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Influences of organic waste and inorganic fertilizer for sustainable production of plantain (*Musa* spp. AAB) in a humid forest zone of Cameroon

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Plantain is commonly grown in gardens and small farms where productivity usually declines over time due to soil nutrient depletion. This soil fertility problem could be overcome if the nutrients removed from harvests are replaced with available fertilizers. This study assessed growth, yield, and cost effectiveness of plantain under organic and inorganic fertilization in the humid forest zone of Cameroon. The experiment design was a Complete Randomized Block Design with 5 single and 3 combined treatments of urea and NPK and/or poultry manure or coffee husk or cocoa pod residue. All the fertilized plantain produced significantly (*P=0.001*) taller plants with wider stem circumference, more functional leaves, and number of leaves produced than the control. Also, yield charateristics like bunch weight, number of hands per bunch, finger length, circumference and weight were significantly higher (*P=0.001*) on treated soils than the control, especially soil treated with 12 tons ha^{-1} of poulty manure. The cost/benefit ratio of the control plots had the least benefit when compared with the other treatments. This study shows that poultry manure is more suitable for small scale plantain farms meanwhile NPK fertilizer for large scale farming.

Key words: Plantain, poultry manure, coffee husk, cocoa pod, bunch yield, cost/benefit ratio.

INTRODUCTION

Plantain and bananas (*Musa* spp.) are among the major staple food commodity in the world and are ranked fourth after rice, wheat, and maize (FAO, 2012). Unlike the dessert banana (AAA) produced at a commercial scale for export, plantains (AAB) and cooking bananas (ABB) are mostly produced and consumed locally in Cameroon and many other developing countries. In these countries, plantains and some varieties of cooking bananas are

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grown in many rural communities, which provide approximately 25% of the food energy needed by people in Sub Saharan Africa (Okolle et al., 2009). Plantain and banana are rich in carbohydrates and some minerals such as phosphorus needed for bone development, calcium and potassium and even iron. They also contain important source of nutrients containing polysaccharides, sugars, and vitamins such as vitamin A, C, B6, and others trace elements (Hui et al., 2006). Plantains do not contain fat and oil and have low sodium which makes them good in salt-free and cholesterol-free diets; as well as beneficial health properties and reduced risk for some forms of cancer, heart disease, stroke and other chronic ailments due to the presence of antioxidants and biologically active ingredients (Nelson *et al.*, 2006; Park et al., 2011). With these nutritional values, inhabitants of Cameroon have plantain as their favorite staple food (Dury et al., 2002) and are consumed in all forms.

The crop produces fruits through out the year and excess from household consumption are sold at farm gate price and later to urban communities creating a constant economic mobility between the rural and urban areas (Chandler, 1995).

The importance of plantains to variety of meals in Cameroon cannot be underestimated. The plantain fruits are consumed in Cameroon in different forms such as; roasted, fried into “dodo” or “chips”, boiled ripe or unripe, dried into plantain flour and paste, cooked porridge and pounded. They can be fermented to produce beverages such as plantain juice and beer (Honfo et al., 2011). Therefor there is a need for steady production of this crop. Plantain plays a key role in the economy and food security in Cameroon, because of its year-round availability that provide a permanent source of income not only to the farmers and rural populations, but also to the traders and retailers, thus playing an important role in poverty alleviation (Patel et al., 2018).

The FAO (2015) report shows that in the year 2013, the quantity of bananas and plantains produced were more than 145 million metric tons in over 130 countries on more than 11 million hectares of land. The annual production of banana plant was estimated at about 95 million tons and both bananas and plantains served as staple foods for at least 4,000 million people in the world especially in sub-Saharan countries (FAO, 2010). Cameroon is one of the 20 major plantain and banana producing, consuming, and exporting nations in Africa. The FAO (2012) report shows that Cameroon is the leading plantain and banana producing nation in Central and West Africa with approximately 4.8 million metric tons produced annually. While FAO (2015) reported that in 2013 Cameroon’s total amount of banana and plantain production was estimated at 5,400,000 metric tons in 2013 with dessert banana accounting for 29.4% whereas plantain and other cooking bananas accounted for 70.6% of the production. Despite this increase in production in bananas in Cameroon, the farmers still face threats by series of abiotic and biotic stresses such as soil nutrient depletion, drought, pests and disease and crop management factors (Okolle et al., 2019; Cheke et al., 2020).

In Cameroon, the humid forest zone is the major area for banana and plantain production. But most of the plantain is mostly grown by small-scale farmers on an average land size of less than a hectare. Due to high pressure on land, most of the land is under plantation agriculture, increase urbanization, and forest protected areas which reduces rotation cycles and leads to soil fertility problems. However, this continued land degradation, rapid population growth, continuous cropping and leaching has drastically reduced the fertility status of most home gardens and farmlands in the humid tropics, thereby posing a challenge to sustainable crop production especially perennial crops such as banana and plantain in the forest humid zone of Cameroon. Plantain requires high amounts of nutrients for optimum growth and fruits production, but these nutrients are often supplied in part by the soil (Guo et al., 2009). This is one of the reasons why in the West and Central African region the crop is predominantly cultivated in the home gardens where it receives continuous supply of organic matter and nutrients from household refuse (Baiyeri and Tenkouano, 2007; Mintah et al., 2017). There is a need for external inputs of nutrients, especially for commercial plantain production in the humid forest zone of Cameroon. This could either be organic waste materials (such as animal waste, which is mostly in the form of animal waste, compost manure and farmyard manure) or inorganic fertilizers or a mixture of organic and inorganic fertilizer.

Application of inorganic (mineral) fertilizers appears to be the most dependable source of nutrients to produce plantain especially under intensive and continuous cultivation system (Mintah et al., 2017). Though the benefits of inorganic fertilizers have been established, its’ use by subsistence farmers in the tropics is limited due to high cost, scarcity, nutrient imbalance, and soil acidity resulting from prolonged usage (Brandjes et al., 1989). Moreover, the types of inorganic fertilizer available on the market comprise mainly the basic nutrients Nitrogen (N), Phosphorous (P) and Potassium (K) and those that contain some micronutrients are rare and more expensive (Mintah et al., 2017).

Meanwhile, organic waste will contain all the macro and micronutrients needed by the plant. However, the use of inorganic fertilizers alone has not been helpful in intensive agriculture because they intensively degrade the soil (Vanilarasu and Balakrishnamurthy, 2014). This soil degradation will lead to the loss of organic matter which consequently results in soil acidity, nutrient imbalance and low yields. But banana and plantain production can be achieved with regular organic matter input. The amount of soil organic matter in the soil depends on the quantity of organic material which can be introduced into the soil. This can either by natural returns through roots, stubbles, sloughed-off root nodules and root exudates or by artificial application in the form of organic manure which can otherwise be called organic fertilizer (Ndukwe et al., 2011a).

The use of organic waste is a valuable source of crop nutrients and organic matter that can improve soil biophysical conditions making the soil more productive and sustainable for food production (Flores-Mangual and González-Vélez, 2019; Monono et al., 2018). Organic amendments add nutrients to the soil and also help to increase beneficial micro-organism activities. The decomposition of organic matters increases soil fertility, improves soil structure, increases organic carbon content, reduces soil erosion and leaching of nutrients, and improves water and nutrient absorption (Monono et al., 2018; Robinson and Saúco, 2010; Vanilarasu and Balakrishnamurthy, 2014). Organic nutrition can restore the biological dynamics of a soil but it usually takes several years to re-establish a sterile soil (Vanilarasu and Balakrishnamurthy, 2014). Farmers therefore face discouraging task as the traditional methods of soil fertility regeneration through fallow systems has become ineffective due to shortened fallow periods resulting in inadequate fertility restoration.

Adoption of suitable agronomic practices such as fertilizer application and mulching plantain with organic waste materials will enhanced their productivity, thus replace the nutrients lost through leaching and crop harvest.

Currently, attention has been curved to the use of organic fertilizer sources alone and in combination with chemical fertilizers, not only to improve yields but also to maintain and improve on the physicochemical and biological properties of the soil (Purabi, 2017). Organic nutrient management includes organic manure as well as bio-fertilizer is economically attractive and eco-friendly. Thus, promote soil health by building organic matter content, increasing aeration, and enhancing microbial abundance and diversity besides improving the quality and quantity of production. Integrated nutrient sources will not only aid in achieving higher yields but also enhancing the sustainability and health of the soil status (Ganapathi and Dharmatti, 2018; Purabi, 2017).

Despite many studies carried out on plantain and banana in Cameroon by different researchers, there is little or no work to improve on plantain production in Cameroon using organic and inorganic fertilizers, as well as assessing the different organic fertilizers, such as such as poultry manure, coffee husk and cocoa pod residues, which are consider as wastes by farmers in this area. Additionally, cost benefit ratio is needed to evaluate risk with more certainty when using organic and inorganic fertilizer in plantain production.

This study also focusses on the integrated fertilizer management on agro-ecological zone in Cameroon which supports the ongoing efforts to improve food security as available arable land decreases.

MATERIALS AND METHODS

Experimental site

The study was carried out in year 2016/2017 on a 6,272 m^2 plot at the Ekona Agricultural Post demonstration field. Ekona is located at 4° 23´ 09˝ N and 9° 33´ 23˝ E in South West Region, Cameroon at an altitude of about 450 m above sea level (Figure 1).

Planting

The planting material was eight weeks old plants issued from Stem Bits (macro-propagated) False Horn “Ebanga” plantain plantlets from the African Research Centre on Bananas and Plantains (CARBAP) Njombe, Cameroon. The plantlets had an average plant height of 15 cm; 5 cm stem circumference, and 3 functional leaves. The plantlets were planted 3×2 m apart giving a planting density of 1,667 plants ha^{-1}. The planting holes were 40 cm deep and 40 cm wide according CARBAP recommendation. The experimental site was divided into 3 replicate blocks of 1200 m^2 with each replicate having eight treatments plots of 15 x 10 m each. The plots were 2 m apart while the blocks were 6 m apart. The experimental design was a completely randomised block design.

Fertilizer treatments

Table 1 shows the eight fertilizer treatments that were used in this study. The fertilizer treatments included three organic waste: Poultry manure, coffee husk, and cocoa pod residue that were applied at a rate of 7.58 kg $plant^{-1}$, one inorganic fertilizer (NPK 20:10:10 + Urea) which was applied at a rate of 176.5 g $plant^{-1}$, and three mixtures of organic waste and inorganic fertilizer combined at 3.79 kg $plant^{-1}$ organic waste and 88.75 g $plant^{-1}$ for inorganic, respectively.

The organic wastes were incorporated in the soil during planting. Meanwhile, the inorganic fertilizer (urea and NPK) was applied in two splits; urea was applied one month after planting and NPK 20:10:10 was applied two months after planting (MAP).

Soil and organic waste characteristics

Soil and organic wastes analyses were carried out before planting, soil samples were collected randomly at each part of the field at a depth of 0-10 cm, 10-20 cm and 20-30 cm using a soil auger. The soil samples from the different parts of the field were bulked according to soil depths and homogenous samples were air dried. The air-dried soil samples were separated using a 2 mm sieve and then stored in coded plastic bags. Chemical analysis of these coded soil samples was done in the Soil Science Laboratory of the Institute of Agricultural Research for Development (IRAD) Ekona, Cameroon using standard procedures. Organic matter was determined using the wet dichromate method, total Nitrogen (N) by Kedjal method, Phosphorous (P) by Brady 2 method. Exchangeable Potassium (K), Calcium (Ca), and Magnesium (Mg) were extracted using ammonium acetate. Whilst K was read on flame photometer, Ca and Mg were obtained from atomic absorption spectrophotometer.

The same chemical analysis was also done for the organic fertilizers after they were oven dried at 75 ºC for 72 h, ground, and separated using a 2 mm sieve.

Management practice

The experimental plots were well managed in terms of weeds and

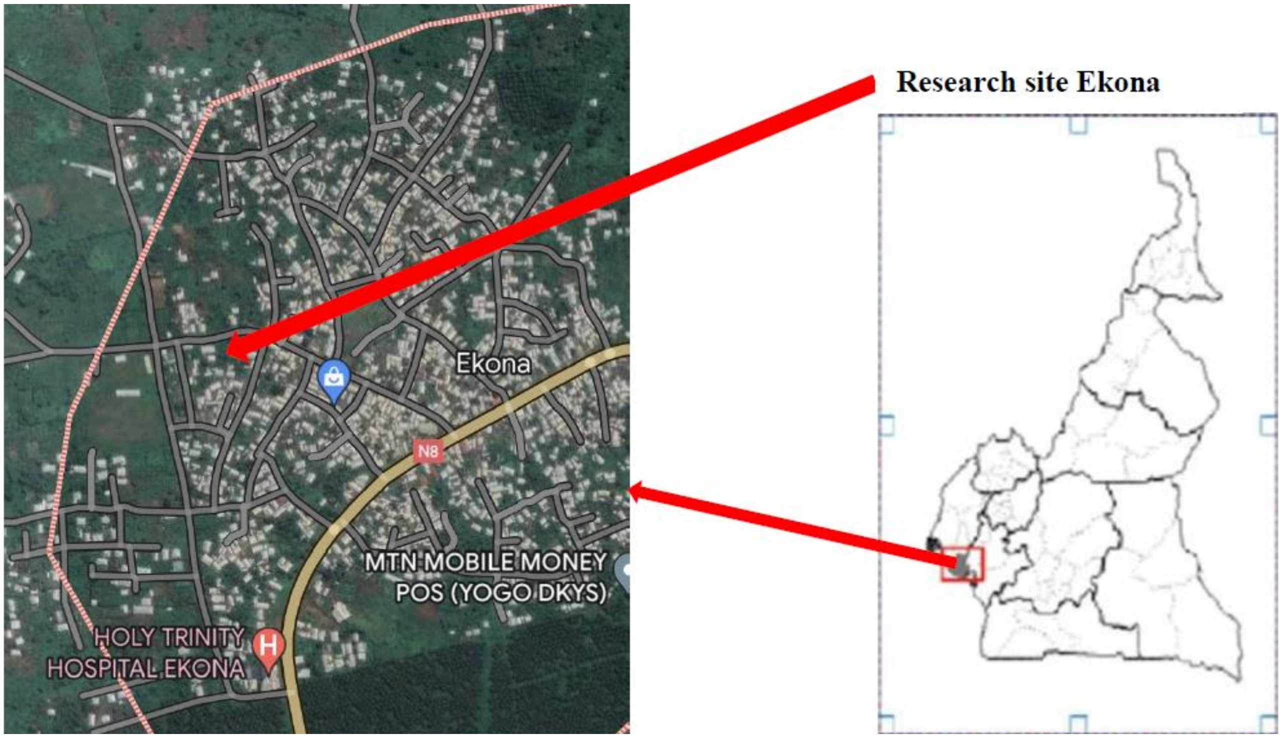


Figure 1. Map showing statilite image of study site in Ekona South West Region of Cameroon (https://mapcarta.com/17535286/Map).
Source: https://mapcarta.com/17535286/Map

Table 1. Fertilizer treatments of either organic, inorganic or a mixture of both applied to plantains grown in Ekona, Cameroon.

Treatment	Treatment names
T_1	No fertilizer (Control)
T_2	300 kg ha^{-1} inorganic fertilizer (100 kg ha^{-1} Urea + 200 kg ha^{-1} NPK 20:10:10)
T_3	12 tons ha^{-1} poultry manure
T_4	12 tons ha^{-1} coffee husk
T_5	12 tons ha^{-1} cocoa pod residue
T_6	6 tons ha^{-1} poultry manure + 150 kg ha^{-1} inorganic fertilizer (50 kg ha^{-1} Urea + 100 kg ha^{-1} NPK 20:10:10)
T_7	6 tons ha^{-1} coffee husk + 150 kg ha^{-1} inorganic fertilizer (50 kg ha^{-1} Urea + 100 kg ha^{-1} NPK 20:10:10)
T_8	6 tons ha^{-1} cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer (50 kg ha^{-1} Urea + 100 kg ha^{-1} NPK 20:10:10)

Source: Authors

insect control (Figure 2). Two weeks before transplanting the plantain plantlet, the experimental plots were sprayed with glyphosate herbicide. After three months of planting, a contact herbicide (gramazone) was applied and manual weeding was done 30 cm around each plant. The field was sprayed with an insecticide, Cypemechrin, in order to control insect pest and black sigatoka. This helped to minimize the loss of leaf area due to excessive leaf pruning. Suckers were pruning to allow maximum of four suckers plant. This was done to reduce competition of nutrients.

Data collection

Vegetative growth of the plant was measured monthly for 11-month period on 15 tagged plants per treatment. The following parameters were assessed during the data collection: Plant height from soil level to the last 2 open leaves using a graduated range pole, stem circumference at 10 cm above soil level using a measuring tape, number of suckers produced were counted, and leaf emergence rate (LER) was measured monthly by marking the last emerged petioles and counting the number of raised leaves. At flowering the plant height, stem circumference, number of functional leaves, actual leaf area was determined at flowering using a destructive method using the formula (leaf length x leaf width x 0.8) (Al-Harthi and Al-Yahyai, 2009), and assimilation area per plant (m^2/plant) was determined using the equation = leaf area × number of functional leaves (Ibrahim, 1993).

Flowering was assessed as follows: number of days from

Figure 2. Area and verticle view of research field after manual and chemical weeding and propping of plantain.
Source: Authors

planting to flower initiation, days from flower initiation to bunch harvest was recorded. The bunch characteristics were assessed as follows; bunch weight, number of hands per bunch, total number of fruits (fingers) per bunch. Number of hands and fingers were obtained by counting. Fruit physical (finger) characteristics; finger length and circumference were determined using a measuring tape. Finger length was determined by measuring the outer curve of individual finger with a tape from the distal end to the point at the proximal end where the pulp was judged to terminate, finger weight, pulp weight and peel weight was obtained using an electronic balance. Pulp and peel ratio were determined by dividing the pulp weight from peel weight (Vanilarasu and Balakrishnamurthy, 2014).
The economic analysis was carried out to assess the profitability of using: the total cost of inputs during planting and growth period, including cost of fertilizers, cost of land preparation, cost of pesticides, purchase of plantlets, transportation of suckers, and organic fertilizers, and cost of labour. Records were also taken for the yield for each treatment was recorded. Gross benefit was assessed using the current market price of plantains. The net benefit was assessed as shown in Equation 1 while the cost/benefit ratio was estimated as illustrated in Equation 2.

$$Net\ benefit = total\ output\ cost - total\ input\ cost \quad (1)$$

$$\frac{Cost}{benefit} ratio = \frac{Total\ input\ cost}{Total\ output\ cost} \quad (2)$$

Statistical analysis

Data were analyzed using a one-way analysis of variance (ANOVA) at *P* = 0.05 in Minitab statistical software package version 17. The treatment means were compared and separated using Tukey's method at 5% probability level.

RESULTS AND DISCUSSION

Meteorological data, soil chemical properties of Ekona and organic fertilizers

The rainfall pattern of Ekona for 2015, 2016, and 2017 (Figure 3) have an annual rainfall of 2,464 mm, 2,359 mm, and 2,373.8 mm, respectively. Although the distribution pattern varies throughout the years, the total rainfall value was greater than the critical annual amount of 1,200 mm required for plantain cultivation (Ndukwe et al., 2011b). The highest monthly rainfall of approximately 600 mm is usually observed in July while there is sometime little or no rainfall in the months of December, January, and February. Planting of the plantains was done in July 2016 because there was enough water in the soil to support the plantlet regenerate roots that will help plant growth since there was no irrigation system in the experimental plot.

The result of the soil and organic fertilizers analyses are shown in Table 2. The soil sample, poultry manure, coffee husk and cocoa pod analyses (Table 2) indicated that the soil of the experimental site was relatively low in nitrogen (N), potassium (K), calcium (Ca), and magnesium (Mg). This is because of mix cropping over five years. The poultry manure, coffee husk and cocoa pod contained high amount of organic carbon.

Effect of fertilizers on the vegetative characteristics of plantain

Plant height and Stem circumference

The vegetative characteristics generally are the early growth of plant producing leaves, stem and branches without flowers in all plants. For this study the following measurements were consider for the vegetative growth; plant height, plant circumference, number of functional leaves, leaf emergence rate, actual leaf area and total number of leaves produce. There was an exponential growth pattern in respect to plant height from September to January. Later an increase in a decreasing rate from February to May. At the end of the May there was a constant growth (Figure 4). The plant circumference showed an exponential growth from September to December and from December there was an increase in

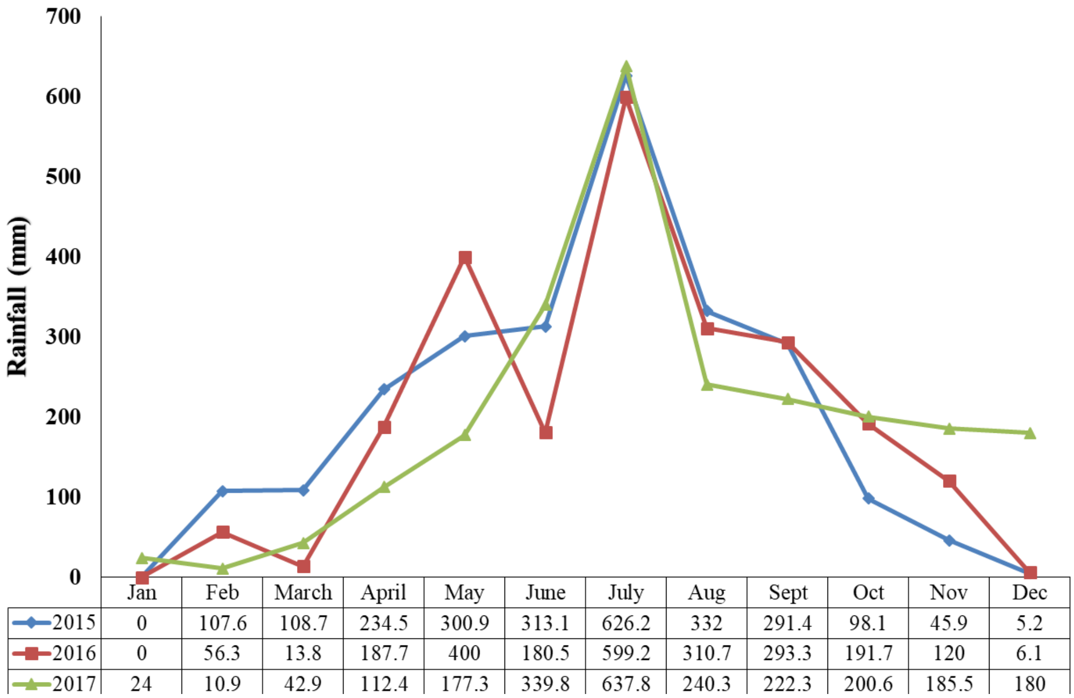


Figure 3. Mean monthly rainfall data for Ekona for the years 2015, 2016 and 2017 (Source: CDC weather station).
Source: Cameroon Development Corporation (CDC) weather station

Table 2. Chemical properties of soil and organic fertilizers used for plantain production in Ekona, Cameroon.

Chemical properties	Soil			Organic fertilizers		
	0-10 cm	**10-20cm**	**20-30 cm**	**Poultry manure**	**Coffee husk**	**Cocoa pod**
pH	5.39	5.17	5.47	7.20	5.25	5.30
Organic carbon (%)	3.67	3.33	3.04	42.95	8.0	16.56
Nitrogen (g kg^{-1})	1.34	1.02	0.11	15.6	0.42	0.99
Phosphorus (mg kg^{-1})	15.00	16.00	12.0	14.0	10.0	2.50
Potassium (cmol kg^{-1})	1.09	0.86	0.69	17.9	5.12	38.6
Calcium (cmol kg^{-1})	4.30	4.02	3.10	3.76	0.10	3.10
Magnesium (cmol kg^{-1})	2.48	1.94	1.61	0.41	1.3	2.40
CEC (cmol kg^{-1})	7.84	10.50	7.35	-	-	-

Source: Authors

a decreasing rate up to April. There was almost constant growth in stem circumference from May to June (Figure 5).

This unlimited growth observed in plant height and circumference might be due to the continuous growth of the shoot system from germination stage to the death or throughout the life span of the plantain. Brukhin and Morozova (2011) reported that the shoot apical meristem (SAM) is the main plant meristem as it is located at the growing tip of the main shoot and is a source of all above-ground plant organs. Cells at the SAM top serves as stem cells to the surrounding peripheral region, where they proliferate rapidly and are incorporated into differentiating leaf or flower primordia (commencements of new plant organs). They also reported SAM increases the diameter of plant body.

Plant height measured at flowering stage showed significantly (p =0.001) increased height on all the fertilized soils over the control. T_3 plots attained the highest height of 195.80 cm while the control (T_1) had the

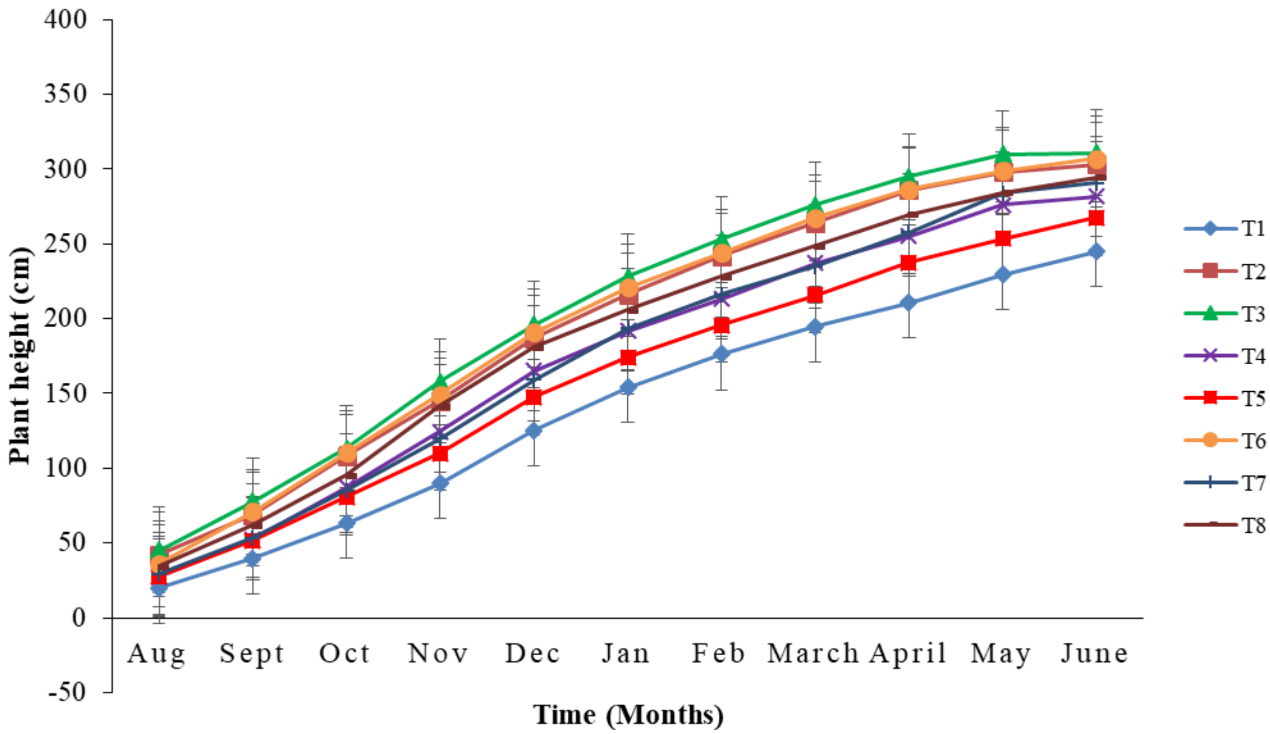


Figure 4. Effect of organic and inorganic fertilizers on the growth pattern of stem height of plantains grown in Ekona with time. T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

shortest height of 140.89 cm (Table 3). Plots treated with T_2, T_3 and T_6 showed no significantly (p =0.05) in plant height of 191.71, 195.80 and 194.38 cm respectively. Plot treated with T_5 (160.13 cm) showed no significantly (p =0.05) in plant height with control (140.89 cm). The lowest circumference at flowering was 36.12 cm for the control (T_1) and these was significantly smaller (p = 0.001) than the fertilized plots.

The largest stem girth was recorded on the plots treated with T_3 (51.45 cm). Generally, plants on treated plots obtained a significantly wider circumference (p =0.001) relative to the control, except for plants treated with T_5 (Table 3). The highest increase in plant height and circumference was in plants supplied with T_3 and T_6, this may be as results of the high levels of nitrogen and phosphorus that improved on crop production and the high carbon enhanced some of the physical properties of the soil. The organic waste may have caused the soil to have less bulk density and more water holding capacity. The less bulk density indicates less soil compactness and greater pore spaces which allowed better root aeration, nutrient and water uptake for subsequent growth enhancement (Monono et al., 2018). These good physical properties of the soil will stimulate the rapid release of cytokinins that influence cell division and, in combination with auxin, promote shoot formation. This explained why Aba et al. (2011) reported that countless proportion of plantain and banana crops cultivated on household garden benefits from this organic matter because of high doses of application. The results in this study were similar with the findings of Baiyeri and Tenkouano (2007, 2008) who reported that manure placement greatly influence plantain height and circumference in southeastern Nigeria. This study was related to the findings of Ndukwe et al. (2009), studying the effects of organic and inorganic fertilizers on growth, and yield of some plantain (*Musa* spp. AAB) genotypes in south-eastern Nigeria. They further reported that at 6 MAP, plants height, plant girth and suckers treated with organic fertilizer had a mean value of 197.10 cm, 38.19 cm, and 147.70 cm respectively as compared with the control (158.90 cm, 32.48 cm and 136.30 cm respectively). It is also in line with the findings of Aba et al. (2011), were they observed that poultry manure had a positive impact on plantain height and circumference in the Cross-River State of Nigeria. They reported that poultry manure increased plant height of PITA24 (324.8 to 345.9 cm) and plant girth (55.5 to 60.0 cm) while in Mbi-Egome plant height was

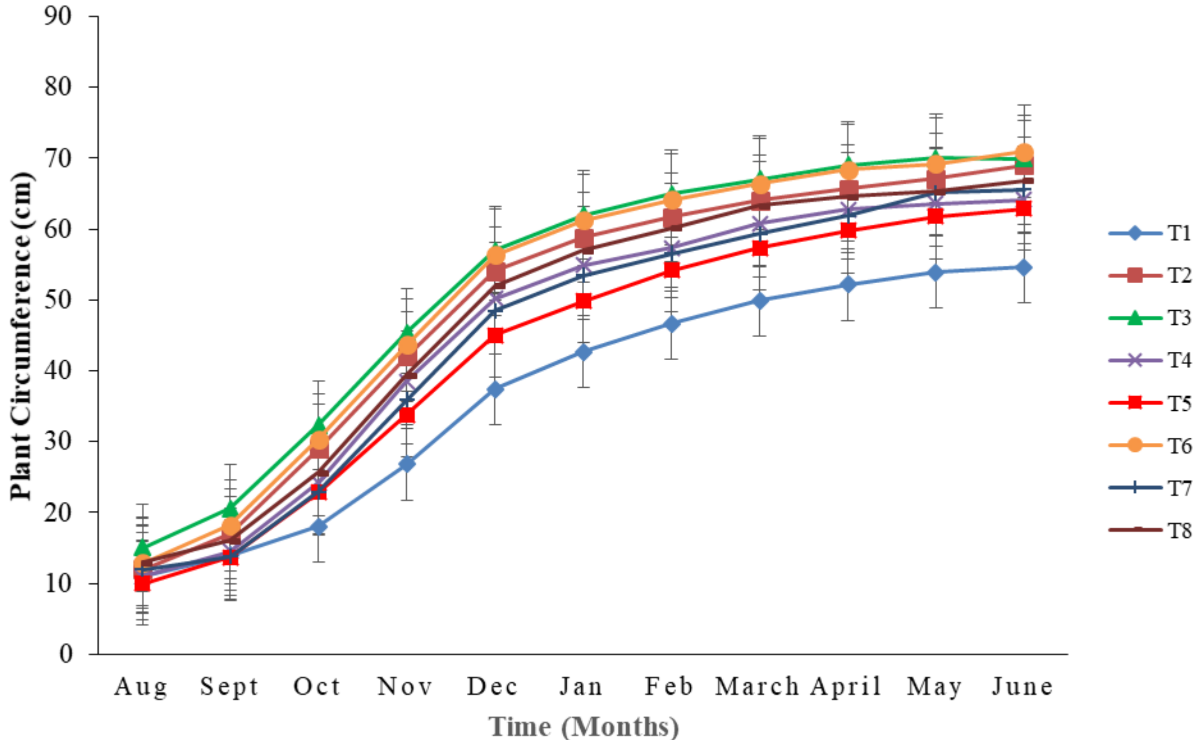


Figure 5. Effect of organic and inorganic fertilizers on the growth pattern of the stem circumference of plantains grown in Ekona with time. T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

increased (316.5 to 348.3 cm) and plant girth (55.5 to 60.5 cm) in the Cross-River State of Nigeria.

Functional leaves and leaf area

There was an exponential increase in growth in respect to the number of functional leaves from August to September, which remained constant from September to October and later decreases from November to January. There was a spontaneous increase in leaf number from February to May and thereafter it was constant (Figure 6).

The decrease of functional leaves from November 2016 to January 2017 might have been caused by little or no rainfall or moisture stress during those months (Figure 3). This finding was also observed by Ngo-Samnick (2011), who reported that bananas and plantains required more than 100 mm rainfall every month for better growth. This was explained by Robison and Saúco (2010), who reported moisture, has severe implications on physiological, pathological and management aspects of growing plantain. During dry season, there is little or no rain fall, the relative humidity is low, and there is high evaporation rate.

The fertilizer treatment had no significant effect (p = 0.05) on the number of emergence leaves and actual leaf area of “false horns” plantain (Table 3). Number of emergence leaves indicated that plantain produces averagely 3 leaves per month. Significant differences (p = 0.001) were observed among the treatments with respect to number of functional leaves at flowering. The highest number of functional leaves at flowering was recorded with plants treated with T_3 (11.80 leaves), as the control recorded the lowest number of functional leaves at flowering (10.76 leaves). The number of functional leaves at flowering for control, T_4, T_5, T_6, T_7 and T_8 plots were statistically similar. The functional leaves of plants treated with T_2 showed no statistically difference from T_3 (Table 3). This indicates that the 300 kg ha^{-1} inorganic fertilizer and 12 tons ha^{-1} poultry manure may have stimulated the increase of cells. Brukhin and Morozova (2011), explained that cells at the shoot apical meristems (SAM) top serve as stem cells producing daughter cells to the surrounding region where they start to proliferate rapidly and next are involved into differentiation resulting in

Table 3. Effects of organic and inorganic fertilizers on vegetative growth of plantain.

Treatments	Vegetative growth							
	PH (cm)	SC (cm)	NEL/month	ALA (m^2)	AAP (m^2)	NS	NFLF	TNLP
T_1	140.89±76.92^{c}	36.12±18.15^{d}	3.04±1.36^{a}	173.19±21.07^{a}	1868.70±331.40^{a}	4.38±0.64^{a}	10.76±0.45^{ab}	33.80±1.21^{d}
T_2	191.71±91.22^{a}	48.87±21.16^{abc}	3.27±1.52a	176.54±17.68^{a}	2062.10±257.40^{a}	4.96 ±0.83^{a}	11.69±0.76^{a}	36.53±0.62^{a}
T_3	195.80±87.05^{a}	51.45±20.12^{a}	3.23±1.40^{a}	176.42±16.77^{a}	2116.40±268.30^{a}	4.89±0.57^{a}	11.80±0.87^{a}	36.53±1.06^{a}
T_4	173.89±87.40^{ab}	45.43±20.38^{abc}	3.14±1.44^{a}	174.16±11.14^{a}	1944.00±194.20^{a}	4.89±0.72^{a}	11.16±0.52^{ab}	35.11±0.92^{bc}
T_5	160.13±81.08^{bc}	42.62±19.77^{cd}	3.07±1.32^{a}	174.04±9.29^{a}	1877.30±202.80^{a}	4.82±0.53^{a}	10.80±0.53^{ab}	34.20±1.40^{cd}
T_6	194.38±92.14^{a}	51.08±20.97^{ab}	3.24±1.60^{a}	176.89±11.22^{a}	1976.60±219.20^{a}	4.69±0.83^{a}	11.18±0.65^{ab}	36.02±0.75^{ab}
T_7	174.84±89.93^{ab}	44.65±20.74^{bc}	3.21±1.45^{a}	175.54±7.21^{a}	1949.60±248.80^{a}	4.76±0.60^{a}	11.11±0.63^{ab}	35.11±1.06^{bc}
T_8	186.95±89.08^{ab}	47.39±20.44^{abc}	3.27±1.51^{a}	175.50±8.71^{a}	1978.50±199.80^{a}	4.82±0.60^{a}	11.27±0.34^{ab}	35.87±0.84^{ab}

Values represent Means were separated using Tukey HSD = 0.05. Mean with similar letters within column indicate no significant differences among treatment, PH = Plant height, PC = Stem circumference, NEL= Number of emergence leaves, ALA= Actual leaf area, AAP = Assimilation area per plant, NS = Number of suckers, NFLF = Number of functional leaves at flowering, and TNLP = Total number of leaves produce. T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

producing leaf or flower primordial.

At the time of flowering, all the plants produced the same number of functional leaves which ranged from 10 – 12 leaves/plant. The highest assimilation area per plants was 2116.40 m^2 for the T_3 and this was not significantly larger (p = 0.05) than the control plots (1868.70 m^2) (Table 3). This indicates that plants with high functional leaves at flowering will have high leaf area, translating into more leaf surface per unit weight available for light interception and photosynthesis which will show a greater capacity for the accumulating photosynthesis within the specific time period for bunch maturity (Baiyeri and Tenkouano, 2007; Mintah et al., 2017; El-Badawy and Ali, 2019; Manju and Pushpalatha, 2022).

In the study it was observed that the number of leaves produced in the production cycle of plantain showed significantly (p = 0.001) increased in number on all the fertilized soils over the control. Plants treated with T_2 and T_3 produced the highest number of leaves of 36.53 leaves/plant while the control plot produced the lowest number of 33.80 leaves/plant. Robinson and Saúco (2010) reported that after flowering no other leaf will emergence because the inflorescence emerges upwards through the center of the pseudostem before bending down under the weight of the developing spike. The number of suckers produced on the fertilized soil and control plots recorded no statistical difference. Although there was not statistically difference, plant treated with T_2 produced the highest number of suckers (4.96 Suckers) while the control produced the lowest (4.38 suckers) (Table 3). The increased in suckers in treated soil indicates nutrient uptake of plantain on soils supplemented with fertilizer resulted in bigger and more vigorous plants, which stimulated sucker proliferation. Mintah et al. (2017) reported that the formation rate of plantain suckers dictates the yield potential and guarantee continuous production since plantain is a perennial crop. Thus, high sucker proliferation increases the chance of high productivity and therefore more revenues to the farmer.

Effect of fertilizers on the flowering (Phenology) characteristics of plantain

Plant phenology gives the knowledge of planting to flower emergence (P-E) and planting to harvest (P-H) which are of great importance to farmers. It was observed that there was a significant difference (p = 0.001) in the phenology characteristics of plantain across treatments (Figure 7). There was a significant reduction (p = 0.001) in the number of days from planting to flowering from 58, 44, 42, 26, 23, 21 and 9 days

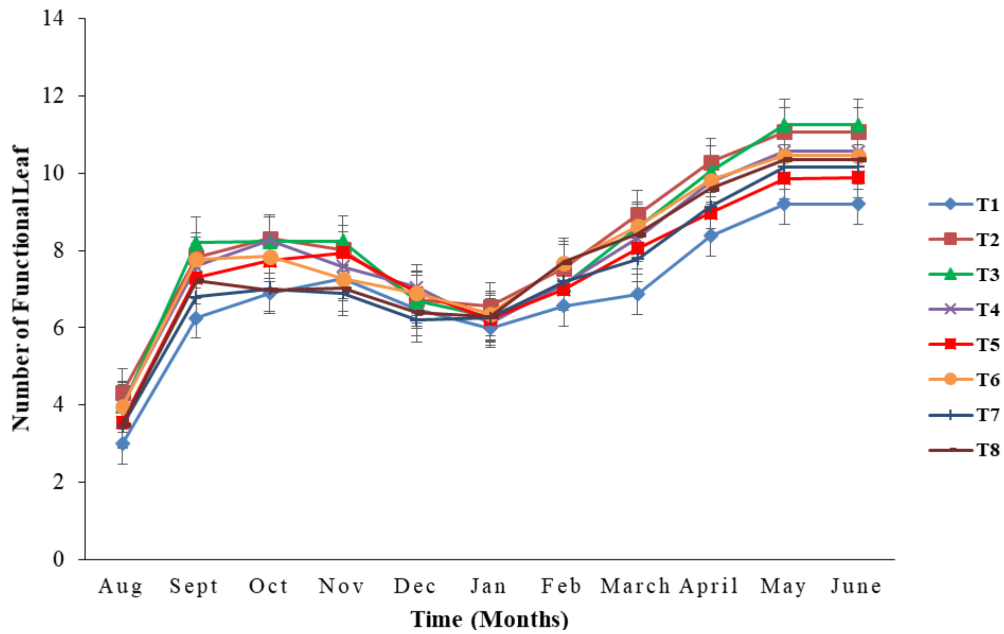


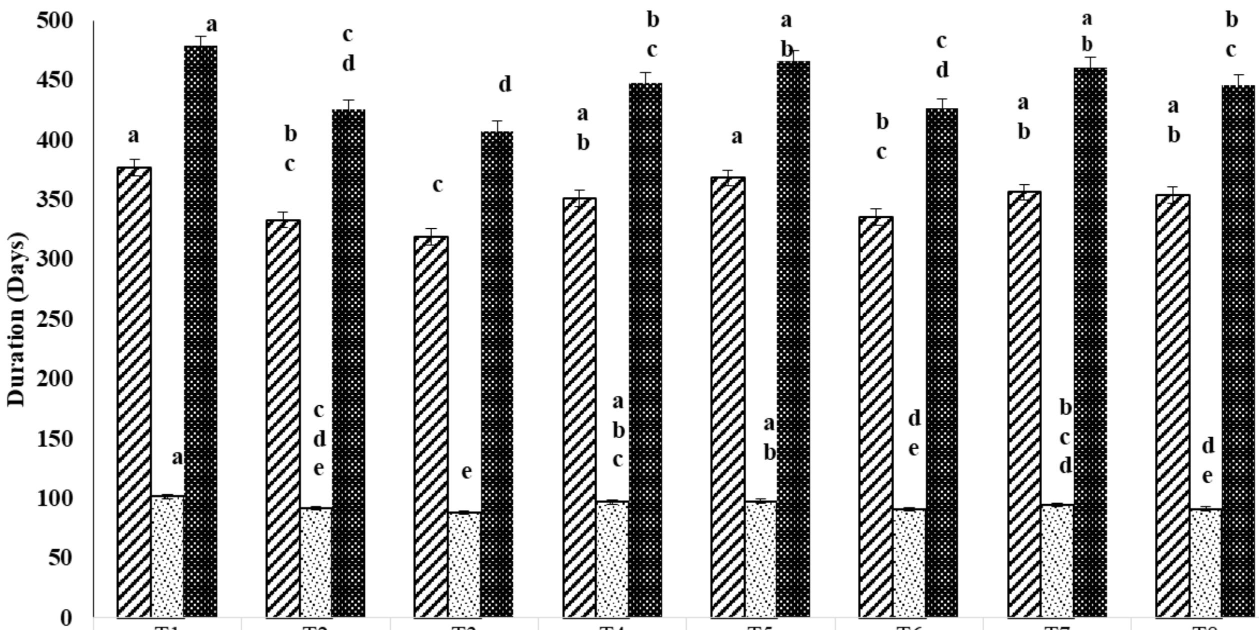
Figure 6. Effect of organic and inorganic fertilizers on the pattern of number of leaves of production of plantains grown in Ekona with time.
T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

for plants treated with T_3, T_2, T_6, T_4, T_8, T_7, and T_5 respectively when compared with plant in control (Figure 7). The number of days from flowering to harvesting was also reduced by 13, 11, 10, 10, 7, 5 and 4 days in plants treated with T_3, T_6, T_8, T_2, T_7, T_4, and T_5 respectively compared with the control plants (Fig. 7). With respect to the control plants the number of days from planting to harvesting was reduced by 72, 54, 53, 33, 31, 18 and 13 days with plants treated with T_3, T_2, T_6, T_8, T_4, T_7 and T_5, respectively (Figure 7). This indicates that the application of fertilizer reduced the number of days from planting to flowering, flowering to harvesting and planting to harvesting in plantain production. The shorter crop duration for fertilized plants might be due to the higher net assimilation rate on account on nutrients supplied leading to the optimum level of production of gibberellins that might have triggered early flower bud initiation and thereby early shooting in plantain. Mintah et al. (2017) reported that adequate fertilization of the soil leads to shorter growing and reproductive cycle is culminating in more frequent harvesting by the farmer. Similar results were reported by Ndukwe et al. (2011a) who reveal that the application of inorganic and organic fertilizer reduced the number of days from planting to flowering by 58 and 74 days respectively in southeastern Nigeria. The results in this research also concord with the findings of Ndukwe et al. (2011b) who reported that the period of poultry manure application reduced the number of days from flowering to harvesting by 20 days and number of days from planting to flowering by 17 days as compared to control in south-south Nigeria. This study was also in line with the findings of Baiyeri et al. (2013); they further reported that plants that had received manure flowered and matured earlier than those that received inorganic fertilizer or no fertilizer in River State of Nigeria. In their study they reported that the number days from planting to flowering and maturation were reduced by 53 and 37 days with organic and inorganic fertilizer treatment respectively as compared to control. Balheit and Elsadig (2015), revealed that the time of flowering and harvesting of banana treated with manure, compost + urea and urea were reduce as compared to the control.

Effect of fertilizer on the reproductive characteristics of plantain

Yield parameter

There was significant effect (p = 0.001) of fertilizer treatment on bunch weight and yield per hectare. The application of organic and inorganic fertilizer on plantain



	T1	T2	T3	T4	T5	T6	T7	T8
P-F	377.02	333.18	318.78	350.87	368.22	335.47	356.24	354.18
F-H	101.69	92.02	88.29	97.04	97.71	90.73	94.4	91.36
P-H	478.71	425.2	407.07	447.91	465.93	426.2	460.64	445.74

Figure 7. Effects of different fertilizer application on flowering of plantainP-F = Planting to flowering duration, F-H = Flowering to harvesting duration and P-H = Planting to harvesting duration. Same letter across each category indicates means are statistically the same at $\alpha < 0.05$. T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

plants increased the bunch weight (Table 4). The highest mean bunch weight was observed with plants treated with T_3 (12.28 kg) while the least was noted in the control plants (8.67 kg). Plants treated with T_2, T_3, T_4, T_5, T_6, T_7 and T_8 increased the bunch weight by 30.68, 41.64, 23.41%, 23.53, 28.47, 28.87, and 26.87%, respectively, when compared with the control plants. Increased number of leaves might have increased the photosynthetic activity resulting in higher accumulation of carbohydrates. Relatively higher carbohydrates could have promoted the growth rate and in turn increased bunch weight (Kuttimani et al., 2013). The result in this study also collaborates the findings of Al-Harthi and Al-Yahyai (2009); Mintah et al. (2017) who reported that NPK and organic fertilizer increases bunch weight by 10 -13 kg as compared with the control. The yield of plantain expressed in tons ha^{-1} showed significant differences (p = 0.001) among the treatments. The highest yield (34.40 tons ha^{-1}) was obtained when the plantain was treated with T_3 followed by the 31.70 tons ha^{-1} for the T_2 treated plantain. The increase in bunch yield, and fruit weight with plants treated with organic and inorganic fertilizers may be due to the supply of nutrients in the soil, thus plants treated with fertilizer will have good growth and produce high yields. Nitrogen, phosphorus, and potassium are required by plantains for better growth, high production quality, and high fruit yield. If any of the nutrients is in short supply, plant growth would be limited, and crop yield is reduced. This increase in yield might also be due to low respiration rate and high assimilation rate thus more of the nutrients will be used for fruit production. This is similar with the study of Baiyeri et al. (2013), who showed that fertilized plants produced the higher yield of 37.29 tons ha^{-1}. Findings in this current study were also consistent with the findings of Ndukwe et al. (2011b), who reported that the bunch yield and yield components in the fertilized plant crops were generally higher than those of control plants. This result was also coherence with the findings of Aba et al. (2009), who conducted an experiment of manure rates and bunch pruning intensities on bunch physical traits of two plantain (*Musa* spp. AAB) genotypes. They noted that 10 tons ha^{-1} application rate of poultry manure produced the best results in plantain yield in ‘PITA 24’ and ‘Mbi-Egome’.

Table 4. The effects of fertilizers on yield of plantain.

Treatment	Yield parameter			
	BW/S (kg)	NH/B	NF/B	BY (t ha^{-1})
T1	8.67±0.82^{b}	6.80±0.68^{b}	30.70±6.65^{a}	24.30±0.82^{b}
T2	11.33±0.92^{a}	7.47±0.52^{ab}	33.33±2.90^{a}	31.70±0.92^{a}
T3	12.28±1.53^{a}	7.80±0.78^{a}	36.40±10.74^{a}	34.40±1.53^{a}
T4	10.70±1.92^{ab}	7.00±0.85^{ab}	33.47±4.63^{a}	30.00±1.92^{ab}
T5	10.71±1.60^{ab}	6.80±0.78^{b}	32.80±5.55^{a}	30.00±1.60^{ab}
T6	11.13±2.08^{a}	7.33±0.70^{ab}	31.40±4.52^{a}	31.20±2.08^{a}
T7	11.13±2.05^{a}	7.27±0.80^{ab}	32.87±3.91^{a}	31.20±2.05^{a}
T8	11.00±2.87^{a}	7.27±0.80^{ab}	31.80±2.76^{a}	30.80±2.87^{a}

Values represent Means were separated using Tukey HSD = 0.05. Mean with similar letters within column indicate no significant differences among treatments, BW= Bunch weight, NH/B = Number of hands per bunch, NF/B = Number of fingers per bunch, FL= Finger length, FC = Finger circumference, FW = finger weight, and BY = Bunch yield with stalk. T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

The yield also showed that plants that were fertilized generally gave higher bunch than control plants (Table 4). With plant treated with T_3 producing outstanding yield (34.40 tons ha^{-1}), though not significant difference (p = 0.05) from plant treated with T_2 (31.70 tons ha^{-1}), T_6 (31.20 tons ha^{-1}), T_7 (31.20 tons ha^{-1}) and T_8 (30.80 tons ha^{-1}). This indicate that organic/inorganic interactions not only release plant available nutrients, but also increase the soil Organic Carbon stock, which improves the retention of the applied mineral fertilizer by the soil, therefore enhancing its utilization efficiency. Meya et al. (2020) reported that the best alternative strategy to manage soil fertility in banana-based farming systems is an integrated system of using organic/inorganic interaction of fertilizers.

The number of hands per bunch showed significant difference (p = 0.001) with fertilizer treatments. All the plant treated with fertilizers had 7.00 to 8.00 hands expect for plant treated with T_5 that had 6.80 hands. There was no significant difference (p = 0.05) on the number of fingers per bunch, but plants treated with T_3 produces the highest number of fingers per bunch (36.40 fingers) (Table 4). This implies that bunches may have the same number of fingers nevertheless inadequate nutrients will affect assimilate supply to the fingers and thus affect the number of well-filled fingers and hence finger weight. This result was coherence with the findings of Mintah et al. (2017), where they concluded that the fingers of the plants that received fertilizers were better filled compared to the control although they have the same number of fingers. This result was collaboration with the findings of Manju and Pushpalatha (2022) who reported that the number of hands per bunch, fingers per bunch, finger weight, finger length and finger girth was significantly high for these banana plants treated with green manure and organic manure.

Fruit physical (finger) characteristics

Significantly (p = 0.001) longer, thicker, and heavier fingers of plantain were produced by plots treated with fertilizers as compared to plots without fertilizer. Plants treated with T_2 showed an increased in finger length (24.12 cm) and finger circumference (14.97 cm). The control plants produced the lowest finger length (21.99 cm) but did not produce the lowest finger circumference (13.78 cm), as compared to T_4 (13.56 cm) and T5 (13.50 cm). These poor results in T_4 and T_5 might be influence by slow decomposition rate of their organic matter present in the coffee husk and cocoa pod residues respectively. Heaviest fingers were obtained under T_3 (263.60 g) and T_6 (261.83 g) while the control (T_1) obtained the lightest finger (230.81 g) (Table 5). The increase in finger number, length, circumference, and weight might be due to promoting endogenous and enhancement of nutrient uptake in addition to the role of nitrogen on productivity of banana plants (Kuttimani et al., 2013). Any factor that stimulates higher finger production and favours better finger development leads to better bunch weight (Kuttimani et al., 2013). Panelo and Diza (2017), reported that the application of chicken manure and goat manure significantly increased the mid-trunk diameter (25.63cm) and (25.62 cm); finger length (14.33

Table 5. The effects of the fertilizers fruit physical (finger) characteristics of plantain.

Treatment	Fruit physical (finger) characteristics					
	FL (cm)	FC (cm)	FW (g)	Pulp weight (g)	Peel weight (g)	Pulp:peel ratio
T_1	21.99±2.20^c	13.78±0.97^b	230.81±42.41^b	151.46±33.34^b	79.35±10.94^a	1.98±0.34^b
T_2	24.12±2.70^a	14.97±0.54^a	261.20±45.94^a	176.82±36.64^a	84.38±13.12^a	2.16±0.42^{ab}
T_3	24.06±2.42^a	14.90±0.63^a	263.60±42.18^a	178.44±37.63^a	85.16±8.80^a	2.12±0.40^{ab}
T_4	22.77±1.55^{abc}	13.56±0.99^a	259.03±37.56^a	176.97±30.75^a	82.06±13.81^a	2.38±1.00^a
T_5	22.15±1.51^c	13.50±1.45^a	254.12±47.38^{ab}	172.37±42.52^{ab}	81.75±8.99^a	2.15±0.55^{ab}
T_6	23.67±1.87^{ab}	14.60±0.83^a	261.83±40.37^a	178.07±35.72^a	83.77±9.89^a	2.17±0.45^{ab}
T_7	22.85±1.99^{abc}	14.52±0.79^a	255.62±42.33^{ab}	170.98±38.82^{ab}	84.63±8.25^a	2.05±0.44^{ab}
T_8	22.51±1.37^{bc}	14.51±0.91^a	258.56±26.82^{ab}	173.44±26.46^{ab}	85.13±7.18^a	2.07±0.38^{ab}

Values represent Means were separated using Tukey HSD = 0.05. Mean with similar letters within column indicate no significant differences among treatments. FL= Finger length, FC = Finger circumference, FW = finger weight, T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer.
Source: Authors

cm) and (13.13 cm); finger diameter (3.60 cm each); and weight of fruits (450kgs each). Manivannan and Selvamani (2014), reported that, maximum bunch weight, a greater number of fingers per bunch was obtained by applying vermicompost as full nitrogen in banana. They also opined that, significantly more finger weight and finger girth was obtained by applying organic + inorganic fertilizers. Ganapathi and Dharmatti (2018) reported that the yield parameters such as bunch weight (26.94 kg), number of hands per bunch (11.75), finger weight (137.38 g), finger length (17.75 cm), plot yield (85.57 kg), yield per ha (66.02 tons) can be obtained when organic and inorganic fertilizer are used mixed or individual. The heaviest pulp was obtained by plants treated with T_3 (178.44 g) treatment, followed in descending order by T_6 (178.07 g), T_4 (176.97 g) and T_2 (176.82 g) treatments, without significant difference between them but significantly difference (p = 0.001) from the control (151.46 g). While the lowest peel weight was detected by T_1 (79.35 g) treatment, which was not significantly difference (p = 0.05) from the other peels treated with fertilizers. This indicates that the pulp of fruits which plants were treated with organic waste and inorganic fertilizer may have accumulated higher nutrients and protein concentration from the fertilizer. However, Flores-Mangual and González-Vélez (2019) reported that chicken manure significantly increased the amount of N-NO^{3-}, available P, K^+, and Mg^{+2} compared to plots with no-chicken manure application. The pulp: peel ratio significantly showed difference (p = 0.001) with fertilizer treatment. The pulp: peel ratio for control (1.98), T_2 (2.16), T_3 (2.12), T_5 (2.15), T_6 (2.17), T_7 (2.05) and T_8 (2.07) plots were statistically similar (Table 5). This might be because of osmotic transfer of moisture from the peel to the pulp as sugar content of pulp increased. It has been reported that pulp to peel ratio can be considered as a coefficient of fruit ripeness. These physiological and chemical changes during ripening period (loss of greenness and increase in yellowness) could be due to the breakdown of the chlorophyll in the peel tissue. The main changes in fruit pulp during ripening are the transformation of starch to sugars. As ripening proceeds, pulp to peel ratio was increased from 2.0 in stage 5 to 2.7 in stage 7 when the fruits become fully ripened (Ganapathi and Dharmatti, 2018). The result of this study agrees with the findings of Ganapathi and Dharmatti (2018) observed that application of organic manures *viz.,* vermicompost equivalent to 40 % RDN (24.20 tons ha^{-1}) + 40 % RDN through chemical fertilizer (urea 535.73 kg ha^{-1}) + Green manure (sunnhemp at 8.88 tons ha^{-1}) and *Azospirillum* (30.86 kg ha^{-1}) equivalent to 20 % RDN + PSB (30.86 kg ha^{-1}) resulted in significantly higher amount of pulp: peel ratio. This was also in line with the study of El-Badawy and Ali (2019), who reported the 75% RD+45g humic+5ml biofertilizer/plant and 75% RD+21kg compost+5ml biofertilizer/plant recorded the highest pulp:peel ratio.

Economic analysis of plantain production

The cost and return analysis of one-hectare plantain production treated with different organic waste and inorganic fertilizers (Table 6). The maximum cost of planting was incurred in plots supplied with T_3 (2,525,916.7 FRS CFA ha^{-1}) to produce plantain with the least in control (2,119,250 FRS CFA ha^{-1}). The maximum net benefit was in plots supplied with T_3 (1,334,083 FRS

Table 6. The effects of organic and inorganic fertilizer on cost/benefit ratio and cost of production ($CFAHa^{-1}$) in the production of plantain.

Parameter	Quality	Unit cost	T1	T2	T3	T4	T5	T6	T7	T8
Land preparation	1 ha	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000
Plantain plantlets	1667	350	583.450	583.450	583.450	583.450	583.450	583.450	583.450	583.450
Labour	4 persons (100 days)	1500	600.000	600.000	600.000	600.000	600.000	600.000	600.000	600.000
NPK 20 10 10	4bags	20.000	-	80.000	-	-	-	400.00	40.000	40.000
Urea	2 bags	18.500	-	37.000	-	-	-	18.500	18.500	18.500
Poultry manure	12t	20.000	-	-	240.000	-	-	120.000	-	-
Coffee husk	12t	10.000	-	-	-	120.000	-	-	60.000	-
Cocoa pod residues	12t	10.000	-	-	-	-	120,000	-	-	60.000
Cypemechrin	40 Kg	600	24.000	24.000	24.000	24.000	24.000	24.000	24.000	24.000
Glyphosate herbicide	5 L	5.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
Staking	1667	400	666.800	666.800	666.800	666.800	666.800	666.800	666.800	666.800
Ropes	400m	50	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
Transportation of sticks	-	-	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
Transportation of fertilizers	-	-	-	25.000	166.666	166.666	166.666	103.333	103.333	103.333
Total Input			2,119,250	2,261,250	2,525,916.7	2,405,916.7	2,405,916.7	2,401,083.3	2,341,083.3	2,341,083.3
Total Output			2,346,666	3,266,666	3,860,000	3,086,666	3,000,000	3,252,000	3,233,333	3,180,000
Net benefit			227,416.7	1,005,416.7	1,334,083.3	680,750	594,083.3	850,916.7	892,250	838,916.7
Cost/benefit ratio			0.90	0.69	0.65	0.78	0.80	0.74	0.72	0.74

T_1= No fertilizer, T_2 =300 kg ha^{-1} inorganic fertilizer, T_3 =12 tons ha^{-1} Poultry manure, T_4 =12 tons ha^{-1} Coffee husk, T_5 =12 tons ha^{-1} Cocoa pod residue, T_6 =6 tons ha^{-1} Poultry manure + 150 kg ha^{-1} inorganic fertilizer, T_7 =6 tons ha^{-1} Coffee husk + 150 kg ha^{-1} inorganic fertilizer, T_8 =6 tons ha^{-1} Cocoa pod residue + 150 kg ha^{-1} inorganic fertilizer. FCFA = African Financial Community (Franc) or "Francs Communaute Francaise Africaine" in French language. This currency is pegged to the Euros at 1 Euro=655.957 FCFA US$1=553.258 FCFA (This rate fluctuates a lot).
Source: Authors

CFA ha^{-1}) and the least in the control (227,417 FRS CFA ha^{-1}) (Table 6). From Table 6, the maximum cost/benefit ratio was observed in the control plot (0.90) and the least in plot supplied with T_3 (0.65). From the economic analysis, though plants supplied with poultry manure incurred high cost of production, the yield was about 42% greater than plant in the control. Nevertheless, the control had the highest cost/benefit ratio, indicating that it had the least benefit when compared with the other treatments. This result supports to the findings that any improvement in fruit quality of plantain harvested, gives a higher market price per unit (Kuttimani et al., 2013). This indicates that the organically produced products reflected higher sale price per kg (Badgujar et al., 2010). Generally, high nutritive food items are of high economic value in the market (Tijani et al., 2009). Panelo and Diza (2017), who reported that the net income and return on investment (ROI) were also influenced by chicken manure and goat manure.

Conclusion

This study showed that 12 tons ha^{-1} poultry manure produces the best plant height, circumference, reduced flowering and maturity time, and gave the best yield compared to the other organic and inorganic fertilizers or control. From the cost/benefit analysis it also shows that poultry manure improves plantain production in the humid forest zone of Cameroon and therefore be easily used in home gardens and for small scale production. For large scale plantain production, there might not be enough supply of poultry manure for a large plantation, 300 kg ha^{-1} of NPK 20:10:10 inorganic fertilizer would be suitable or preferable for easy handling and its application.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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