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Original Research Article

Growth and Yield of Sweet Potato *(Ipomoea batatas (*L) Lam) as Influenced by Chicken Manure and Inorganic Fertilizers

ABSTRACT

Two field experiments were conducted 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 to investigate into the growth, yield and yield components of two varieties of sweet potato (Apomuden and Okumkom) roots as influenced by chicken manure and inorganic mineral fertilizers. The application of chicken manure and inorganic fertilizer supplementation for soil fertility supplementation in sweet potato production are a better option than either organic or inorganic mineral input applied alone. Apomuden grown on 15 – 30 – 30 kg/ha NPK + 5t/ha CM gave the highest marketable and total tuber yield during the major cropping seasons, while Okumkom grown on amended and control treatments gave the highest vegetative biomass (number of leaves, vine fresh weight at harvest) in both seasons. An increase in tuber number per plot was accompanied by a general decline in tuber weight with Apomuden grown on amended treatments especially 15 – 30 – 30 kg/haNPK + 5t/ha CM during the major season producing the largest tuber weighing 0.53 kg. Correlation coefficient (r) among number of leaves, and marketable tuber number was non-significant and negative ($p < 0.05$) for minor season ($F = 0.20ns$) while during major season correlation coefficients (r) among number of leaves and branches were significant and positive ($p < 0.05$) for unmarketable tuber number ($r = 0.32$ to 0.34).

INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam), is an important and popularstaple food grown in Ghana andmany 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 cultivar and soil types. Use of both

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organic and mineral fertilizers is often limited and this has resulted in a gradual depletion of soil nutrients in sub-Saharan Africa [4]. Chicken manure is a rich source of nitrogen, phosphorus, organic carbon and exchangeable Ca and Mg [5]. Appropriate application of poultry 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, improved soil microbial activity, improved water infiltration and structural stability of the soil [6]. Poultry 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 manures and their efficient management. It is a heavy feeder hence fertilization with the three major nutrients, nitrogen, phosphate and potassium is therefore indispensable [7]. 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.

MATERIALS AND METHODS

Two field experiments were conducted at the multi-purpose 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 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. The weather conditions during the experimental periods are summed up in Tables1a and 1b. The chicken manure used for the research project for both seasons was four (4) 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 (2) weeks before planting of vines. Soil samples were taken prior to and after application of organic manure and fertilizers

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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 and total nitrogen was determined by the micro Kjeldahl method. The available phosphorus was extracted by the Bray's method and exchangeable cations were determined by flame emission photometry.

Table 1a: Weather conditions of Mampong-Ashanti during the minor rainy season in 2011 experimental period

Month	**Total monthly Rainfall (mm)**	**Mean monthly Relative humidity (%) (hour GMT)**		**Mean monthly Max. &Min. temperature (°c)**	
		06.00	**15.00**	**Min.**	**Max.**
January	65.8	82	43	21.0	32.7
February	136.4	90	48	22.0	33.5
March	230.5	96	59	22.3	33.1
April	122.8	95	59	23.1	33.2
May	100.1	96	60	23.0	32.7
June	244.4	97	68	22.3	30.5
July	178.6	97	71	21.7	28.9
August	60.0	97	70	21.8	28.5
September	155.6	98	73	22.3	29.4
October	188.1	97	67	22.3	30.9
November	38.0	96	54	28.0	32.7
December	0.0	92	41	22.2	32.9
Total	1520.3				

(Meteorological Department – Mampong Ashanti, 2011)

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Table1b: The Total Rainfall (Mm), Mean Temperature (^{O} C) and Mean Relative Humidity (%) (Hour GMT) of Mampong-Ashanti during the Major Rainy Season in 2012 Experimental period

Month	Total monthly Rainfall (mm)	Mean monthly Relative humidity (%) (hours GMT) 06.00	15.00	Mean monthly Max. & Min. temperature (°c) Min.	Max.
January	48.1	84	35	20.8	33.7
February	74.9	84	46	22.4	33.4
March	92.0	93	52	23.1	33.4
April	119.3	96	61	23.0	33.3
May	270.8	96	63	23.0	31.4
June	379.8	97	71	22.6	29.5
July	178.6	96	71	21.9	28.2
August	93.8	96	71	21.9	28.2
September	3.4	98	70	22.5	28.9
October	73.5	97	65	22.4	31.2
November	225.5	95	66	22.7	32.4
December	60.6	93	53	22.5	31.9
Total	1620.3				

(Meteorological Department – Mampong Ashanti, 2012)

The experimental design was a 2 x 8 factorial arranged in randomized complete block design (RCBD) with four replicates made up of seven organic manure and fertilizer rates and the control (without any amendment) and two sweet potato varieties was assigned to each block.Each treatment plot measured 4.0 m x 3.0 m. Ridges were constructed 1.0 m between rows and planted at 0.3m within row plants. Vine cuttings of two sweet potato varieties " *Apomuden*" and " *Okumkom* " of length 0.3m topmost apical sections and other actively growing sections were planted two weeks after chicken manure application. Inorganic mineral fertilizer, NPK

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(15:15:15), triple super phosphate and muriate of potash were applied two weeks after planting of vines at appropriate rates as per treatments.Number of leaves and branches were counted on five plants from the two central rows whilethree plants were randomly sampled for dry matter accumulation and leaf chlorophyll content. This was measured using a Fieldscout CM 100 chlorophyll meter (Spectrum Technologies Inc.). Data were collected at four weeks after planting andat two weeks interval. The number of days to first flowering, from seedling emergence, per plantwas recorded for eighteen plants on the two central rows for each treatment plot. 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 ANOVA and GenStat Release 9.2 (PC/Windows XP) statistical package. Least Significant Difference (LSD) was used to separate means at 5 % level of probability.

RESULTS AND DISCUSSION

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 2011 and 2012 experimental site are shown in Tables 2 and 3. Both the untreated soil (no-manure) and manured supplemented soils were within the sandy loam textural range. 10t/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 and manured soils had an acidic pH; however, 10t/ha chicken manure supplemented soil had a slightly acidic pH. In general, 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 soil physical properties such as soil structure, bulk density and water holding capacity.

Table 2: Physico - Chemical Properties of Soil and Soil Plus Manure Ap Horizon At 0-20 cm depth for the minor season (2011)

Property	Untreated Soil (Control)	Value Inorganic Fertilizer + Soil	10t/Ha Chicken Manure + Soil	5t/Ha Chicken Manure + Inorganic

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				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/100g)	2.49	2.97	12.80	6.14
Mg^{2+}(mg/100g)	2.94	2.94	6.74	2.14
K^+ (mg/100g)	0.35	1.34	0.48	0.67
Na^+ (mg/100g)	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/100g	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 3: Physico - Chemical Properties of Soil and Soil Plus Manure Ap Horizon At 0-20cm depth for major season (2012)

Property	Untreated Soil (Control)	Value Inorganic Fertilizer + Soil	10t/Ha Chicken Manure + Soil	5t/Ha Chicken Manure + Inorganic Fertilizer +Soil

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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/100g)	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/100g	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

GROWTH PERFORMANCE

Number of leaves per plant

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Leaf number of Okumkom cultivar planted during the minor season on the amended treatments with the exception of 10t/ha CM was significantly higher than the control (fig 1). Significant difference in plant growth observed between amended and control plots could be attributed to differences in organic matter and effective cation exchange capacity (ECEC) [8]. Apomuden cultivar did not show any significant difference in leaf number for the amended and the control treatments. Okumkom produced significantly higher leaf number than Apomuden across all treatments. This could be due to variety characteristics. Apomuden and Okumkom planted on amended plots with exception of 30-30-30 kg/haNPK and 10tlha CM gave higher leaf numbers than the control at 12 WAP during the major season. The relatively lower soil fertility status, especially, exchangeable Ca and low effective cation exchange capacity (E.C.E.C) in chicken manure during the major growing season might have contributed to low plant growth and leaf appearance on 10t/ha CM treatment plot. 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 cultivars planted on amended and control plots during the major season produced significantly higher leaf numbers than during the minor season. This observation might be attributed to high rainfall that resulted in better soil moisture supply coupled with a relatively higher soil N, especially, at the early planting stage of sweetpotato during the major season leading to better nutrient availability. According to [9] excessive rain or nitrogen can lead to vigorous vine growth.

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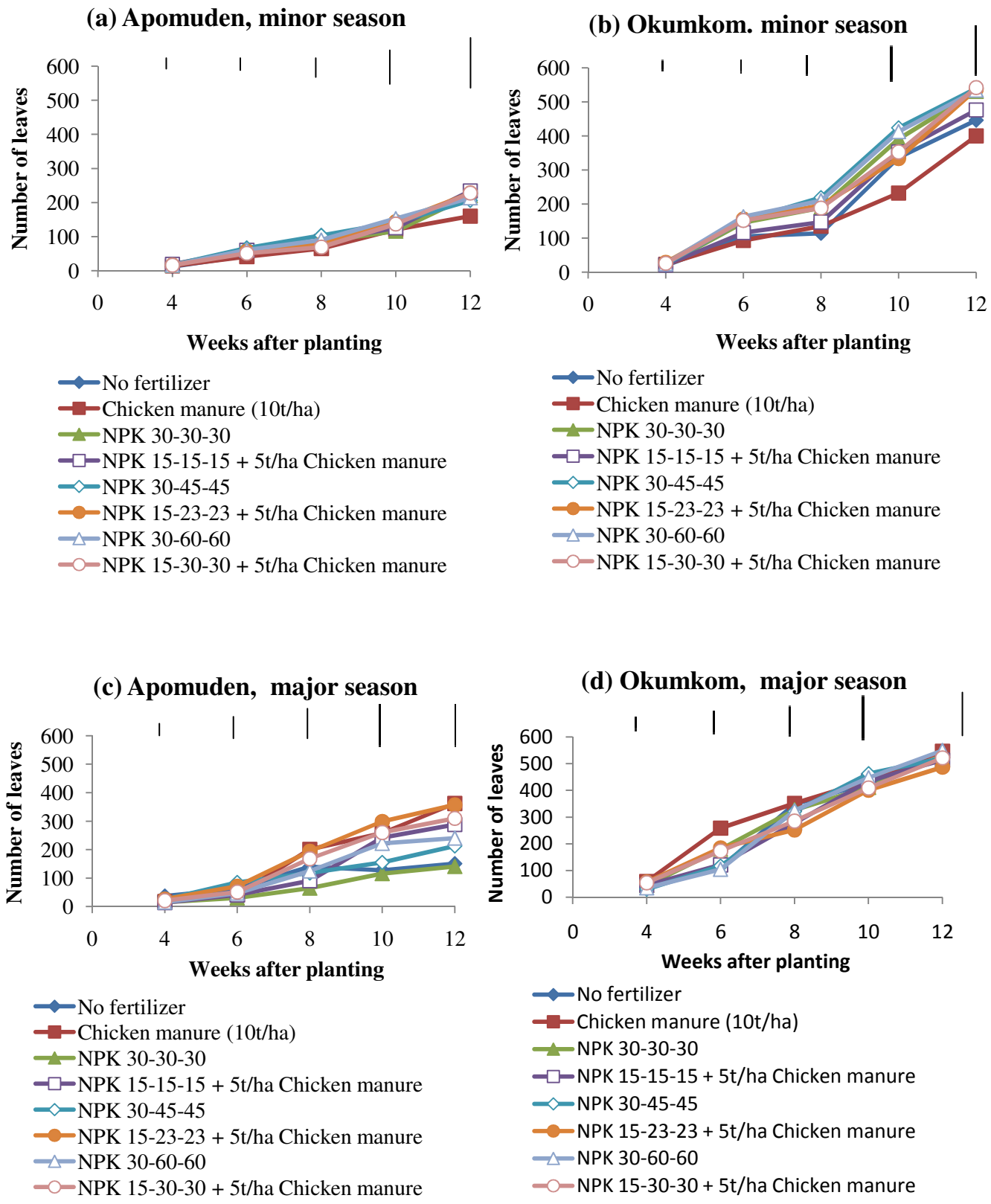

Fig.1: Leaf number as influenced by chicken manure and inorganic fertilizer during (a) minor season, 2011 (a, b) and major season 2012 (b, c)

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Number of branches

Number of vine branches of both sweet potato cultivars (Okumkom and Apomuden) grown on amended treatments were significantly higher than the control in both seasons (fig 2). This might be due to differences in soil fertility status through increased availability of nitrogen on manured plots. [10] reported that in sweet potato, 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 tuber bulking and maturation. Similarly, according to [11] too much nitrogen could result in excessive vine growth. Application of organic and inorganic fertilizer to the two cultivars of sweet potato produced significantly different number of branches and might be attributed to differences in genetic composition of the sweet potato varieties and number of sprouts at planting. Stem number may be influenced by other factors such as genetic potential of the cultivar and number of viable sprouts at planting [12]. Apomuden and Okumkom grown on amended and control plots during the major season produced significantly higher number of vine branches over those grown under the same treatments during the minor season at 12 weeks after planting. The differences in sweet potato growth observed in the two seasons might be attributed to high rainfall during the major season coupled with slow and effective release of nutrients from manure applied during the major season. [13] indicated that vine growth habit of sweet potato depend on cultivar and environment, particularly, the climate of the growing area available to the plant and the plant's nutrition. The results obtained during the major season were similar to those of [14 and 15] who observed that sweet potato response to nutrient input was greatly affected by other factors such as rainfall and number of cropping seasons. Apomuden and Okumkom planted on 10t/ha CM had significantly lower number of branchesthan the other amended and control plots during the minor season compared to 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 significantly lower number of branches of both sweet potato cultivars grown on 10t/ha CM, during the minor season. [16] indicated that the use of well-rotted manure prior to planting and a pre-planting application of complete fertilizer is generally beneficial and required for good plant growth and yield.

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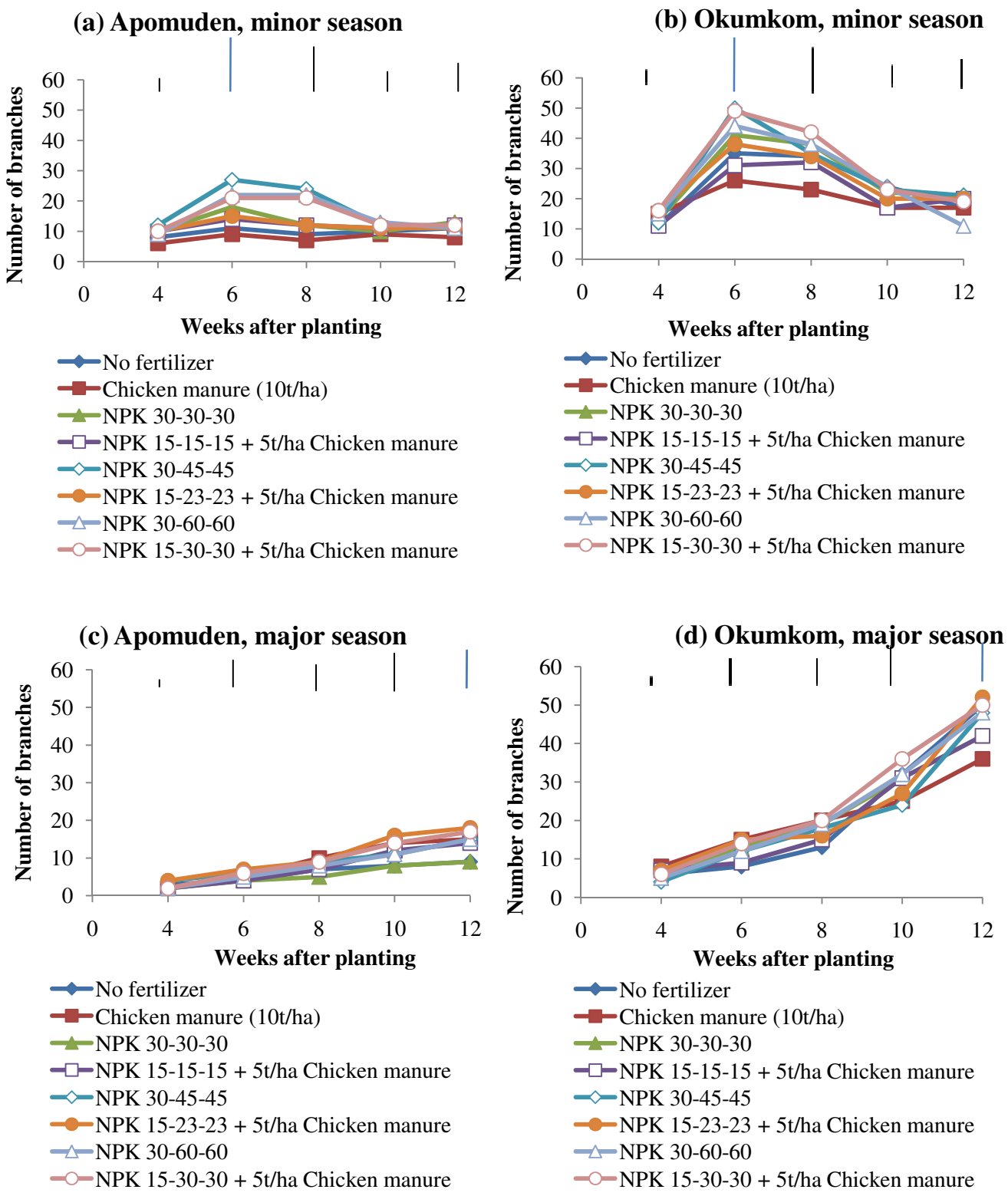

Fig.2: Number of branches as influenced by chicken manure and inorganic fertilizer during minor season (a, b), 2011 and major season (c, d), 2012

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Chlorophyll content of sweet potato leaves

Chlorophyll content of leaves for Apomuden grown on 15 – 23 – 23 kg/ha NPK + 5t/ha CM was significantly higher than the other amended treatments and the control at 16 weeks after planting in both seasons (fig 3). This result indicates positive influence of chicken manure on leaf chlorophyll content in combination with inorganic inputs over unamended soils. The significantly higher chlorophyll content of leaves observed on Apomuden than Okumkom and on the manured plots than control plots could be due to differences in varieties as well as N, Mg and presence of Zn in chicken manure. According to [17] and [18] plants need nitrogen for growth, reproduction and photosynthesis which depend directly on chlorophyll content of leaves.

Apomuden and Okumkom grown on amended and control plots during the minor season had substantially higher chlorophyll content of leaves than the major season. The moderate rainfall observed during the minor cropping period might have accounted for this result. The initial high rainfall experienced during the major cropping period coupled with temporal waterlogging in the field might have resulted in nitrogen deficiency through leaching of nutrients in the soil. Sweet potato is intolerant to waterlogging, particularly, during tuber initiation though the crop is sometimes tolerant to drought; growth rate and dry matter partitioning between storage roots and vegetative organs are sensitive to plant structure and nutrition [19 and 20].

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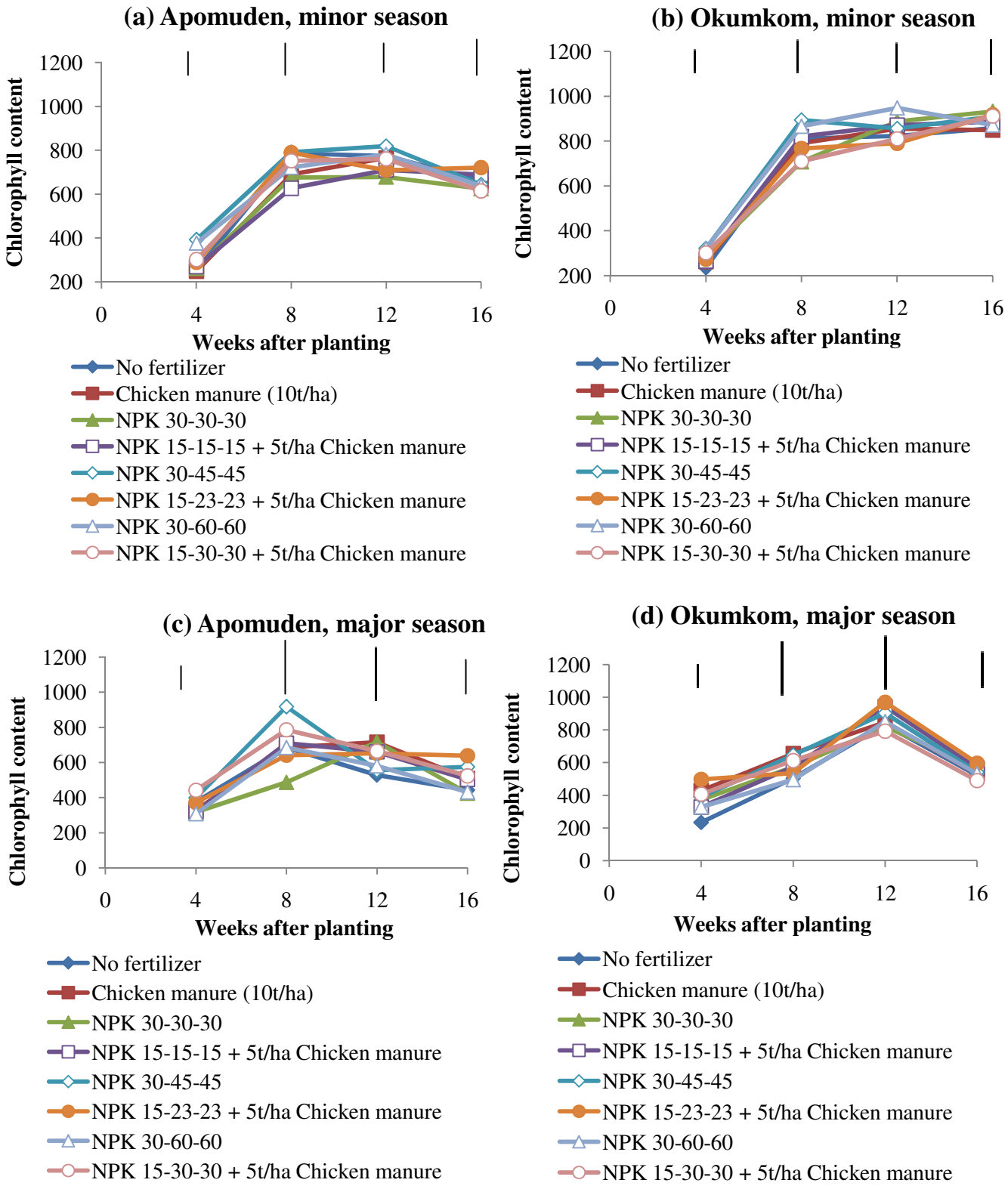

Fig. 3: Chlorophyll content of leaves as influenced by chicken manure and inorganic fertilizer during minor season, 2011 (a, b) and major season, 2012 (c, d).

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Mean root and vine dry weight gain

Application of 15 – 15 – 15 kg/haNPK+ 5t/ha CM to Apomuden increased root dry weight than the other amended treatments and control at 12 WAP in both seasons (fig 4). The advantage of manured plots over control in leaf number and vine branches was reflected in root and vine dry weight. The greater number of leaves and vine branches enhanced effective sunlight interception for photosynthesis, hence more dry matter accumulation in manured plants than the control. Significant increase in root (fig 4) and vine (fig 5) dry weight was observed with the application of chicken manure in combination with inorganic fertilizer to both Apomuden and Okumkom than organic manure alone (10t/ha CM) and the control at 12 WAP in both seasons. The increase in root and vine dry weight might be due to reduced number of leaves and branches that resulted in decreased sunlight interception for photosynthesis hence decreased root and vine dry weight gain. Application of amended treatments, especially, 15 – 15 – 15 kg/haNPK + 5t/ha CM and 15 – 23 – 23 kg/ha NPK + 5t/ha CM to Apomuden and Okumkom significantly increased root and vine dry weight during the major season in 2012 than during the minor season in 2011 at 12 WAP. The differences in growth potential of sweet potato due to cultivar and climatic conditions have been reported to be essential for dry weight of plants [13].

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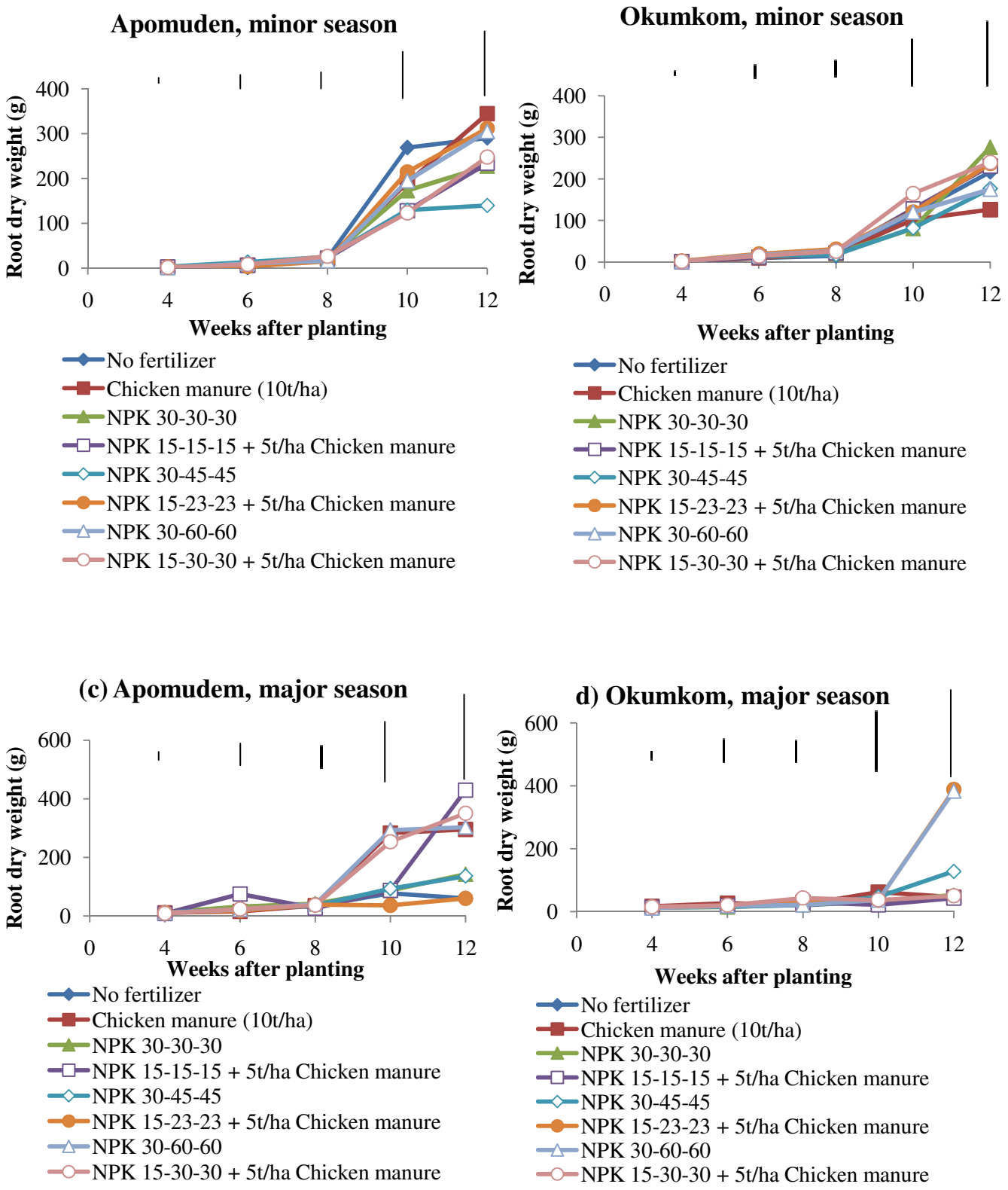

Fig. 4. Root dry weight as influenced by chicken manure and inorganic fertilizer during minor season, 2011 (a, b) and major season, 2012 (c, d).

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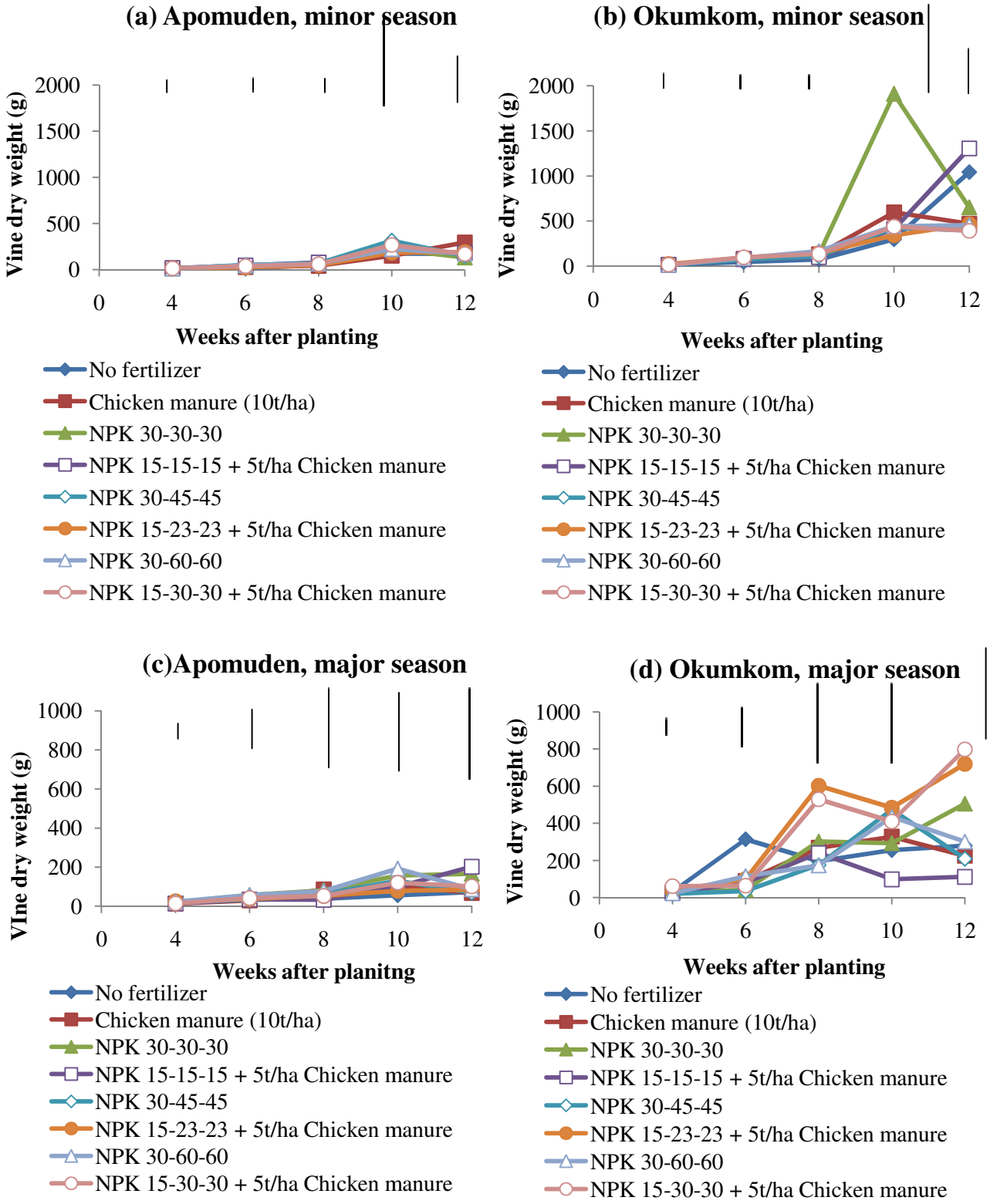

Fig. 5: Vine dry weight as influenced by chicken manure and inorganic fertilizer during minor season, 2011 (a, b) and major season, 2012 (c, d).

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Mean days to 50% flowering

Integrated fertility management schemes of mineral fertility and organic manure (chicken manure) and manure nutrients alone did not influence days to 50% flowering of Okumkom grown in both seasons (table 4). This observation could be attributed to differences in cultivar characteristic. Apomuden cultivar showed non significant increase in days to 50% flowering in response to fertilization in both seasons. This could be because this trait is much more influenced by the inherent characteristics of the crop than application of fertilizers. Apomuden grown on amended plots, especially, 15 – 15 – 15 kg/ha NPK + 5t/ha CM, 15 – 30 – 30 kg/ha NPK + 5t/ha CM and 10t/ha CM during the major season were earliest to flower than those grown on the same treatments during the minor season. The significant difference in days to flowering for Apomuden grown on amended plots might be due to differences in phosphorus, nitrogen and presence of boron in chicken manure. [16 and 17] have also indicated the need for nitrogen for plant growth, reproduction and photosynthesis. [21] indicated that phosphorus is essential for energy transfer in plants and helps early growth and plant maturation including flowering.

Table 4: Days to 50% flowering as influenced by chicken manure and inorganic fertilizer during (a) minor season, 2011 and (b) major season, 2012

Variety	Days to 50 % flowering (Minor season) Apomuden	Days to 50% flowering (major season) Apomuden
Fertilizer Rates		
10t/ha CM	63.0	59.0
15-15-15 kg/ha NPK + 5t/ha CM	58.0	53.0
15-23-23 kg/ha NPK + 5t/ha CM	59.0	65.0
15-30-30 kg/ha NPK + 5t/ha CM	62.0	60.0
30-30-30 kg/ha NPK	59.0	62.0
30-45-45 kg/ha NPK	57.0	62.0
30-60-60 kg/ha NPK	62.0	56.0
No fertilizer	62.0	68.0
Mean	60.3	60.6
LSD (P< 0.05)	NS	NS

Fresh Vine Weight at Harvest

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Apomuden and Okumkom grown on amended plots in both seasons had significantly higher fresh vine weight at harvest than the control except for Apomuden grown on 30 – 30 – 30 kg/ha NPK during the minor season (table 5). This result is similar to the findings of [13] and [22] and followed the trends in leaf number, number of branches and dry matter accumulation. The effect of organic and inorganic fertilization either singly or in combination on Okumkom was manifested as a significant influence on fresh vine weight at harvest over Apomuden across both cropping periods except for 15 – 15 – 15 kg/ha NPK +5t/ha CM. This might be due to differences in cultivar characteristics. Apomuden and Okumkom grown on amended and control plots during the minor season had significantly higher fresh vine weight at harvest than during the major season in 2012 although application of 15-15-15 kg/ha NPK + 5t/ha CM and 15-23-23 kg/ha NPK + 5t/ha CM resulted inthe highest fresh vine weight. The relatively high initial levels of soil nutrients, especially, total exchangeable Ca, Mg and ECEC at the experimental site during the minor cropping season might have accounted for the results obtained. Micronutrients in chicken manure and NPK fertilizer further improved the chemical properties of the soil resulting in high fresh vine weight at harvestin addition to carbon content in the manure is utilized as food by soil micro organisms which increases microbial activity to convert unavailable plant nutrients to available forms through biological mineralization [23].

Table 5: Fresh vine weight at harvest of sweet potato as influenced by poultry manure and inorganic fertilizer during minor season, 2011 and major season, 2012

	Fresh vine weight at harvest (t/ha) (minor season)			Fresh vine weight at harvest (t/ha) (major season)		
	Apomud.	Okumk.	Mean	Apomud.	Okumk.	Mean
Fertilizer rate						
10t/ha CM	19.0	64.5	41.7	4.60	16.00	10.30
15-15-15 kg/ha NPK + 5t/ha CM	20.0	59.0	39.5	6.92	6.30	6.61
15-23-23 kg/ha NPK + 5t/ha CM	27.0	63.5	45.2	4.80	20.23	12.52
15-30-30 kg/ha NPK + 5t/ha 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	

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LSD (0.05)	Variety	6.1	3 23
LSD (0.05)	Fertilizer	NS	NS
LSD (0.05)	Variety * Fertilizer	NS	NS

Yield and Yield Components of Sweet Potato

Marketable Tuber Number

In both seasons Apomuden grown on 10t/ha CM, 30 – 30 – 30 kg/ha NPK and 15 – 15 – 15kg/ha NPK + 5t/ha CM) recorded significantly higher marketable tuber number than Okumkom grown on the same treatments (table 6). [14] reported significant marketable tuber increases with both poultry manure and inorganic nitrogen inputs. The relatively lower soil fertility status, especially, nitrogen and ECEC [24], at both sites, the amended treatments would have supported better tuber formation in terms of numbers and weight as observed. The results obtained at both sites were similar to those found by [8] 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. [11] similarly indicated that addition of organic matter in combination with fertilizer can create a beneficial interaction. The findings of [25] however indicated that sweet potato clones utilize N differently and may require different N fertilization rates.

Generally, both sweet potato cultivars grown on amended and control plots during the major season gave marketable tuber numbers which were higher than yields obtained during the minor season. The poor climatic conditions as a result of long periods of drought at tuber bulking stage during the cropping period (September-December) might have accounted for lower number of marketable tubers during the minor season. [14 and 15], further indicated that rainfall can affect sweet potato response to nutrient input. [21], also reported that regular irrigation of sweet potato is required, especially when they are in the tuber formation stage.

Table 6: Number of marketable tubers as influenced by poultry manure and inorganic fertilizer during minor season, 2011 and major season, 2012

	Number of marketable tubers (minor season)			Number of marketable tubers (major season)		
	Apomud.	Okumk.	Mean	Apomud.	Okumk.	Mean
Fertilizer rate						

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10t/ha CM	14.0	10.0	12.0	31.0	20.0	25.0
15-15-15 kg/ha NPK + 5t/ha CM	22.0	9.0	16.0	37.0	20.0	28.0
15-23-23 kg/ha NPK + 5t/ha CM	19.0	19.0	19.0	36.0	35.0	36.0
15-30-30 kg/ha NPK + 5t/ha 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 * Fertilizer	NS			NS		

Unmarketable Tuber Number

The unmarketable number of tubers of Apomuden grown on amended and control plots was significantly higher than Okumkom during the minor season (table 7). The differences in cultivar characteristics with regard to lower number of branches and leaf numbers of Apomuden compared with Okumkom might have accounted for late canopy closure and subsequent dryer soils and high soil temperatures. [21] indicated that very dry soil results in small-sized tubers. According to [26] a relatively small increase in soil temperature can have a direct effect on tuber quality. Generally, both Apomuden and Okumkom grown on amended and control plots had significantly higher unmarketable tuber number during the major season than during the minor season. High initial rainfall during the major cropping period (April – July) might have negatively affected the quality of tubers. [9] indicated that excessive rain prevents proper root formation and that luxurious growing conditions caused by excessive watering or nitrogen can lead to vigorous vine growth and result in poorly developed stringy roots.

Table 7: Number of unmarketable tubers as influenced by chicken manure and inorganic fertilizer during minor season, 2011 and major season, 2012

	Number of unmarketable tubers (major season)			Number of unmarketable tubers (minor season)		
	Apomud.	Okumk.	Mean	Apomud.	Okumk.	Mean
Fertilizer rate						
10t/ha CM	35.0	22.0	29.0	11.0	6.0	8.0
15-15-15 kg/ha NPK + 5t/ha CM	24.0	19.0	22.0	16.0	6.0	11.0

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15-23-23 kg/ha NPK + 5t/ha CM	17.0	61.0	39.0	12.0	8.0	10.0
15-30-30 kg/ha NPK + 5t/ha 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 * Fertilizer	22.23			NS		

Total Tuber Yield

The effect of organic and inorganic fertilization either singly or in combination on both cultivars had a significant influence on tuber yield during the minor cropping season (table 8). The significantly higher total tuber yield observed in Apomuden grown on amended and control plots in the minor season over Okumkom could be attributed to the fact that is highly dependent on genetic make- up of a given trait than fertilization. Apomuden grown on 15 - 30 – 30 kg/ha NPK + 5t/ha CM plotshowever, recorded a significantly higher total tuber yield during the major season than during the minor season. This observation might be due to better climatic conditions coupled with the high initial fertility status of the soil [14] and [11].

The total tuber yield for both varieties grown on amended treatments, especially, 10t/ha CM during the minor season was relatively lower than during the major cropping season. The slow release of nutrients from chicken manure combined with intermittent long period of drought during the minor cropping season might have accounted for the low tuber yield in the10t/ha CM treatment. These results, obtained during the minor cropping season with 10t/ha CM, is similar to those found by [27] who reported that low nutrient content and slow mineralization of farm yard manure affects plant uptake during critical stages. The high vine fresh weight at harvest might have also contributed to the low total tuber yield

Table 8: Total tuber yield as influenced by poultry manure and inorganic fertilizer during minor season, 2011 and major season, 2012

	Total tubers yield (t/ha), (minor season)			Total tubers yield (t/ha), (major season)		
	Apomud.	Okumk.	Mean	Apomud.	Okumk.	Mean
Fertilizer rate						

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10t/ha CM	25.0	16.0	20.0	64.0	52.0	58.0
15-15-15 kg/ha NPK + 5t/ha CM	38.0	15.0	26.0	65.0	49.0	57.0
15-23-23 kg/ha NPK + 5t/ha CM	31.0	27.0	30.0	58.0	85.0	72.0
15-30-30 kg/ha NPK + 5t/ha 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			NS		
LSD (0.05) Fertilizer	NS			NS		
LSD (0.05) Variety x Fertilizer	NS			NS		

Tuber Length

Okumkom grown on amended plots had higher tuber length than that of control plots in both seasons except for 15 – 15 – 15 kg/ha NPK + 5t/ha CM treatment in the major season (table 9). However, Apomuden grown on amended and control plots recorded significantly higher tuber length than Okumkom in both seasons although Apomuden grown on 15 – 23 – 23 kg/haNPK+5t/ha CM had the lowest tuber length in the major season. The increase in tuber length of Apomuden grown on amended plots might be due to differences in cultivar and its response to increased soil fertility and structural stability of the manured soil, especially, the presence of chicken manure which might have enhanced penetration of tuber in the soil. [28] 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 [6], poultry manure improves the physical conditions of soil in terms of better water holding capacity, improved soil microbial activity, improved water infiltration and structural stability of the soil in addition organic matter improve soil bulk density creating a conducive environment for crops like sweet potato [29]. [30] 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.

Table 9 Average tuber length as influenced by poultry manure and inorganic fertilizer during minor season, 2011 and major season, 2012

	Average tuber length (cm), (major season)	Mean	AverageTuber length(cm), (minor season)	Mean

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	Apomud.	Okumk.		Apomud.	Okumk.	
Fertilizer rate						
10t/ha CM	19.43	17.57	18.50	15.82	14.00	14.91
15-15-15 kg/ha NPK + 5t/ha CM	22.29	16.83	19.56	15.00	12.12	13.56
15-23-23 kg/ha NPK + 5t/ha CM	19.38	20.03	19.71	14.30	12.02	13.16
15-30-30 kg/ha NPK + 5t/ha 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	NS			NS		

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 10). In both seasons Apomuden grown on 30 – 30 – 30 kg/ha NPK had the highest harvest index which might be due to the relatively high total tuber yield observed in both seasons with corresponding lower fresh vine weight at harvest. Okumkom grown on amended and unamended plots in both seasons hadlower harvest index than Apomuden grown on the same treatments. The high vine fresh weight at harvest for Okumkom compared to Apomuden with corresponding lower total tuber yield, especially, in the minor cropping season might have resulted in this observation. Higher fresh vine weight at harvest tends to lower tuber yield and consequently lower harvest index and could be attributed to high partitioning of assimilates to vegetative biomass at the expense of tuber (sinks). [10] have observed that high luxuriant growth of the vines as a result of nitrogen results in low storage root yield and consequently lower harvest index.

Table 10: Harvest index of sweet potato as influenced by poultry manure and inorganic fertilizer during minor season, 2011 and major season, 2012

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	Harvest index Minor season-2011			Harvest index Major season-2012		
	Apomud	Okumk	Mean	Apomud	Okumk.	Mean
Fertilizer rate						
10t/ha CM	0.55	0.21	0.38	0.61	0.21	0.41
15-15-15 kg/ha NPK + 5t/ha CM	0.66	0.22	0.44	0.57	0.36	0.47
15-23-23 kg/ha NPK + 5t/ha CM	0.57	0.35	0.46	0.58	0.41	0.50
15-30-30 kg/ha NPK + 5t/ha 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		

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) in both varieties (table 11). Even though there were non-consistent values obtained at the levels and statistically non-significant difference between Okumkom grown on amendment, application of inorganic fertilizer in combination with chicken manure tended to increase commercial harvest index in both seasons. Apomuden grown on amendment and the control plots recorded higher commercial harvest index during the major season than during the minor season indicating high marketable root yield production.. This result is in conformity with the findings of [32] who found quite high commercial harvest index of sweet potato in response to inorganic fertilizer in combination with chicken manure applied at planting.

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Table 11: Commercial Harvest index of sweet potato as influenced by poultry manure and inorganic fertilizer during minor season, 2011 and major season, 2012

	Commercial Harvest index (major season)			Commercial harvest index (minor season)		
	Apomud	Okumk	Mean	Apomud	Okumk.	Mean
Fertilizer rate						
10t/ha CM	0.93	0.88	0.90	0.88	0.87	0.87
15-15-15 kg/ha NPK + 5t/ha CM	0.95	0.91	0.93	0.90	0.91	0.91
15-23-23 kg/ha NPK + 5t/ha CM	0.97	0.80	0.88	0.89	0.93	0.91
15-30-30 kg/ha NPK + 5t/ha 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 * Fertilizer =	NS			NS		

Relationship Between Vegetative and Yield Parameters Measured on Sweet Potato for the Minor Season, 2011

Table 12a shows the relationship among number of leaves, number of branches, stem diameter, vine length, marketable tuber number, marketable tuber weight, total tuber weight, average tuber diameter, and average tuber weight for the minor season using correlation matrix. In the minor season (2011), there were highly significant positive correlation between 40% of the traits including total tuber weight and marketable tuber weight (0.99**), number of leaves and number of branches (0.89**), unmarketable tuber number and unmarketable tuber weight (0,89**), total tuber weight and marketable tuber number (0.80 **), marketable tuber weight and marketable tuber number (0.78**), vine length and number of branches (0.64**), stem diameter and number of branches (0.50**), and slightly positive correlation between marketable tuber weight and

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average tuber diameter (0.46**), and total tuber weight and average tuber diameter (0.42**). However, negative correlation occurred between number of branches and number of unmarketable tubers (-0.46**). Again, vine length and number of unmarketable tubers showed negative correlation (-0.44**), number of leaves and number of unmarketable tubers (-0.43**), number of leaves and marketable tuber number (-0.20). Generally, the vegetative growth was negatively correlated with tuber weight and market quality while tuber market quality was highly positively correlated with total weight of tuber. The vegetative characters were positively and significantly correlated with each other (Table 12a). Correlation analyses for both seasons showed that the vegetative growth was negatively correlated with tuber weight and market quality while tuber market quality was highly positively correlated with total weight of tuber. The vegetative characters were positively and significantly correlated which suggests a weak association among number of leaves and yield parameters. This observation might be due to high soil nitrogen

Table 12a: Correlation Matrix among Growth and Yield Parameters during the Minor Season, 2011

	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	-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	

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Table 12b: Correlation Matrix among Growth and Yield Parameters During the Major Season, 2012

	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	-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

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Table 12b shows the relationship among number of leaves, number of branches, stem diameter, vine length, marketable tuber number, marketable tuber weight, total tuber weight, average tuber diameter, and average tuber weight for the major season using correlation matrix. In the major season (2012), there were highly significant positive correlation between 40% of the traits including total tuber weight and marketable tuber weight (0.98**), number of leaves and number of branches (0.93**), unmarketable tuber number and unmarketable tuber weight (0,91**), total tuber weight and marketable tuber number (0.71**), marketable tuber weight and marketable tuber number (0.70**), marketable tuber weight and average tuber diameter (0.0.68**), and, total tuber weight and average tuber diameter (0.66**), and slightly positive correlation between vine length and number of branches (0.49**), stem diameter and number of branches (0.39**). However, negative correlation occurred between number of branches and number of unmarketable tubers (-0.26). Again, number of leaves and marketable tuber number showed negative correlation (-0.22), stem diameter and marketable tuber weight (-0.15). Generally, the vegetative growth was negatively correlated with tuber weight and market quality. While tuber market quality was highly positively correlated with total weight of tuber. The vegetative characters were positively and significantly correlated with each other (Table 12b).

CONCLUSION

Increased soil organic matter from organic manure in combination with inorganic fertilization improved both soil physical and chemical properties compared to the application of inorganic fertilizer alone and the control. 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 poultry manure and inorganic fertilizer application. In this study the application of chicken manure and inorganic fertilizer as mineral supplements either singly or in combination generally increased the yield and market qualities of sweet potato especially Apomuden grown on 15 – 15 – 15 kg/haNPK +5t/ha CM and 15 – 30 – 30 kg/haNPK+ 5t/ha CM in both seasons although increased tuber crack was recorded with these treatments. However, application of 15 – 23 – 23 kg/ha NPK + 5t/ha CM to Okumkom increased the vegetative biomass of sweet potato during major cropping season in 2012 compared to minor season in 2011 although increased forked tubers was recorded in both seasons. Farmers may significantly improve yields and vegetative biomass of sweet potato through the application of chicken

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manure in combination with inorganic fertilizer to Apomuden and Okumkom respectively. However for increased marketable and unmarketable tuber number farmers should manure their plots and plant Okumkom during the major season.

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