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Evaluation of different sweet potato varieties for growth, quality and yield traits under chemical fertilizer and organic amendments in sandy ferralitic soils

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Growth, quality and yield components of sweet potato ((*Ipomoea batatas* (L.) Lam. Var. Tib1, IRA1112 and Red tuber coat) were investigated under three fertilizer sources (inorganic-NPK (100 kg/ha), green manure (*Eichhornia crassipes*) or poultry manure at 12 t/ha, singly or in combination) with three replications. Application of *E. crassipes* and poultry manure fertilizers in combination significantly (P < 0.05) increased the shoot length, tuber yield, chlorophyll content and harvest index in all varieties. The highest plant dry weight (480.60 g/plant), shoot length (263.23 cm), number of leaves (75.33) and tuber yield (18.66 t/ha) harvested were found in Tib1 when plants were supplied with both *E. crassipes* and poultry manure; while the lowest plant dry weight (62.54 g/plant), shoot length (195.45 cm) and tuber yield (2.11 t/ha) were recorded in Red tuber coat when plants were enriched only with inorganic-NPK. Leaf protein content of sweet potato varieties was positively influenced by inorganic-NPK, *E. crassipes* and poultry manure, singly or in combined treatments compared to leaf lipid and carbohydrate contents. A combination of high-yielding sweet potato varieties (Tib1) and adequate use of *E. crassipes* and poultry manure, singly or in combination could enhance sweet potato growth performance in sandy ferralitic soils.

Key words: Field performance, nutritional potential, soil amendments, fertilizer, *Ipomoea batatas.*

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is a vegetable used as human diets component. It is a source of mineral, vitamins, some hormones precursors, proteins and energy. It is an herbaceous and rambling vegetable with smooth, green-like leaves having a purple pigmentation along their veins. The major economic part of this plant is the starchy tuberous root (Oyenuga and Fetuga, 1975; Antia et al., 2006). Its leaves are used to accompany the dishes of yam and cocoyam in some parts of Nigeria, namely among the Efik-Ibibio people of South-Eastern Nigeria (Antia et al., 2006). Moreover, it can be used as fodder and browse for cattle, sheep, goats, pigs and other domestic animals (Oyenuga, 1968). Hence, its leaves look like an essential component of diets.

In Sub-Saharan Africa, vegetables are necessary dietary components for soup or sauces that accompany

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carbohydrates. Its tuber crops provide carbohydrates while its leaves are major sources of vitamins, dietary fibers, essential amino acids and antioxidants (Fasuyi, 2006; Nkongho et al., 2014). In Cameroon, sweet potato is traditionally consumed in boiled form with varying accompaniments including cowpea, rice and millet. Plant nutrients are the main source of carbohydrates, proteins, minerals and dietary fibers as well as other bioactive nutrient compounds. The growth and yield of potato and sweet potato is affected by factors such as stem density, plant population and nutrient supply (Masarirambi et al., 2012; Sayanowako et al., 2014).

Despite the importance or the well-known health advantages of sweat potatoes, their disposability and consumption are still insufficient in tropical and sub-tropical Africa. This may be due to low production, seasonality and their vulnerability to various environmental stresses. Hence, organic and inorganic fertilizers are required to improve the yield and the growth rate of sweet potato. However, the use of inorganic fertilizer in the singularized form may have a negative impact on human health and the environment (Arisha and Bardisi, 1999; Basel and Atif, 2008).

Plant metabolism requires minerals such as nitrogen (N), phosphorus (P) and potassium (K). Among these minerals, N amount should be the highest as a deficiency of N will reduce the total dry matter, fruit N intake, protein content and grain yield (Mark et al., 1983). N is needed during leaf formation and contributes to increase the growth and size of tuber; furthermore, it enhances photosynthesis in the leaves (Taffouo, 1994).

Providing N at an early stage of crop development would make up for the overall size of the leaf canopy. When provided at a later stage of growth, N contributes to maintain the greenness and maximize the yield of the canopy. In cowpea plants, the amount of N required for the development of pods comes from root uptake, symbiotic N_2 fixation and N mobilization in vegetative tissues (Douglas and Weaver, 1993). It has been underlined that high dose of P could compensate the loss in grain yield of wheat associated to late sowing, and then it enhances root and seedling development (Blue et al., 1990).

At the vegetative and pod filling stages, cowpea plant supplied with low P fertilization revealed a significantly higher root colonization than the one supplied with medium and high P fertilization (Taffouo et al., 2014). The wheat grain yields increased when supplied with 60 to 120 kg P/ha of crop fertilizer, the maximum being 120 kg P/ha (Hussain et al., 2008).

It has been underlined that when K is in short supply, the enlargement of root or tuber is more depressed than leaf development (Inal, 1997). Length, strength and thinness of fiber in both cotton and ramie may be improved by balancing N and P, with adequate K (Zheng, 1999). Plant height and stem yield were influenced by K fertilization while stem number did not change (Tatar et al., 2010).

Physical and chemical properties of soil such as water retention, erodibility, cation exchange capacity and nutrients availability are affected by their organic matter amount (Rice, 2002; Deksissa et al., 2008). Moreover, these systems are beneficial for the overall health of agro-environment, development and management of effective fertilization practices like the manipulation of the quantity and type of organic amendments, thus improving soil ecosystems and fertility (Nzguheba et al., 2004; Manqiang et al., 2009). The sustained productivity of agricultural systems is needed for the level of soil organic matter and the optimization of nutrient cycling to be maintained (Odendo et al., 2004; Khan et al., 2013).

Regardless of the provision of nutrients available for plants by organic amendments, nutrients transformation during the decomposition of organic matter strongly interacts with nutrients uptake by plants, leading to competition between soil microorganisms and plants for available nutrients (Kaye and Hart, 1997). Organic manure can be used to replace mineral fertilizer (Wong et al., 1999; Togun and Akanbi, 2003; Naeem et al., 2006) in order to enhance soil structure (Dauda et al., 2008), microbial biomass (Suresh et al., 2004) and plant growth (Radwan et al., 1993). Hence, the use of manures produced by vegetables may improve crop yield and reduce the use of chemical fertilizers.

Nowadays, consumers are more interested in quality and safe food stuff than paying attention to organic products (Bhattacharyya et al., 2008; Basel and Atif, 2008). Farmers' participation in the advanced stages of sweet potato variety selection has been reported to be successful in Ethiopia, Kenya and Uganda (Ndolo et al., 2001; Abidin, 2004; Laurie and Faber, 2008).

The application of 60 kg/ha organic manure with 60 kg/ha inorganic fertilizer can raise the yield of *Brassica oleracea* to the optimum rate (40.05 t/ha) (Ouda and Mahadeen, 2008). The application of foliar fertilizer, urea, *Tithonia* and nitrogen (N), phosphorus (P) and potassium (K) (NPK) recorded the highest growth, and yield must be adopted by farmers to maximize their yields (Kwayep et al., 2017). In a survey on the production and use of sweet potato in 14 areas of South Africa, the main factors hindering sweet potato production were low yields and yield instability resulting from the use of old landraces (Thompson et al., 1999).

The need for worthy changes in the global food system has been underlined: agriculture must overcome both the challenges of feeding a growing population with a rising demand for meat and high calorie diets (Laurie and Faber, 2008; Seufert et al., 2012). Sweet potato contributes highly to the diet of many people in the tropics, more especially in Cameroon. But its production is seriously affected by poor soil fertility. The use of poultry manure as an organic amendment to restore worn-out soils can thus be encouraged (Sanchez-Monedero et al., 2004). The green manure such as *E.*

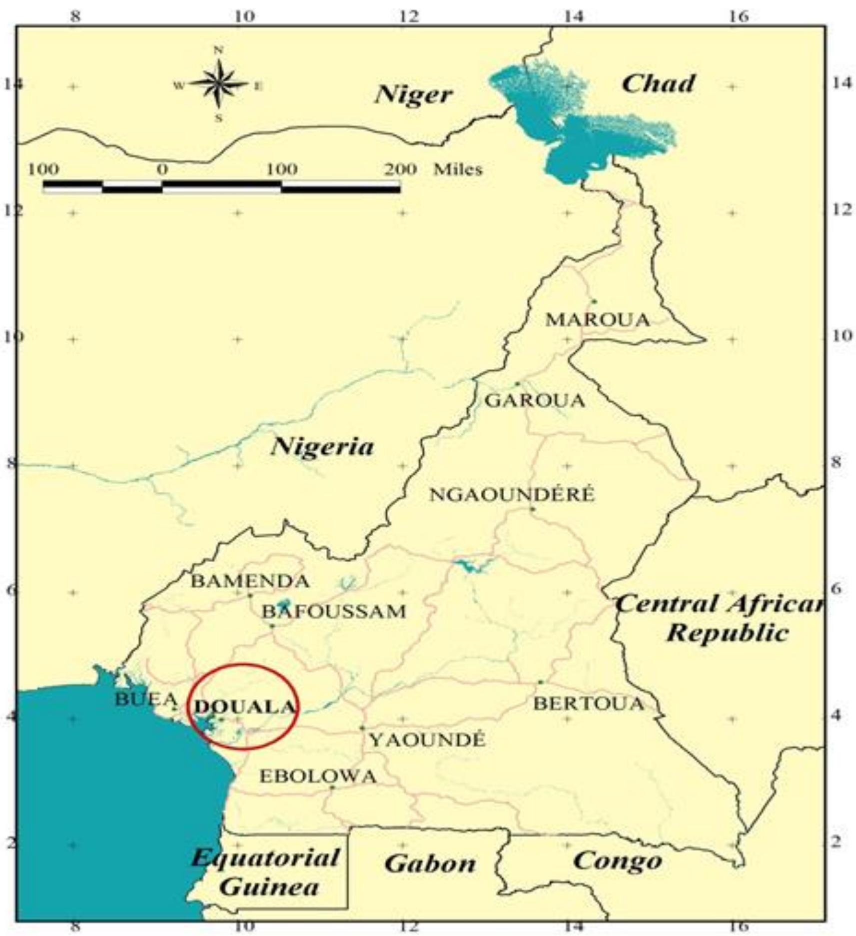

Figure 1. Map of the study area.

crassipes must be also used to replace soil nitrogen and other elements, and to build up soil organic matter content (Hammad et al., 2011; Wamba et al., 2012).

The objective of this study is to evaluate the physiological and agronomic responses of sweet potato (*Ipomoea batatas*) under chemical fertilizer and organic amendments in sandy ferralitic soils for increasing sweet potato production.

MATERIALS AND METHODS

Description of the study site

The study was conducted in the coastal region of Cameroon in the experimental field of the University of Douala during 2013 and 2014 cropping seasons. The study site (Figure 1) is located on the geographic coordinates of 4°01' North latitude and 9°44' East longitudes. The altitude is about 13 m. The climate is of equatorial type with Cameroonian features and with two seasons per year: one short dry season (3 months) and a longer rainy season (9 months); it has an average annual rainfall of 3597 mm and an average annual temperature of 26.7°C. The relative humidity is usually high and close to 90% throughout the year. The experimental site has yellow sandy loam ferralitic soils.

Experimental design and procedures

Three sweet potatos (Tib1 and IRA112 a selected variety and Red-tuber coat local variety), inorganic fertilization (100 kg/ha NPK) and two organic fertilizers such as green manure (*E. crassipes*) and poultry manure applied at 12 t/ha were used singly or in combination in a randomized block design experiment with three replications (Wamba et al., 2012). Before the experimentation, the nutrient contents (g/kg) of *E. crassipes* plant samples (127.16 N, 87.62 P and 214.34 K) and poultry manure (21.76 N, 8.74 P and 11.22 K) were determined. N was applied as urea (46% N), whereas P and K were used as simple superphosphate (7.9% P) and potassium chloride (49.8% K), respectively. Each sub-plot had 4 x 4 m area. The potato stem fragments (cuttings) cut to 30 cm with 6 nodes were collected from the apical portions of the plant at maturity (Taffouo, 1994). These selected cuttings were introduced in the ground at the level of the stem's median region with a 30 cm spacing in order to have a population of 90 000 plants/ha. The treatment with the various fertilizers was done three weeks after planting (WAP). Thiodan (endosulfan organochlorate insecticide) was applied to the soil 4 to 8 WAP, as a preventive pre-emergence measure to fight against pests. The parameters assessed at harvest were the plant dry weight, shoot length, number of leaves

Table 1. Physico-chemical properties of the soil (0-20 cm).

Parameter	Units	Value
Texture	-	Sandy loam
Clay	(%)	14.20 (1.2)[a]
Sand	(%)	53.50 (1.9)
Silt	(%)	32.30 (1.05)
Nitrogen	(%)	0.32 (0.01)
Organic C	(%)	0.75 (0.05)
Ratio C/N	-	2.34 (0.02)
Phosphorus	(ppm)	4.60 (0.1)
Potassium	(g Kg^{-1})	0.25 (0.02)
Sodium	(g Kg^{-1})	0.07 (0.01)
Calcium	(g Kg^{-1})	0.23(0.01)
Magnesium	(g Kg^{-1})	0.17 (0.01)
Zinc	(g Kg^{-1})	0.29 (0.02)
Cu	(g Kg^{-1})	1.42 (0.01)
Fe	(g Kg^{-1})	3.26 (0.1)
pH- Water	-	6.45 (0.1)

[a]Values in parenthesis represent the standard error of the mean.

per plant, stem diameter, total chlorophyll content, tuber yield and harvest index.

Soil, green and poultry manures sampling and determination of soil physical and chemical properties

Soil samples were taken using auger from the experimental site from a depth of 0 to 20 cm. Ten sub-samples were chosen to get a composite sample for the analysis of soil physical and chemical properties (Table 1). *E. crassipes* samples were washed with distilled water, pressed under blotting-paper and their fresh weight recorded. The plant samples were then air-dried, crushed and sieved using a 2 mm sieve. The poultry manure was stocked in an airtight recipient at 22°C before use. The following chemical analyses were done to the soil, the green crop manure and the poultry manure: Organic carbon (C) was determined using humid oxidation procedure (Walkley and Black, 11934) and total nitrogen (N) by Kjeldahl method. Magnesium (Mg) was extracted using Mehlich 3 method and determined by Technicon autoanalysers (Technicon 2). Total available phosphorus (P) was determined by Okalebo et al. (1993) method. The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter. Calcium (Ca), potassium (K) and sodium (Na) were determined using a flame photometer (JENWAY) as described by Taffouo et al. (2008).

Plant sampling and determination of growth and yield characteristics, protein, lipid and carbohydrate contents

The plants were sampled at complete maturity 12 WAP, for their dry weight, shoot length, total chlorophyll content, number of leaves per plant and tuber yield. Ten plants from which measures of shoot length were taken periodically 4, 8 and 12 WAP were identified randomly per plot. Ten plants were also randomly selected in each plot, and their aerial parts were cut at ground level; their fresh weight was registered. A representative sub-sample of about 1000 g per plot was dried in an oven at 70°C for 72 h in order to determine its dry weight. The fresh tubers were carefully uprooted and weighed. Harvest index was determined as a ratio of yield to total plant biomass (shoots plus roots). Chlorophyll content in leaves was estimated after extracting 20 mg of the ground material, following the procedure described by Arnon (1949). Chlorophyll of samples was extracted with 80% alkaline acetone (v/v). The absorption of the extracts was measured at 663 nm and 645 nm with a spectrophotometer (BECKMAN DU 68). For quantifying tissue lipid content, the Soxhlet was used for extraction with hexane as solvent (Taffouo, 1994). The total carbohydrates and protein contents were determined using AOAC (1995).

Statistical analysis

Results obtained are expressed as mean ± standard deviation, and analyzed using statistical package for social sciences (SPSS) software. Statistical differences between treatment means were established using the Fisher least significant difference (LSD) test at p values<0.05. Analysis of variance (ANOVA) was used to estimate whether varieties, fertilization type, singly or in combination had a significant influence on the measured parameters. The multiple comparisons of data in experimental groups compared to those recorded in the control group were done using Dunnett's procedure (Sigma Stat 2.03 software).

RESULTS AND DISCUSSION

Plant growth

Means of the growth traits of the sweet potato varieties (12 WAP) are depicted in Table 2 and Figure 2. Application of inorganic-NPK significantly (P< 0.05) influenced the dry weight in Tib1, and the shoot length in Tib1 and IRA1112, on the contrary, led to a significant (P< 0.05) decrease of shoot length and number of leaves per plant in Red tuber coat compared to untreated plants (Table 2, Figure 2).

Similar results were obtained by Wong et al. (1999), Magnusson (2002), Basel et al. (2008), Ouda and Mahadeen (2008) and Wamba et al. (2012) on several vegetable crops. Numerous studies have reported that inorganic-NPK fertilizer increased growth in some species by enhancing nitrogen, phosphorus and potassium uptake (MMhango et al., 2008; Anyanzwa et al., 2010; Bado et al., 2010; Shehu et al., 2010; Tauro et al., 2010; Bala et al., 2011).

Nitrogen, phosphorus and potassium are among the essential elements required for plant metabolism and the improvement of soil water-holding capacity (Wamba et al., 2012). Nitrogen is largely needed during leaf formation and then for increasing tuber growth and size, when it ensures optimal photosynthate production in the leaves (Taffouo, 1994). Nitrogen fed at an early stage of crop development will help build the overall size of the leaf canopy, whereas at later stage of growth, nitrogen helps maintain the greenness of the canopy and maximize yield (Mark et al., 1983).

Poultry manure and *E. crassipes* supply singly

Table 2. Effect of organic and inorganic fertilization sources on growth characteristics of sweet potato cultivars (12 WAP).

Treatment	Plant growth parameters								
	Shoot length (cm)			Stem diameter (cm)			No. of leaves per plant		
	Tib1	IRA1112	Red tuber coat	Tib1	IRA1112	Red tuber coat	Tib1	IRA1112	Red tuber coat
Control	130.00±7.81^{c}	101.50±5.48^{c}	203.92± 5.68^{c}	8.82±0.35^{a}	6.58±0.15^{a}	5.52±0.26^{a}	68.14±3.60^{b}	33.66±3.05^{b}	38.33±2.51^{a}
NPK	156.58±4.55^{a}	125.86±6.22^{a}	195.45±4.90d	9.21±0.17^{a}	7.37±0.30^{a}	5.32±0.15^{a}	71.45±4.18^{b}	33.40±2.11^{b}	31.65±1.32^{b}
GM	214.20±5.56d	99.50±5.39^{c}	205.11±6.08^{c}	8.65±0.14^{a}	6.60±0.25^{a}	5.24± 0.11^{a}	70.66±2.08^{b}	36.66±2.80^{b}	37.66±1.73^{a}
PM	240.70±3.52^{b}	111.79±5.16^{b}	220.52±5.02^{b}	9.40±0.52^{a}	7.16±0.20 ^{a}	5.38± 0.18^{a}	72.48±5.01^{b}	37.52±3.31^{b}	37.52±2.67^{a}
GM+PM	263.23±6.24^{a}	121.45±6.35^{a}	235.22±8.08^{a}	10.34±022^{a}	7.45±022^{a}	5.63±0.26^{a}	75.33±0.21^{a}	40.33±2.51^{a}	38.68±3.71^{a}

Means±SE (n=10) with different letters in the same columns are significantly different (*P*<0.05). NPK: nitrogen, phosphorus and potassium fertilizers, GM: *Eichhornia crassipes*, PM: poultre manure.

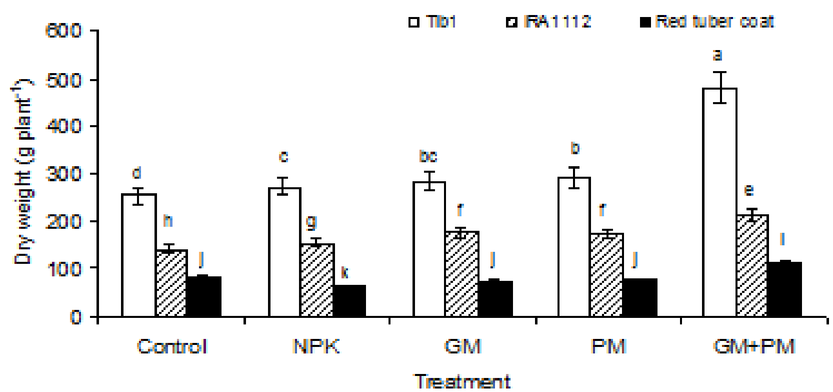

Figure 2. Effects of organic and inorganic fertilizers on dry weight (g plant^{-1}) of sweet potato cultivars. NPK: nitrogen, phosphorus and potassium fertilizers, GM: *Eichhornia crassipes*, PM: poultry manure. Means followed by the same letter are not significantly different (P <0.05) as determined by Duncan test. Bars indicate standard deviation.

or in combination had significant effects on plant growth compared to untreated plants (Table 2). Application of poultry manure singly or in combination with *E. crassipes* led to a significant (P< 0.05) increase in dry weight and shoot length of all varieties compared to untreated plants (Table 2, Figure 2). Poultry manure is a readily available nutrient source for crop production (Boateng et al., 2006; Schomberg et al., 2011).

Incorporation of poultry manure into soil promoted transformation and mineralization of less-labile inorganic and organic phosphorus into labile-P_i in the rhizosphere, which resulted in higher root phosphorus concentrations and higher total phosphorus uptake by plants (Waldrip et al., 2011). Regardless of the provision of available nutrients for plants by organic amendments, nutrients transformation during the decomposition of organic matter strongly interacts with nutrients uptake by plants, leading to competition between soil microorganisms and plants for available

Table 3. Effect of organic and inorganic fertilization sources on yield components of sweet potato varieties (12 WAP).

Treatment	Tuber yield (t ha^{-1})			Leaf chlorophyll content (mg g^{1} FW)			Harvest Index (%)		
	Tib1	IRA1112	Red tuber coat	Tib1	IRA1112	Red tuber coat	Tib1	IRA1112	Red tuber coat
Control	10.33^{c}	11.01^{b}	4.10^{b}	30.55^{c}	24.06d	23.13^{c}	0.45^{b}	0.87^{a}	0.57^{a}
NPK	11.77^{c}	9.78^{c}	2.11^{c}	38.25^{b}	30.34^{c}	27.67^{c}	0.48^{b}	0.69^{b}	0.37^{b}
GM	14.00^{b}	10.66^{b}	4.33^{b}	41.10^{ab}	34.47^{bc}	33.59^{b}	0.55^{a}	0.68^{b}	0.66^{a}
PM	14.35^{b}	10.55^{b}	4.19^{b}	43.23^{a}	36.33^{b}	34.67^{b}	0.54^{a}	0.68^{b}	0.63^{a}
GM+PM	18.66^{a}	14.33^{a}	6.00^{a}	47.57^{a}	45.32^{a}	43.66^{a}	0.43^{b}	0.74^{b}	0.61^{a}

Means±SE (*n*=10) with different letters are significantly different (*P*<0.05). NPK: nitrogen, phosphorus and potassium fertilizers, GM: *Eichhornia crassipes*, PM: poultre manure.

Table 4. Probabilities of significance for analyses of variance of growth characteristics, yield components and quality in sweet potato varieties grown under organic (*Eichhornia crassipes* and poultre manure, in combination) fertilization.

Trait	Fertilization	Variety	Fertilization x Variety
Dry weight	*	*	*
Shoot length	*	*	NS
Stem diameter	*	*	NS
No. of leaves per plant	*	*	NS
Tuber yield	**	*	*
Leaf chlorophyll content	**	*	*
Harvest Index	**	*	*
Leaf proteins	*	*	*
Leaf lipids	*	NS	NS
Leaf carbohydrates	*	*	NS

*, ** Significant at P <0.05 and P <0.01, P <0.01 respectively; ns: not significant.

nutrients (Kaye and Hart, 1997). There were no significant differences in stem diameter and number of leaves per plant in all the varieties except in Tib1 and IRA1112 when poultry manure and *E. crassipes* were supplied in combination (Table 2).

A significant (P< 0.05) two-way interaction between the factors variety and organic fertilization sources was observed for dry weight (Table 4). These results could be explained by the fact that the combination of the organic manures activates many microorganisms, which release phytohormones and may stimulate the plant's growth and absorption of nutrients (Arisha et al., 2003). These results could also be due to an increase in organic matter caused by the generation of carbon dioxide during compost decomposition and improvement in the soil structure conditions and root development by improving soil aeration (Arisha et al., 2003).

According to Hossner and Juo (1999), organic matter increases the capacity of the soil to buffer changes in pH, enhances cation exchange capacity (CEC), reduces phosphate fixation and serves as a reservoir for secondary nutrients and micronutrients.

Yield traits

The tuber yield, total chlorophyll content and harvest index (12 WAP) were affected by inorganic-NPK, poultry manure and *E. crassipes* fertilizers supply singly or in combination in all varieties (Table 3). Previous studies have shown that high dose of P can compensate for the loss in grain yield of wheat and cowpea, since it helps in rapid development of root and seedling (Blue et al., 1990; Karikari et al., 2015). There was a progressive increase in grain yield of wheat from 60 to 120 kg P/ha from the crop fertilized with 120 kg P/ha (Hussain et al., 2008).

It is commonly observed that root or tube enlargement is depressed relatively more than leaf development, when potassium is in short supply (Inal, 1997). Zheng (1999) stated that balancing nitrogen and phosphorus with adequate potassium improves length, strength and thinness of fiber in both cotton and ramie. Potassium fertilization impacted plant height and stem yield, whereas stem number did not change (Tatar et al., 2010).

The direct effect of potassium on yield is less marked than nitrogen, which constitutes a part of the organic matter synthesized during growth (Abdel-Motagally and Attia, 2009). In agreement with the results obtained by Christianson and Vlek (1991) and Chukwuka et al. (2015), inorganic-N, P and K in combination is a key element in the production of vegetables as it enhances yield by promoting cell division, expansion in leaves and root development.

According to Maiti and Jana (1985), the combined supply of inorganic-N and K is beneficial for protein metabolism that promotes cell division and enlargement, resulting in higher yield of *sesamum* seeds. Furthermore, inorganic-N, P and K in combination increased root density and proliferation. It aids extensive soil exploration and supply of nutriments and water to the growing plant. This results in increased growth and yield traits, thereby ensuring more dry matter yield (Shehu et al., 2010).

The combination of the poultry manure and *E. crassipes* fertilizers showed significantly (P< 0.05) higher tuber yield in Tib1 and IRA1112 than Red tuber coat compared to the plants fed with inorganic-NPK, poultry manure and *E. crassipes* singly (Table 3). Similar results were found by Abdelrazzag (2002) on *Allium cepa* var. Geza. Organic matter is a key component of soils which affects their physical and chemical properties such as water retention, erodibility, cation exchange capacity and nutrient availability (Rice, 2002; Deksissa et al., 2008). The maintenance of soil organic matter levels and the optimization of nutrient cycling are essential for the sustained productivity of agricultural systems (Ayuke et al., 2004; Khan et al., 2013).

Application of inorganic-NPK, poultry manure and *E. crassipes* fertilizers increased significantly (P< 0.05) the total chlorophyll in all varieties compared to control (Table 3). These results are similar to those obtained by Wamba et al. (2012) which found that total chlorophyll content increased markedly with the supply of both organic and inorganic fertilizers.

According to Maiti and Jana (1985) and Kilinc et al. (2005), organic and inorganic fertilizers contain macro and trace elements that increase root density and proliferation thereby favoring water and nutrient uptake for the growth of the different plant organs. This favors increase in dry weight and total chlorophyll content. The harvest index decreased significantly (P< 0.05) in IRA1112 while no significant differences were found between Tib1 and Red tuber coat except when the poultry manure and green manure fertilizers were supplied singly in Tib1 (Table 3). A significant (P< 0.05) two-way interaction between the factors variety and organic fertilization sources was observed for tuber yield, leaf chlorophyll content and harvest index (Table 4). Katwate et al. (2011) reported that grain yield was influenced by varieties and fertilizers in *Sesamum indicum*.

Proteins, lipids and carbohydrates contents

Application of inorganic-NPK, poultry manure and *E. crassipes* fertilizers supply singly or in combination had a positive effect on leaf proteins content, on the contrary, decreased significantly (P< 0.05) the carbohydrate contents in all varieties compared to untreated plants (Figure 3). The increase in leaf proteins content with application of inorganic-NPK and organic manure may be due to better nutrient availability and its uptake by plants (Channabasanagowda et al., 2008).

A higher value of leaf proteins content could be attributed to the ability of organic manure to supply nutrients throughout mineralization and improvement of the physical and chemical properties of the soil and the ability of organic fertilizer to release nutrients gradually throughout the growing season (Ouda and Mahadeen, 2008). An adequate supply of nitrogen to plants is beneficial for carbohydrate and protein metabolism resulting in higher yield (Shehu et al., 2010), while nitrogen deficiency may result in the reduction of total dry weight, lower intake of nitrogen into fruits, and less protein content and grain yield (Mark et al., 1983).

Taffouo et al. (2014) reported that nitrogen is directly transferred from the roots towards the leaves of leguminous plants where the nitrogen compounds are used for protein biosynthesis. According to Maiti and Jana (1985), the combined supply of inorganic-N, P and K is beneficial for protein metabolism. No significant differences were found in lipid content of leaves when plants were supplied with inorganic-NPK, poultry manure and *E. crassipes* supply singly except for IRA1112 with poultry manure and green manure combination treatment (Figure 3). This might have led to the increase in lipid and carbohydrates metabolism which helps in increasing the protein content in leaf (Taffouo, 1994; Channabasanagowda et al., 2008).

Conclusion

The dry weight, shoot length, tuber yield and chlorophyll content were positively influenced by the combination of poultry manure and *E. crassipes* fertilizers in all varieties. Tib1 showed higher dry weight, shoot length, tuber yield and chlorophyll content when plants were supplied with poultry manure and *E. crassipes* fertilizers in combination; while the lowest plant dry weight, shoot length and tuber yield were recorded in red tuber coat when plants were enriched only with inorganic-NPK. Leaf protein contents of sweet potato varieties were positively influenced by inorganic-NPK, poultry manure and *E. crassipes* fertilizers singly or in combination compared to leaf lipid and carbohydrate contents. In the analysis of

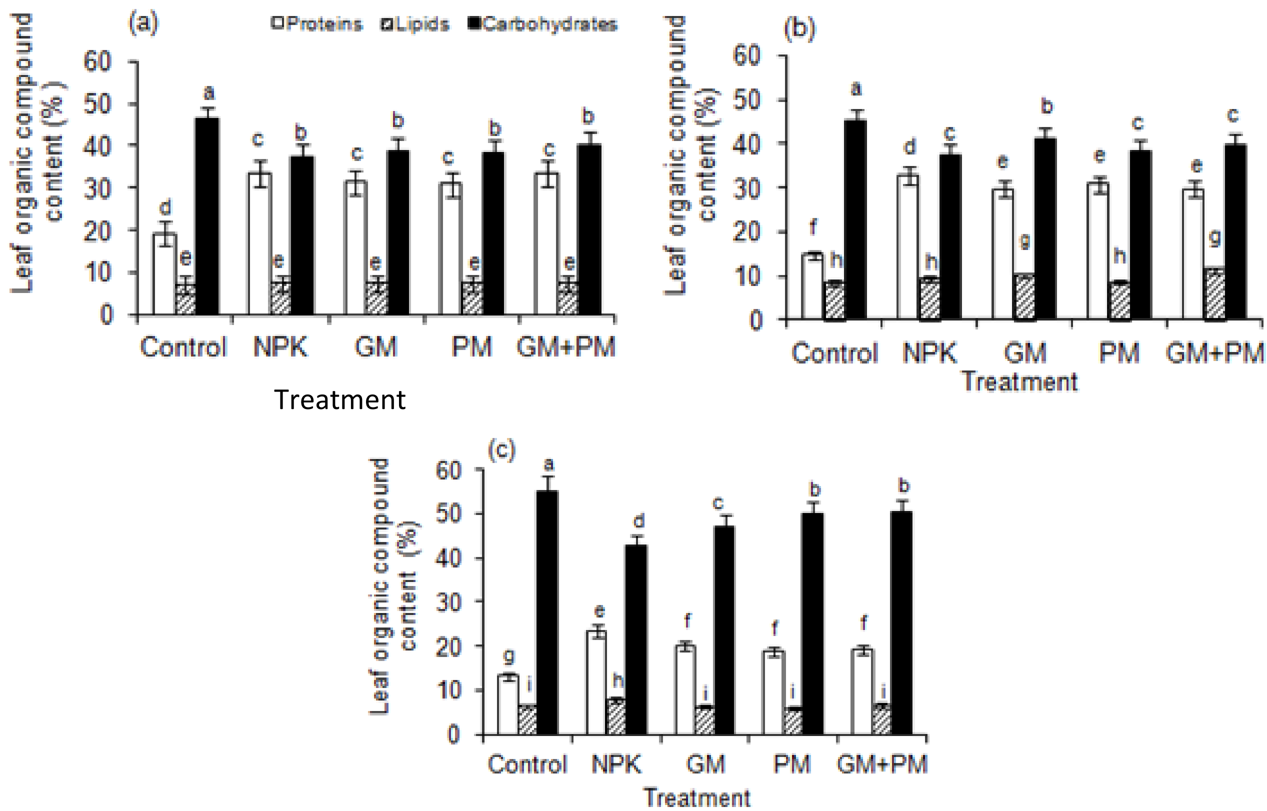

Figure 3. Effects of organic and inorganic fertilizers on leaf proteins, lipids and carbohydrates (g 100 g DM^{-1}) of sweet potato cultivars. (a): Tib1, (b): IRA1112, (c): Red tuber coat, NPK: nitrogen, phosphorus and potassium fertilizers, GM: *Eichhornia crassipes*, PM: poultry manure. Means followed by the same letter are not significantly different ($p < 0.05$) as determined by Duncan test. Bars indicate standard deviation.

combined growth, nutritional potential of leaves and yield components of the parameters measured, Tib1 showed higher field performance than other varieties studied**.** A combination of high-yielding sweet potato varieties (Tib1) and adequate use of poultry manure and *E. crassipes* fertilizers singly or in combination could enhance sweet potato growth performance in sandy ferralitic soils.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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