a significant difference between *Apomuden* and *Okumkom* in root dry weight from 10 to 12 WAP during the minor season (Fig. 4). This might be due to differences in variety. There was no significant difference between the two varieties in root dry weight from 4 to 12 WAP during the major season. Root dry weight for the entire growing period was not significantly influenced by amended and the control plots in both seasons. *Apomuden* and *Okumkom* grown on amended and the control plots for the entire growing period during the major season produced substantially higher root dry weight than those grown on the same treatments and at the same period during the minor season (Fig. 4). The low root dry weight during the minor season might be due to the low rainfall and high temperature experienced during the growing season. This agrees with Erickson [25] that high temperatures during the mid and late seasons cause extensive damage to root yields in many crops.

There was a significant difference between *Okumkom* and *Apomuden* in vine dry weight from 10 to 12 WAP during the major season. However, no significant difference was observed between the two varieties in vine dry weight during the minor season (Fig. 5). This might be due to differences in variety and climatic conditions. Vine dry weight for the two varieties from 4 to 12 WAP was not influenced by amended and the control treatments in both growing seasons although application of 30-30-30 kg/ha NPK to *Okumkom* produced higher vine dry weight at 10 WAP than the other amended plots during the minor season. *Okumkom* grown on amended and the control plots produced higher vine dry weight from 10 to 12 WAP during the minor season than in the major season (Fig. 5). This might be due to differences in variety and climatic conditions. The differences in growth potential of sweetpotato due to variety and climatic conditions have been reported to be essential for dry weight of plants [19].

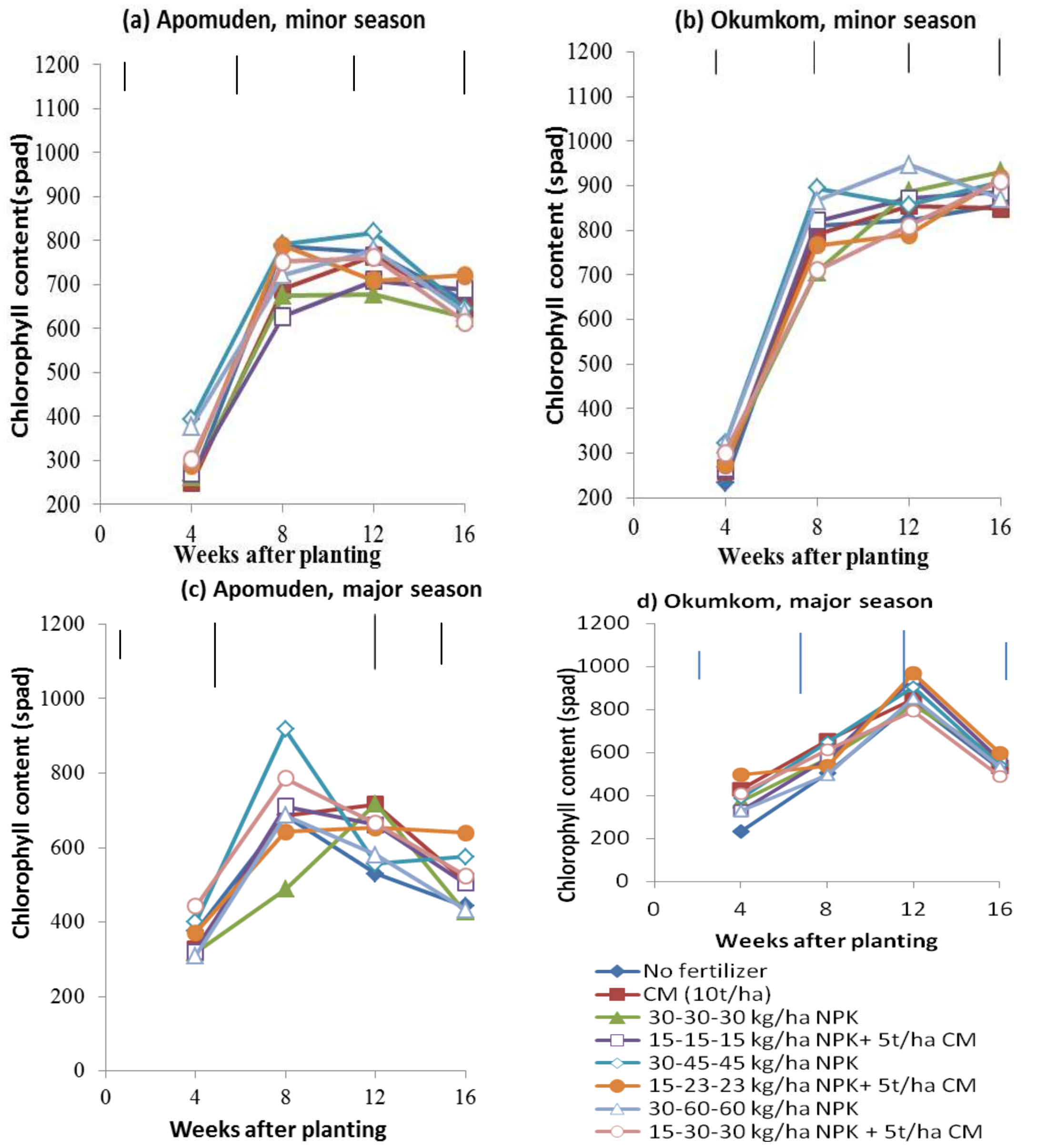

Fig. 3. Chlorophyll content of leaves as influenced by chicken manure and inorganic fertilizer during the minor season (a, b) and the major season (c, d)

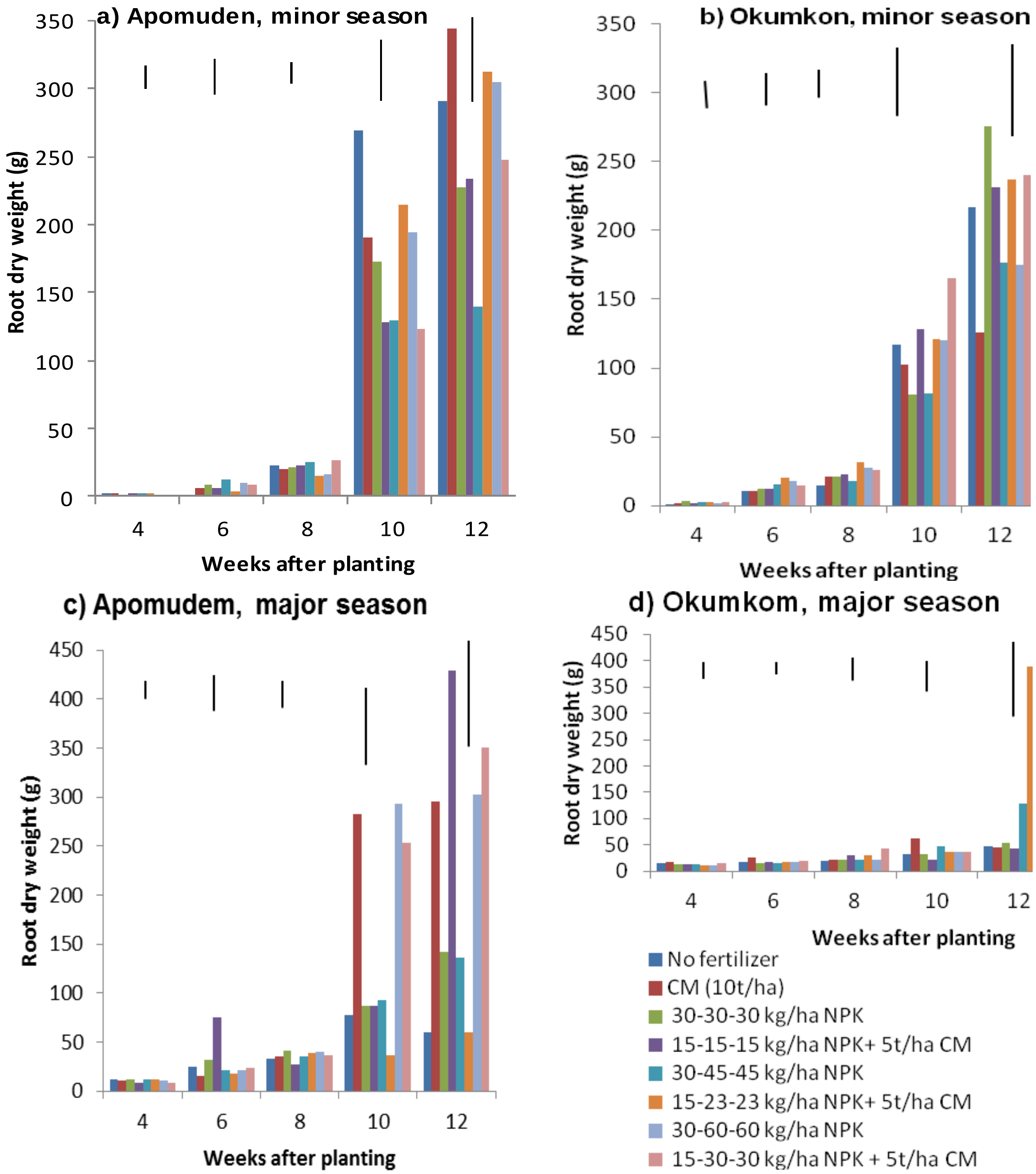

Fig. 4. Root dry weight as influenced by chicken manure and inorganic fertilizer during the minor season (a, b) and the major season (c, d)

3.2.5 Fresh vine weight at harvest

There was a significant difference between *Okumkom* and *Apomuden* in fresh vine weight at harvest in both growing seasons. Fresh vine weight at harvest of *Okumkom* was significantly influenced by 30-30-60 kg/ha NPK and 15-23-23 kg/ha NPK + 5 t ha^{-1} CM from the other amended and the control plots during the minor season and the major season respectively (Table 6). This might be due to differences in variety and their response to soil fertility.

Fresh vine weight at harvest was not significantly influenced by amended and the control in both seasons (Table 6). The non-significant difference between amended and the control in fresh vine weight at harvest might be due to the fact that probably sweetpotato does not respond to soil fertility but rather variety. *Apomuden* and

Okumkom grown on amended and control plots during the minor season gave higher fresh vine weight at harvest than during the major season (Table 6). The relatively high initial levels of soil nutrients, especially total exchangeable Ca, Mg and ECEC from chicken manure and inorganic fertilizer applied coupled with initial moderate rainfall experienced during the minor cropping season might have accounted for the result obtained. This result is similar to that found by Balesh [26] that micronutrients in chicken manure and NPK fertilizer further improved the chemical properties of the soil resulting in high fresh vine weight at harvesting.

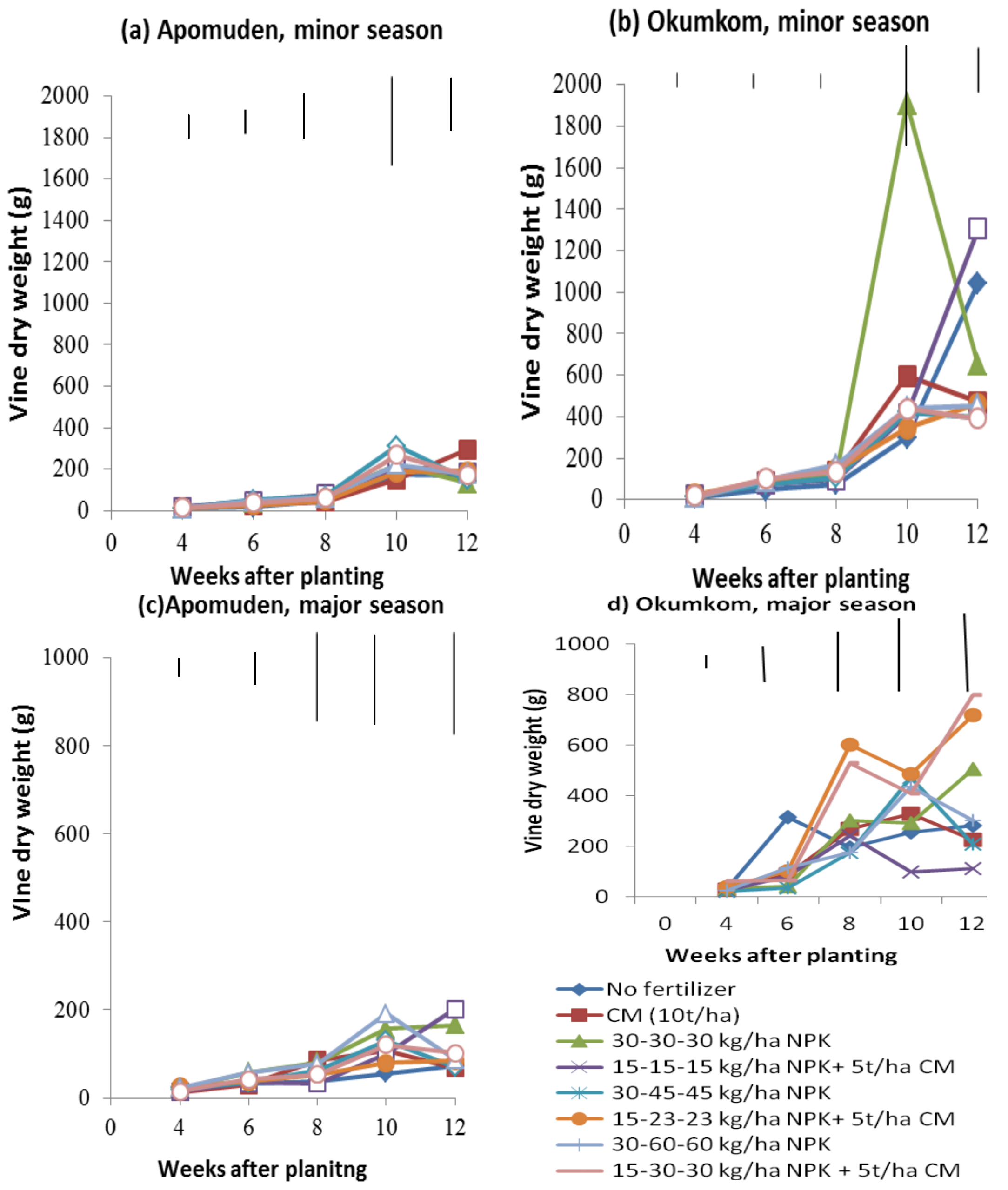

Fig. 5. Vine dry weight as influenced by chicken manure and inorganic fertilizer during the minor season (a, b) and the major season (c, d)

3.3 Yield and Yield Components of Sweetpotato

3.3.1 Marketable tuber number

There was a significant difference between *Apomuden* and *Okumkom* in marketable tuber number in both growing seasons (Table 7). Marketable tuber number of *Apomuden* was significantly influenced by 30-45-45 kg/ha NPK and 15-15-15 kg/ha NPK + 5 t ha^{-1} CM from the other amended and the control plots during the minor season. *Apomuden* grown on 15-23-23 kg/ha NPK + 5 t ha^{-1} CM differed significantly from the other amended and the control plots during the major season (Table 7). This might be due to differences in variety and their response to soil fertility and climatic condition. Hartemink et al. [20] reported significant marketable tuber increases with both chicken manure and inorganic nitrogen inputs. Marketable tuber number was not significantly influenced by amended and the control in both growing seasons (Table 7). *Apomuden* and *Okumkom* grown on amended and control plots during the major season gave higher marketable tuber number than during the minor season (Table 7). The poor climatic condition as a result of long period of drought at tuber bulking stage during the cropping period might explain the low

Table 6. Fresh vine weight at harvest of sweetpotato as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Fresh vine weight at harvest (t ha^{-1}) (minor season)		Mean	Fresh vine weight at harvest (t ha^{-1}) (major season)		Mean
	Apomud.	Okumk.		Apomud.	Okumk.	
Fertilizer rate						
10 t ha^{-1} CM	19.0	64.5	41.7	4.60	16.00	10.30
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	20.0	59.0	39.5	6.92	6.30	6.61
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	27.0	63.5	45.2	4.80	20.23	12.52
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	20/7	60.0	40.4	6.83	11.40	9.12
30-30-30 kg/ha NPK	18.0	57.2	37.6	3.83	8.87	6.35
30-45-45 kg/ha NPK	26.0	58.5	42.5	3.70	14.07	8.88
30-60-60 kg/ha NPK	24.7	67.7	46.2	4.30	12.60	8.45
No fertilizer	22.2	54.0	38.1	3.47	8.20	5.83
Mean	22.3	60.6		4.81	12.21	
LSD (0.05) Variety	6.1			3 23		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety x Fertilizer	NS			NS		

Table 7. Number of marketable tubers as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Number of marketable tubers (minor season)		Mean	Number of marketable tubers (major season)		Mean
	Apomud.	Okumk.		Apomud.	Okumk.	
Fertilizer rate						
10 t ha^{-1} CM	14.0	10.0	12.0	31.0	20.0	25.0
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	22.0	9.0	16.0	37.0	20.0	28.0
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	19.0	19.0	19.0	36.0	35.0	36.0
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	15.0	17.0	16.0	49.0	21.0	35.0
30-30-30 kg/ha NPK	21.0	14.0	17.0	34.0	26.0	30.0
30-45-45 kg/ha NPK	22.0	16.0	19.0	28.0	25.0	27.0
30-60-60 kg/ha NPK	19.0	16.0	18.0	35.0	33.0	34.0
No fertilizer	18.0	19.0	18.0	34.0	15.0	25.0
Mean	19.0	15.0		35.0	25.0	
LSD (0.05) Variety	3.60			7.86		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety x Fertilizer	NS			NS		

numbers of marketable tubers during the minor season. This agrees with Hartemink et al. [20] that rainfall can affect sweetpotato response to nutrient input. Degras [27] reported that regular irrigation of sweetpotato is required, especially during the tuber formation stage.

3.3.2 Unmarketable tuber number

There was a significant difference between *Apomuden* and *Okumkom* in unmarketable number of tubers during the minor season (Table 8). *Apomuden* grown on 30-30-30 kg/ha NPK differed significantly from the other amended and the control plots in unmarketable number of tubers during the minor season. This might be due to differences in variety and soil fertility. The low number of branches and leaf numbers of *Apomuden* compared with *Okumkom* might have resulted in late canopy closure and subsequent dryer soils and high soil temperatures. This is similar to Degras [27] that very dry soil results in small-sized tubers. According to Balesh [26] a relatively small increase in soil temperature can have a direct effect on tuber quality. Unmarketable tuber number of *Okumkom* was significantly influenced by 15-30-30 kg/ha NPK + 5 t ha^{-1} CM from the other amended plots except 10 t ha^{-1} CM and 30-60-60 kg/ha NPK and the control during the major season. *Apomuden* and *Okumkom* grown on amended and control plots during the major season had higher unmarketable tuber number than during the minor season (Table 8). High initial rainfall during the major cropping period might have negatively affected the quality of tubers. Maynard [18] reported that excessive rain prevents proper root formation and that luxurious growing conditions caused by excessive watering can lead to vigorous vine growth and result in poorly developed stringy tubers.

3.3.3 Total tuber yield

There was a significant difference between *Apomuden and Okumkom* in total tuber yield during the minor season. *Apomuden* grown on 30-30-30 kg/ha NPK produced higher total tuber yield than other amended and the control plots during the minor season. *Okumkom* grown on 30-60-60 kg/ha NPK produced significantly higher total tuber yield than other amended and the control plots during the major season (Table 9). This might be due to differences in variety and soil fertility. Growth rate and partitioning between root tubers and vegetative organs are sensitive to plant structure and nutrition [28]. The higher number of leaves per plant, vine branches and fresh vine weight at harvest of *Okumkom* compared with *Apomuden* might have resulted in low total tuber yield in *Okumkom* during the minor season. Leaf shading due to high vegetative cover is a key determinant of soil temperature, relatively small increase in soil temperature can have a direct effect on tuber yield and quality Janssens [29]. The low vegetative growth in *Apomuden* might have led to the high total tuber yield substantiating the report by Bradbury [30] that luxuriant growth of sweetpotato vines can lead to low root tuber

Table 8. Number of unmarketable tubers as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Number of unmarketable tubers (major season)		Mean	Number of unmarketable tubers (minor season)		Mean
	Apomud.	Okumk.		Apomud.	Okumk.	
Fertilizer rate						
10 t ha^{-1} CM	35.0	22.0	29.0	11.0	6.0	8.0
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	24.0	19.0	22.0	16.0	6.0	11.0
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	17.0	61.0	39.0	12.0	8.0	10.0
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	40.0	47.0	44.0	13.0	6.0	10.0
30-30-30 kg/ha NPK	24.0	31.0	28.0	20.0	6.0	13.0
30-45-45 kg/ha NPK	16.0	32.0	24.0	14.0	9.0	11.0
30-60-60 kg/ha NPK	35.0	48.0	41.0	16.0	6.0	11.0
No fertilizer	24.0	20.0	22.0	17.0	7.0	12.0
Mean	27.0	35.0		15.0	7.0	
LSD (0.05) Variety	7.86			2.82		
LSD (0.05) Fertilizer	15.72			NS		
LSD (0.05) Variety x Fertilizer	22.23			NS		

Table 9. Total tuber yield as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Total tubers yield (t ha^{-1}), (minor season)		Mean	Total tubers yield (t ha^{-1}), (major season)		Mean
	Apomud.	Okumk.		Apomud.	Okumk.	
Fertilizer rate						
10 t ha^{-1} CM	25.0	16.0	20.0	64.0	52.0	58.0
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	38.0	15.0	26.0	65.0	49.0	57.0
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	31.0	27.0	30.0	58.0	85.0	72.0
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	28.0	23.0	26.0	86.0	89.3	88.0
30-30-30 kg/ha NPK	41.0	20.0	30.0	61.0	66.0	63.0
30-45-45 kg/ha NPK	36.0	25.0	30.0	45.0	62.0	53.0
30-60-60 kg/ha NPK	34.0	22.0	28.0	70.0	93.0	82.0
No fertilizer	35.0	26.0	30.0	59.0	38.0	49.0
Mean	33.0	22.0		64.0	67.0	
LSD (0.05) Variety	5.18			1.43		
LSD (0.05) Fertilizer	NS			2.87		
LSD (0.05) Variety x Fertilizer	NS			4.06		

yield. Total tuber yield of both varieties was not significantly influenced by amended and the control plots during the minor season. However, there was a significant difference between amended and the control plots in total tuber yield during the major season (Table 9). The significant difference between amended and the control plots during the major season might be due to differences in soil fertility. Total tuber yield for both varieties during the major season was higher than during the minor season. The low total tuber yield for both varieties during the minor season might be due to low rainfall and high temperature experienced during the growing period. Bandara et al. [31] reported that high temperatures can cause irreversible damage to plant processes that affect the final yield.

3.3.4 Tuber length

There was a significant difference between *Apomuden* and *Okumkom* in tuber length during both growing seasons. Tuber length of *Apomuden* was significantly influenced by 15 - 30- 30 kg/ha NPK + 5 t ha^{-1} CM from the other amended and the control plots in both seasons (Table 10). The significant difference might be due to differences in variety, organic matter and structural stability of the manured soil from chicken manure. The application of chicken manure might have enhanced penetration of tuber in the soil. Dennis [32] indicated that the combination of organic and inorganic fertilizers not only improved crop yields but also improved the physical status of the soil. According to Bonsu [8], chicken manure improves the physical conditions of soil in terms of better water holding capacity, soil microbial activity, water infiltration and structural stability of the soil. Additionally, organic matter improves soil bulk density creating a conducive environment for crops like sweetpotato [33]. Ojeniyi [34] reported that crop grown for their root and tubers benefit from organic matter not only as a source of nutrients but also as a room for good root extension and tuber bulking. There was no significant difference between amended and the control treatments in tuber length during both growing seasons (Table 10).

3.3.5 Harvest index

Results obtained in both seasons did not elicit significant effect of the inorganic fertilizer either alone or in combination with chicken manure on harvest index in both varieties (Table 11). There was a significant difference between *Apomuden* and *Okumkom* in harvest index during both growing seasons. *Apomuden* grown on 30–30–30 kg/ha NPK and 15-15-15 kg/ha NPK + 5 t ha^{-1} CM produced the highest harvest index during the minor season. Harvest index of *Apomuden* was significantly influenced by 30-45-45 kg/ha NPK from other amended and the control plots during the major season (Table 11). The significant difference might be due to differences in variety, soil fertility and climatic condition. Generally, *Okumkom* grown on amended and control plots in both seasons had lower harvest index than *Apomuden* grown on the same treatments. The high vine fresh weight at harvest for *Okumkom* compared with *Apomuden* with corresponding low total tuber yield, especially during the minor cropping season might have resulted in this result. High fresh vine weight at harvest tends to lower tuber yield and consequently lower harvest index. This might be due to high partitioning of assimilates to vegetative biomass at the expense of tuber (sinks). Bradbury [30] reported that high luxuriant growth of the vines as a result of nitrogen results in low storage root yield and consequently lower harvest index.

3.3.6 Commercial harvest index

Results obtained in both seasons did not elicit significant effect of the inorganic fertilizer either alone or in combination with chicken manure on commercial harvest index (CHI) (Table 12). There was a significant difference between *Apomuden* and *Okumkom* in commercial harvest index during the major season. *Apomuden* grown on amended and the control plots produced higher commercial harvest index during the major season than during the minor season. This result indicates high marketable root yield production. This agrees with Yeng [35] that high commercial harvest index of sweetpotato was obtained in response to inorganic fertilizer in combination with chicken manure applied at planting.

Table 10. Tuber length as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Tuber length (cm) (major season)		Mean	Tuber length(cm) (minor season)		Mean
	Apomud.	**Okumk.**		**Apomud.**	**Okumk.**	
Fertilizer rate						
10 t ha^{-1} CM	19.43	17.57	18.50	15.82	14.00	14.91
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	22.29	16.83	19.56	15.00	12.12	13.56
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	19.38	20.03	19.71	14.30	12.02	13.16
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	24.50	17.40	20.95	17.88	11.32	14.60
30-30-30 kg/ha NPK	19.87	17.33	18.60	14.52	11.95	13.24
30-45-45 kg/ha NPK	20.79	18.40	19.59	16.17	11.15	13.66
30-60-60 kg/ha NPK	21.59	20.26	20.92	13.80	12.40	13.10
No fertilizer	20.74	17.17	18.95	16.67	10.77	13.72
Mean	21.07	18.12		15.52	11.97	
LSD (0.05) Variety	1.05			1.48		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety * Fertilizer	2.97			NS		

Table 11. Harvest index of sweetpotato as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Harvest index (minor season)		Mean	Harvest index (major season)		Mean
	Apomud.	**Okumk.**		**Apomud.**	**Okumk.**	
Fertilizer rate						
10 t ha^{-1} CM	0.55	0.21	0.38	0.61	0.21	0.41
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	0.66	0.22	0.44	0.57	0.36	0.47
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	0.57	0.35	0.46	0.58	0.41	0.50
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	0.61	0.33	0.47	0.64	0.30	0.47
30-30-30 kg/ha NPK	0.66	0.27	0.46	0.64	0.30	0.47
30-45-45 kg/ha NPK	0.61	0.33	0.47	0.65	0.24	0.44
30-60-60 kg/ha NPK	0.58	0.27	0.42	0.64	0.34	0.49
No fertilizer	0.60	0.41	0.50	0.52	0.23	0.37
Mean	0.61	0.30		0.88	0.91	
LSD (0.05) Variety	0.043				0.079	
LSD (0.05) Fertilizer	NS				NS	
LSD(0.05) Variety x Fertilizer	NS				NS	

Table 12. Commercial harvest index of sweetpotato as influenced by chicken manure and inorganic fertilizer during the minor season and the major season

	Commercial harvest index (major season)		Mean	Commercial harvest index (minor season)		Mean
	Apomud.	Okumk.		Apomud.	Okumk.	
Fertilizer rate						
10 t ha^{-1} CM	0.93	0.88	0.90	0.88	0.87	0.87
15-15-15 kg/ha NPK + 5 t ha^{-1} CM	0.95	0.91	0.93	0.90	0.91	0.91
15-23-23 kg/ha NPK + 5 t ha^{-1} CM	0.97	0.80	0.88	0.89	0.93	0.91
15-30-30 kg/ha NPK + 5 t ha^{-1} CM	0.95	0.73	0.84	0.92	0.94	0.93
30-30-30 kg/ha NPK	0.95	0.91	0.93	0.84	0.89	0.86
30-45-45 kg/ha NPK	0.95	0.85	0.90	0.93	0.89	0.91
30-60-60 kg/ha NPK	0.91	0.84	0.88	0.85	0.92	0.89
No fertilizer	0.86	0.87	0.87	0.85	0.94	0.90
Mean	0.93	0.85		0.88	0.91	
LSD (0.05) Variety	0.04			NS		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety x Fertilizer	NS			NS		

Table 13a. Correlation matrix among growth and yield parameters during the minor season

	1	2	3	4	5	6	7	8	9	10	11
1. Total weight of tubers											
2. Ave. tuber diameter	0.42**										
3. Marketable tuber number	0.80**	0.01ns									
4.Marketable tuber weight	0.99**	0.46**	0.78**								
5. Number of branches	-0.11ns	0.37**	-0.18ns	-0.07ns							
6. Number of leaves per plant	-0.16ns	0.33**	-0.20ns	-0.12ns	0.89**						
7. Stem diameter	-0.05ns	0.25*	-0.23ns	-0.02ns	0.50**	0.48**					
8.Unmarketable tuber number	0.24*	-0.34**	0.35**	0.13ns	-0.46**	-0.43**	-0.36**				
9.Unmarketable tuber weight	0.23ns	-0.19ns	0.29*	0.11ns	-0.30**	-0.29**	-0.26*	0.89**			
10.Vine length	0.02ns	0.37**	-0.09ns	0.07ns	0.64**	0.56**	0.42**	-0.44**	-0.32**		
11. Ave. tuber weight	0.56**	0.51**	0.15ns	0.58**	-0.13ns	-0.21ns	0.03ns	-0.07ns	-0.07ns	0.08ns	

Table 13b. Correlation matrix among growth and yield parameters during the major season

	1	2	3	4	5	6	7	8	9	10	11
1.Total weight of tubers											
2. Ave. tuber diameter	0.66**										
3.Marketable number	0.71**	0.32*									
4. Marketable weight	0.98**	0.68**	0.70**								
5.Number of branches	-0.13ns	-0.16ns	-0.26ns	-0.21ns							
6.Number of leaves per plant	-0.12ns	-0.17ns	-0.22ns	-0.18ns	0.93**						
7. Stem diameter	0.09ns	0.12ns	-0.15ns	0.08ns	0.39**	0.31*					
8.Unmarketable number	0.36**	0.03ns	0.37**	0.24ns	0.34**	0.32*	0.10ns				
9.Unmarketable weight	0.38**	0.04ns	0.30*	0.24ns	0.46**	0.48**	0.13ns	0.91**			
10. Vine length	0.34**	0.36**	0.07ns	0.30*	0.49**	0.47**	0.45**	0.35**	0.39**		
11. Ave. tuber weight	0.70**	0.84**	0.35**	0.73**	-0.26ns	-0.25ns	0.02ns	0.02ns	0.02ns	0.27*	

**Significant at 1%, **Significant at 5%, ns Not significant*

3.4 Relationship between Vegetative and Yield Parameters Measured on Sweetpotato for the Minor and Major Seasons

Results of simple correlation between total tuber weight, growth and yield components in sweetpotato are shown in (Tables 13a and 13b). In the minor season, number of leaves per plant, number of branches, vine length, stem diameter and average tuber diameter were significantly and positively correlated. On the other hand, number of leaves per plant was negatively correlated to the total tuber weight, marketable tuber number and marketable tuber weight. Vine length was negatively correlated to the marketable tuber number and unmarketable tuber weight. The vegetative characters were positively and significantly correlated. This suggests a weak association among number of leaves and yield parameters. This observation might be due to high soil nitrogen. High nitrogen encourages vine growth and tends to cause a decline in yields. This result however contradicts Yahaya [36] that number of leaves per plant, number of tubers per plant and average root weight were significantly and positively correlated to yields.

In the major season, number of leaves per plant, number of branches, vine length and stem diameter were significantly and positively correlated. However, number of leaves per plant was negatively correlated to the total tuber weight, average tuber diameter, marketable tuber number and marketable tuber weight. This is an indication that vegetative characters did not influenced yield during the major growing period of sweetpotato.

4. CONCLUSION

Application of chicken manure and inorganic fertilizer increased organic manure moderately in the different treatments in both seasons.

The pH and exchangeable cation increased with chicken manure and inorganic fertilizer as mineral supplements either singly or in combination. Bulk density also decreased with chicken manure and inorganic fertilizer application. *Okumkom* grown on amended and the control produced significantly higher number of leaves per plant, number of branches and vine fresh weight at harvest for the entire period in both growing seasons than *Apomuden*. This is an indication of the use of *Okumkom* for higher vegetative biomass that can serve as animal feed in other agro-ecologies. Farmers are encouraged to grow *Apomuden* on 30-45-45 kg/ha NPK, 30-30-30 kg/ha NPK. 15-15-15 kg/ha NPK + 5 t ha^{-1} CM and 15-30-30 kg/ha NPK + 5 t ha^{-1} CM for high marketable tuber number, total tuber yield and harvest index during the minor season. For high number of marketable tubers, tuber length and commercial harvest index farmers should grow *Apomuden* on 15-23-23 kg/ha NPK + 5 t ha^{-1} CM, 15-30-30 kg/ha NPK + 5 t ha^{-1} CM and 30-45-45 kg/ha NPK during the major season. Correlation analyses for both seasons show that the vegetative growth was negatively correlated with tuber weight and marketable tuber number and marketable tuber weight, while tuber market quality was highly positively correlated with total weight of tuber. The vegetative characters were positively and significantly correlated. This suggests a weak association among number of leaves per plant and yield parameters.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Awojobi BF. Indigenous knowledge in potato utilization, processing and preservation. In Olakesusi F, (Eds). Proceedings of Post-Harvest seminar. Ilorin: Nigerian Stored Products Research Institute. 2004;1-127.
2. Hakiza JI, Taryamureeba G, Kakuhenzire RM, Odongo B, Mwanga RM, Kanzikwer AR, Adipala E. Potato and sweetpotato improvement in Uganda. A histirical perspective. African Potato Association Conference Proceedings*.* 2000;5:47-58
3. Scott GJ, Rosegrant M, Ringler C. Tubers and tubers for the 21st century. Trends,

Projections and Policy for developing countries. Food, Agriculture and the Environmental Discussion Paper. International Food Policy Research Institute (IFPRI). Washington D.C. USA; 2000.
4. Smailing EMA, Nandwa SM, Janssen BH. Soil fertility in Africa. Buresh RJ, Sanshez PA, Calboun F, (Eds). Madison WI. USA: SSSA Special Public No. 51. 1997;47-61.
5. Miah MMU. Prospects and Problems of organic farming in Bangladesh. Paper presented at the workshop on integrated nutrient management for sustainable agriculture held at SRDI, Dhaka. 1994;26-28.
6. Singh GB, Yadav DV. Integrated plant nutrition system in sugarcane. Fertilizer News. 1992;37:15-22.
7. Kingery WL, Wood CW, Delaney DP, William JP, Mullins GL. Impact of long term application of broiler litter on economically related soil properties. Jnl Environ. Qual. 1993;22:51.
8. Bonsu M. Organic residues of less erosion in Ghana. Soil erosion and conservation. Soil Conservation Society of America. 1986;615-62.
9. Norman JC. Tropical vegetable crops*.* Arthur H. Publishers. Stockwell Ltd. Great Britain. 1992;221.
10. Asiamah RD. Soils and soil suitability of Ashanti region. Soil Research Institute - Council for Scientific and Industrial Research, Kwadaso-Kumasi. Report. 1988;l93:21.
11. Ghana Meteorological Agency-Mampong – Ashanti. 2011
12. Ghana Meteorological Agency, Mampong –Ashanti; 2012.
13. Walkley A, Black IA. An examination of the method for determining soil organic matter and proposed modification of the chronic acid titration method. Soil Sci. 1934;37:29-38.
14. AOAC. Official methods of analysis, Association of Official Agricultural Chemists, 2^{nd} ed, Washington D.C. 1975; 832.
15. Bray RH, Kutz LT. Determination of total, organic and available forms of phosphorus in soils. Soil Science. 1945;59:39-45.
16. GenStat Procedure Library Release. Eleventh Edition, VSN International Ltd; 2008.
17. Crop Research Institute. Council for Scientific and Industrial Research, Ghana. Annual Report; 2006.
18. Maynard AA, Hill EV. How to grow sweetpotatoes in connecticut. The Connecticut Agricultural Experimental Station. New Haven. CT 06504; 2000.

    Available:http:www.ct.gov\caes
19. Raemaekers RH. Crop production in tropical Africa. CIP Royal Library Albert I Brussels. 2001;204:220-221.
20. Hartemink EA, Johnson M, O'Sullivan JN, Poloma S. Nitrogen use efficiency of taro and sweetpotato in the humid lowland of Papua New Guinea. Agriculture, Ecosystems and Environment. 2000a;79: 271-280.
21. Hartemink EA, Poloma S, Maino M, Powell KS, Egenae J, O'Sullivan-Hileman LH. The fertilizer value of broiler litter. Arkansas Agricultural Exp. L Station, Report Series. 2000b;158:3-7.
22. Rice PP, Rice LW. Fruit and vegetable production in Africa*.* Macmillan Publishers London. 1987;231.
23. Mascianica MP, Bellinder RR, Graves B, Morse RD, Talleyrand H. Forecasting of N fertilization requirements for sweetpotatoes. Journal of the American Society for Horticultural Science. 1985; 110:358-361.
24. Walker DW, Woodson WR. Nitrogen rate and variety effects on nitrogen and nitrate concentrations of sweetpotato leaf tissue. Communications in Soil Science and Plant Analysis. 1987;18:529-541.
25. Erickson AN, Markhart AH. Flower developmental stage and organ sensitivity of bell pepper (*Capsicum annuum* L.) to elevated temperature. Plant Cell Environ. 2002;25:123–130.
26. Balesh T. Integrated plant nutrient management in crop production in the central Ethiopia highlands. Doctor of philosophy (PhD) Norwegian University of Life Science; 2005.
27. Degras L. Sweetpotato: The tropical Agriculturalist. Macmillan publishers Ltd. Lima, Peru; 2003.
28. Hahn SK, Hozyo Y. Sweetpotato. In: The physiology of field crops Ed. Goldworthy PR, Fisher NM Chichester. Wiley. 1984; 551-8.

29. Janssens M. Crop production in tropical Africa. CIP Royal Library Albert I. Brussels. 2001;204:220-221.
30. Bradbury JH, Holloway WD. Chemistry of tropical root crops: Significance for nutrition and agriculture in the Pacific. ACIAR Monograph 6, Australian Centre for International Agricultural Research; 1988.
31. Bandara GK, Raja R, Shankle MW. Quantifying growth and developmental responses of sweetpotato to mid-and late-season temperature. Conf. paper; 2015.
32. Dennis EA, Anane-Sakyi C, Affi-Pungu G. The effect of cowdung and mineral fertilizers on the yield of dry season onion gardening in Upper East Region of Ghana. Paper Presented at First National Workshop on Food and Industrial Crops. 1994;25-27. Kumasi, Ghana.
33. Arriaga JF, Lowery B. Soil physical properties and crop productivity of an eroded soil amended with cattle manure. J. Soil Sc. 2003;168:888-899.
34. Ojeniyi SO, Ezekiel PO, Asawalam DO, Awo AO, Odelina SA. Odelina JN. Root growth and NPK status of cassava as influenced by oil palm bunch ash. Afr. J. Biotechnol. 2009;8(18):4407-4417.
35. Yeng SB, Agyarko K, Dapaah HK, Adomako WJ, Asare E. Growth and yield of sweetpotato (*Ipomoea batatas* L.) as influenced by integrated application of chicken manure and inorganic fertilizer. Afri. J. of Agriculture Research. 2012; 7(39):5387-6395.
36. Yahaya SU, Saad AM, Mohammed SG, Afuafe SO. Growth and yield components of sweetpotato (*Ipomoea batatas* L.) and their relationships with root yield. American Journal of Experimental Agriculture. 2015; 9(5):1-7.

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