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# Effects of Organic Amendments on Growth, Establishment and Yield of Cacao (*Theobroma cacao* L) in Southwestern Nigeria

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author AKB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AS and AOP managed the analyses of the study. All authors read and approved the final manuscript.*

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## ABSTRACT

Low soil fertility is a major problem of growth and establishment of cacao seedlings, as well as the yield on the field. However, cacao (*Theobroma cacao* L) is characterized by high nutrient demand particularly N, P, K, Ca and Mg, during establishment. In this study, the manurial potentials of some organic wastes and their effects on growth, development and yield of cacao in Ibadan and Owena soils of Southwestern Nigeria were investigated. The experiments in Ibadan and Owena were Randomized Complete Block Design (RCBD) with 3 replicates. Fertilizers were: Goat Dung (GD), Sunshine Organic and Organo-Mineral Fertilizers (OF and OMF) and NPK 15:15:15 at 0, 200, 400 and 600 kg/ha. The fertilizers were applied to treatment plots one month after cacao seedlings were transplanted using ring method (July, 2011). Four hundred and thirty two (432) plantain suckers were planted at 3 x 3 m spacing as shade crop while 432 cacao seedlings (F3 Amazon) were also transplanted at 3 x 3 m respectively at each experimental site. Top soil samples were analysed with standard methodologies. Data were collected monthly on cacao growth parameters

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such as plant height, stem diameter, number of leaves and number of branches, commencing at 3 months after transplanting (MAT). The experiments were monitored for 36 months (144 weeks after planting of cacao). Survival count was carried out 12 MAT. Data collected were subjected to statistical analysis using Analysis of variance (ANOVA) and significant means were separated by Tukey's HSD ($P < 0.05$) test. Cacao seedlings grown under 600 kg/ha OF application had 100 and 95 percent survival count at Ibadan and Owena respectively. All fertilizer types and rates at Ibadan and Owena significantly increased cacao seedlings height, number of leaves, stem diameter and number of branches, relative to the control plots at 3, 4, 5, 15, 16 and 17 MAT. Goat dung applied at 600 kg/ha gave the highest number of flowers, cherelles and pods at 24 and 36 MAT at Owena. However, there were no yield parameters recorded for Ibadan experiment at 24 and 36 MAT.

*Keywords: Cacao; fertilizers; survival count; performance; production.*

## 1. INTRODUCTION

Cocoa is one of the most important tropical crops [1]. West Africa contributes about 70% of the world's cocoa production. The crop significantly contributed to the economies of countries in this sub-region, as well as economics of many other countries in Central America and South East Asia. Nigeria is the fourth largest producer of cocoa in the world with an estimated production of 485,000 metric tons in 2006 [1]. Cocoa is therefore a major commodity crop cultivated in Nigeria and is a major raw material used in the production of cocoa powder (for beverage drink), various chocolate based products, biscuits and confectioneries. Processed cocoa bean is also used to make sweets, sweetening products, cocoa butter (used in making chocolate), perfume, and in pharmaceuticals. Locally, cocoa bean is used in cooking soup that has resemblance of okra and in treating various abdominal problems or ailments [2].

The production of cocoa in Nigeria has witnessed a downward trend since the early 1970s due to numerous factors like ageing trees, ageing farmers, wrong application of recommended agronomic techniques by farmers, effects of pests and diseases and deficiencies in macro and micro nutrients in the soils [3]. Previous studies have attributed this yield decline essentially to soil nutrients imbalance [4]. One way of combating this problem is the use of fertilizer. However, African farmers use very little fertilizer (8kg/ha) compared to their counterparts in other parts of the agrarian world, hence, Africa's soils are increasingly depleted of nutrients [5]. This is particularly true with cocoa farmers in Nigeria. Ogunlade et al. [6] reported that more than 85% of cocoa farmers in Nigeria do not use fertilizers on their cocoa crops. Reasons for this low usage of fertilizers vary from lack of farmers' knowledge of the nutrients status of their soils to scarcity and high cost of fertilizers where available. The need to pay attention to soil fertilization is now almost as important as the control of capsids and black-pod disease in cocoa. Ayanlaja [7], Adejobi et al. [3a,b,c] and Moyin-Jesu [8] reported the use of organic residues such as animal manures, urban refuse, agro-industrial processing wastes, refuse dump compost, pit latrine compost, foot of the hill compost, mulching, passive refuse dump in home gardens and alley cropping with appropriate nitrogen fixing shrubs, have been found capable of increasing and balancing soil nutrients with consequential increase in yield and crop performance. Also, it has been researched that manures are capable of enhancing yield of tree crops such as coffee (Michori [9]; Obatolu [10]), teak [11] and tea [12,13]. Recent findings indicated that leaf chlorophyll, K: Na and C: Na ratios of organic fertilizer treated crops were higher than NPK fertilizer. These high K and Ca contents might have been responsible for the enhancement of growth, yield and yield quality for manured crops, compared to NPK fertilizer treatment [14,15]. Therefore, the main objective of this study was to examine the influence of different organic, organo-mineral and NPK fertilizers on cacao seedlings growth, establishment and yield on the field.

## 2. MATERIALS METHODS

### 2.1 Experimental Sites and Condition

Field experiments were conducted at Ibadan, headquarters of the Cocoa Research Institute of Nigeria (CRIN), and in Owena, a CRIN Sub-station in Ondo State.

### 2.2 Ibadan Experimental Location

Ibadan, Oyo State, is located on latitude 07° 10' N and longitude 03° 52'E, and an altitude of

about 122 meters above sea level in the humid tropical rain forest zone of Nigeria. Ibadan is characteristically hot and humid, reputed for seasonal rainfall, high temperatures and high humidity and distinct dry and rainy seasons. The dry season extends from early November to March and is characterized by dry atmosphere and intense scorching sun. The rainy season which is characterized by high humidity and cloudy sky, runs from end of March to early November. There is usually a two-week dry spell in August. The annual rainfall is between 1200-1500 mm. The maximum temperature ranges between 26 to 35°C with an average of about 30.1°C while the minimum temperature ranges from 15 to 24°C with an average of 19.5°C. Relative humidity is high throughout the year and ranges from of 50 to 89% with an average of 79%. There are seasonal variations in the values of relative humidity, which varies from 65 to 89% during the rainy season and 46–70% during the dry season.

## 2.3 Owena Experimental Location

The Owena substation of the Cocoa Research Institute of Nigeria, located in Ondo State, lies on latitude 07° N and longitude 05°, 7$^{1}$E and at an altitude of about 22.5 meters above sea level. Owena is situated at about 21 k south –east of Akure between Akure and Ondo. There are two seasons: rainy (wet) season which spans late March to November of the same year and a dry season that runs from December to late March of the following year. The dry season on the contrary to the situation in Ibadan` has characteristic of scanty rainfall, the average ranges between 1500 – 1600 mm per annum. The maximum temperature in Owena is usually between 28 and 34°C while the daily minimum temperature ranges between 18 and 23°C. The relative humidity during the rainy season ranges from 69 to 80%, and between 56 and 64% during the dry season.

## 2.4 Acquisition and Preparation of Experimental Materials

Seedlings of cacao F3 Amazon genotype were collected from CRIN Seed Garden, while plantain suckers were collected from experimental plots in Ibadan and Owena. Experimental plots of about 30 by 120 m were mapped out and the experiment was laid out in rows of 3 x 3 m. Sunshine organic and organo-minerals fertilizers used for the experiments in Ondo State were obtained from the Ministry of Agriculture, while the N.P.K. 15:15:15 was obtained at Ayedaade Local Government Gbongan, Osun State. Goat dung was obtained from Ilesha Garage Akure, Ondo State. The goat dung was collected dried and carefully sorted to remove foreign materials and packed in 50 kg bags for application on the field.

## 2.5 Field Experiments

### 2.5.1 Treatments and experimental design

Field experiments were conducted in two stations of the Cocoa Research Institute of Nigeria (CRIN), Ibadan Headquarters and Owena Sub-Station, Ondo State. The experiments were conducted between June, 2011 and June, 2014. The experiments were Randomized Complete Block Design (RCBD) with 3 replications. The 4 fertilizers were: Goat Dung (GD), Sunshine Organic and Organo-Mineral Fertilizers (OF and OMF) and NPK 15:15:15 and the rates of application were: 0, 200, 400 and 600 kg/ha. Four hundred and thirty two (432) plantain suckers were planted at 3 x 3 m spacing as shade crop while 432 cacao seedlings (F3 Amazon) were also transplanted at 3 x 3 m respectively at each experimental site for 2011 experiment. Lay-out of each experimental site (Measurement, pegging and holing) was carried out before planting. Four hundred and thirty two (432) plantain suckers were planted as shade crop at the spacing of 3 x 3 m in each of the experimental sites in Ibadan and Owena between second and third week of June, 2011. Four hundred and thirty two (432) five months old cacao seedlings (F3 Amazon) of average height of 46 cm (already raised in the nursery) were transplanted at the spacing of 3 x 3 m on each of the sites in Ibadan and Owena, four plants were randomly tagged for data collection. For 2012 experiments, plantain suckers were established in June, 2011 and thus, cocoa seedlings were transplanted into one year old plantain in 2012. In each experimental site, plantain suckers were planted at 3 x 3 m spacing as shade crop. Top soil samples were collected randomly at the depth of 15 cm from each experimental site (Ibadan and Owena) using soil auger. The samples were bulked and air dried before being subjected to routine laboratory analysis of particle size analysis was determined by the hydrometer method [16] and organic carbon content (OC) by the potassium dichromate oxidation method [17]. Soil pH was determined with a pH meter (1:1 water). Organic matter was determined by Walkley-Black acid digestion

method [18]. Phosphorus determination was done by the Bray method as described by Bray and Kurt. [19]. Soil available potassium (K), calcium (Ca) and Magnesium (Mg) were extracted with $lMNH_4$ OAC, $pH_7$ and were determined with flame photometer; Mg was determined with an atomic absorption spectrophotometer. The total nitrogen (N) was determined by the Microkjedahl method [20].

Two grammes (2 g) each of the organic fertilizers used were also analyzed for nutrient composition. The fertilizers were applied to treatment plots one month after transplanting using ring method of fertilizer application at 5 cm away from the base of cacao (July, 2011). Monthly Data collection on growth parameters (plant height, stem diameter, number of leaves and number of branches) commenced 3 months after transplanting. The experiments were monitored for 36 months (144 weeks after planting). Survival count was carried out 12 months after transplanting.

## 2.6 Data Collection

Data were collected on the growth parameters of cacao seedlings such as: Plant height measured in centimeter using a meter rule on the surface and the tip of the main stem; Number of leaves was counted. Stem diameter was measured in centimeter with the use of Vernier'Caliper 30 cm above the ground level. Number of branches was also counted. These growth parameters were taken monthly for 24 months commencing from 3 months after transplanting (3 MAT).

## 2.7 Statistical Analyses

Analysis of variance was performed on all data to test the treatment effect on different parameters and significant means were separated using Tukey's Honest Significant Difference (HSD) ($P < 0.05$).

## 3. RESULTS AND DISCUSSION

The result of the initial physical and chemical properties of the soil used for the experiments is presented in Table 1. The particle-size analysis of the soils of both Ibadan and Owena 2011 experimental sites showed that the soils were sandy loam and Alfisols [21]. The silt + clay contents of the soils at Ibadan and Owena 2011 (23.98% and 27.9%) experiments respectively, were below the 32% estimated to be adequate for soils considered to be ideal for tree crops production especially cacao [22]. Based on the established critical levels for soils in southwestern Nigeria, the soils at Ibadan and Owena were acidic with pH ranging between 4.56 – 5.76 and low in organic matter (0.99 – 2.51%) compared to the reported critical levels of 3% organic matter [23]. The total nitrogen of Owena soil was less than 0.15% which is considered optimal for most crops including cacao and the soils also had low CEC [24]. This suggests the need to improve on the soil organic matter and hence the CEC for enhanced nutrient retention and the release of same to crops upon external fertilizer application [25]. The application of inorganic fertilizer to a soil with low organic matter content is a waste of resources and time [26]. Hence there is need for proper SOM management on Ibadan and Owena soils to reduce the deleterious effects on soil physical and chemical properties. Although, available P was also low, this level of available P is considered inadequate for cacao [27,22]. Both Ibadan and Owena soils gave exchangeable potassium below the critical value of 0.3 cmol/kg required for cacao. The exchangeable $Ca^+$ of Owena soil fell below the critical value of 5 cmol/kg required for cacao growth. At Ibadan, the exchangeable $Mg^+$ was adequate for cacao production. Obatolu [10] earlier observed the general low $Mg^+$ nutrient content of Owena soil. The low nutrient contents of the soils implied the need for external input of nutrients in order to meet the requirements for optimal cacao growth. It is obvious that the soils of both Ibadan and Owena were inherently low in fertility and were therefore expected to show positive response to soil amendment. The insufficient levels of the major nutrients in the soils in both locations showed that the soils were depleted in nutrients and would not be able to meet the nutritional needs of cacao plants unless external nutrients supply is made to support optimum growth of cacao plants.

Table 2 presented data on the nutrient composition of the organic materials used for the experiments. Among the organic fertilizers applied, goat dung (GD) had the highest pH, though all the organic and organo-mineral fertilizers had pH above 5 (acidity levels) which indicated that they could be effective as liming materials. The organo-mineral fertilizer (OMF) had the highest available P followed by GD and organic fertilizer (OF) had highest percentage N. The results were in agreement with the works of Adejobi et al. [3] who found out that GD, OMF and OF were as effective as NPK fertilizer which

can be used as effective sources of plant nutrients. In particular, OF had the highest OM, K, Mg, Ca and Na concentrations relative to other organic fertilizers, this implied that OF could be a good source of these nutrients for plant growth.

Effects of organic and inorganic fertilizers on survival count of cacao seedlings are represented in Table 3. 600 kg/ha OF, 400 kg/ha OF, 600 kg/ha GD, 600, 400 and 200 kg/ha OMF significantly improved the survival count of cacao in Ibadan relative to other fertilizer types, rates and the control while 600 kg/ha OF and 400 kg/ha NPK gave the highest survival count in Owena experiment compared with other fertilizer treatments and the control (Table 3). The highest seedlings survival count recorded across the two locations (Ibadan and Owena) under 600 kg/ha OF could be as a result of increased soil organic matter after fertilizer application. This could have led to greater water retention to sustain plant survival on the field during dry spell. This finding was in agreement with Adeoye [28] who reported significant greater amount of water retention on the soil following application of 5t/ha cow-dung. The manuring effects on soil water retention may be explained by enhanced stability of soil structure.

Effect of fertilizers on growth parameters of cacao is presented in Tables 4 to 11. The fertilizer treatments enhanced plant height of cacao seedlings than control in both locations at 3, 4 and 5 months after transplanting (MAT). Cacao plants were taller at Ibadan than Owena at 5 MAT. The differences in height between both locations were attributed to the differences in the nutrient- releasing pattern and growing environmental conditions between the two locations. Application of OMF at 400 kg/ha significantly ($P< 0.05$) increased number of

**Table 1. Physical and chemical characteristics of the soils before planting in Ibadan and Owena (2011 experiments)**

| Soil properties | Ibadan 2011 experiment | Owena 2011 experiment |
|---|---|---|
| Sand (%) | 76.1 | 72.1 |
| Silt (Silt (%)) | 16.3 | 18.2 |
| Clay (%) | 7.6 | 9.7 |
| Textural class | Sandy loam | Sandy loam |
| pH (water) | 5.44 | 5.76 |
| Organic carbon (g/kg) | 3.20 | 0.57 |
| Organ Organic matter (%) | 2.51 | 0.99 |
| Total I Nitrogen (%) | 0.32 | 0.06 |
| Available P (cmol/kg) | 11.67 | 9.96 |
| $K^+$ (cmol/kg) | 0.28 | 0.22 |
| $Ca^{++}Ca^{++}$ (cmol/kg) | 6.60 | 1.00 |
| $Mg^{++}$ (cmol/kg) | 3.40 | 0.40 |
| $Na^+$ (cmol/kg) | 2.87 | 0.16 |
| $Al^{+++}$ | 1.22 | 2.36 |
| H+(cmol/kg) | 6.32 | 7.89 |
| ECEC (cmol/kg) | 28.69 | 12.03 |

**Table 2. Chemical composition of the organic materials used**

| Properties | Goat dung (GD) | Organo-mineral fertilizer (OMF) | Organic fertilizer (OF) |
|---|---|---|---|
| pH (water) | 8.17 | 7.00 | 7.30 |
| Organic carbon (g/kg) | 2.86 | 0.63 | 3.64 |
| Organic matter (%) | 4.80 | 1.09 | 6.27 |
| Total nitrogen (%) | 1.26 | 0.06 | 2.16 |
| Available P (cmol/kg) | 113.24 | 138.06 | 7.08 |
| $K^+$ (cmol/kg) | 0.41 | 0.19 | 5.56 |
| $Mg^{++}$ (cmol/kg) | 1.20 | 1.00 | 6.00 |
| $Ca^{++}$ (c $Ca^{++}$ cmol/kg) | 2.60 | 2.00 | 13.10 |
| $Na^+$ (cmol/kg) | 0.38 | 0.18 | 2.30 |
| C:N | 1:4 | 1:1 | 1:6 |

**Table 3. Survival of cacao seedlings as affected by organic and inorganic fertilizers at Ibadan and Owena (2011 experiments) at 12 MAT)**

| Treatments | | Ibadan experiment | Owena experiment |
|---|---|---|---|
| **Fertilizers** | **Rates (kg/ha)** | **2011** | **2011** |
| Goat dung | 600 | 94.44a | 69.45ab |
| | 400 | 91.67ab | 69.44ab |
| | 200 | 88.89abc | 86.44ab |
| | Control | 80.54abcd | 55.55b |
| Organo-mineral fertilizer | 600 | 94.44a | 83.33ab |
| | 400 | 97.22a | 55.56b |
| | 200 | 94.44a | 77.78ab |
| | Control | 80.53abcd | 55.54b |
| Organic fertilizer | 600 | 100.00a | 94.45a |
| | 400 | 97.22a | 77.78ab |
| | 200 | 97.22a | 83.33ab |
| | Control | 80.67abcd | 55.86b |
| NPK 15: 15: 15 | 600 | 66.67cd | 77.78ab |
| | 400 | 61.11d | 91.67a |
| | 200 | 69.44bcd | 69.44ab |
| | Control | 80.55abcd | 55.56b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

leaves than other treatments and control at 3, 4 and 5 MAT in Ibadan experiment. But at Owena experiment, GD applied at 200 kg/ha gave higher number of leaves at 3 and 4 MAT than the other treatments and the control. At both locations (Ibadan and Owena 2011 experiments), the fertilizers applied increased number of branches relative to the control plot. The significant increases in the growth parameters of cacao seedlings at 3, 4 and 5 MAT in Ibadan and Owena (2011experiments) relative to the control under the fertilizer treatments can be attributed to the nutrient contents of organic fertilizers applied which enhanced cacao seedlings growth. This finding that the manure (GD, OMF and OF) improved the growth of cacao is consistent with earlier findings of Adeniyan and Ojeniyi, [29] and Moyin-Jesu, [30] who reported that manures supported the growth and development of maize and coffee. Poor growth of cacao seedlings as a result of low nutrient status of soil was generally observed in the unfertilized treatment plots in the two locations in 2011 indicating that the soils of both locations were low in fertility and not supportive of good cacao growth.

The values of growth parameters due to manures of both animal and plant origins were higher compared to that of inorganic origin (NPK 15: 15: 15 fertilizer). This might be due to presence of other vital nutrient elements like Ca, Mg, OC and other micro-nutrients that are required for cacao seedlings growth which are absent in the NPK 15: 15:15 fertilizer [12].

At 15, 16 and 17 MAT in Ibadan and Owena, the fertilized treatments and rates reflected in higher plant height relative to the unfertilized control. This result indicated short supply of nutrients to cacao seedlings under the control and consequently led to poor seedlings growth. The relatively higher plant height under 400 kg/ha OMF, 400 kg/ha OF in Ibadan and 200 kg/ha GD in Owena at 15, 16 and 17 MAT could have stemmed from the nutrient contents of the organic fertilizers (essential soil nutrients) which though released slowly, last longer in the soil for optimum crop performance [31]. Agboola et al. [32] and Titiloye et al. [33] have reported a survey of 45 waste materials which were found to be rich in the nutrient elements (N, P, K, Ca, Mg, Zn, Cu, Fe and Mn contents). The farm wastes therefore represent a potential source of nutrients that could be harnessed to boost crop growth and productivity [34]. The number of branches recorded at control was not significantly different from plots where the fertilizer types were applied in Ibadan and Owena at 3 MAT. Though application of fertilizers improved number of branches relative to the control plot.

**Table 4. Effects of fertilizer types and rates on plant height (cm) of cacao at (Ibadan and Owena, 2011 Experiments)**

| Treatments | | Ibadan experiment | | | Owena experiment | | |
|---|---|---|---|---|---|---|---|
| | | Months after planting | | | Months after planting | | |
| **Fertilizers** | **Rates (kg/ha)** | **3** | **4** | **5** | **3** | **4** | **5** |
| Goat dung | 600 | 46.33ab | 55.83ab | 59.62a | 40.10b | 52.92ab | 58.75bcd |
| | 400 | 40.67ab | 5058ab | 53.33ab | 39.80b | 49.92ab | 64.42abc |
| | 200 | 39.58ab | 47.00ab | 48.33ab | 46.10a | 55.83ab | 76.17a |
| Organo-mineral fertilizer | 600 | 47.58ab | 58.08a | 58.90a | 43.77b | 65.67a | 75.42ab |
| | 400 | 49.67ab | 59.40a | 56.94a | 43.77b | 50.00ab | 55.42cde |
| | 200 | 46.42ab | 59.42a | 60.16a | 43.00b | 50.42ab | 57.92cde |
| Organic fertilizer | 600 | 49.25ab | 55.67ab | 56.19a | 46.43a | 53.67ab | 72.33abc |
| | 400 | 47.04ab | 55.83ab | 53.29ab | 46.50a | 55.00ab | 67.75abcd |
| | 200 | 51.17a | 56.17 | 57.33a | 40.27b | 48.33b | 65.33abcd |
| NPK 15: 15: 15 | 600 | 43.33ab | 47.75ab | 50.00ab | 44.83b | 55.29ab | 61.75abcde |
| | 400 | 39.92ab | 45.58ab | 46.02ab | 42.83b | 52.58ab | 66.67abcd |
| | 200 | 43.37ab | 49.50ab | 50.35ab | 49.19a | 56.51ab | 65.33abcd |
| Control | | 36.83b | 41.25b | 41.32b | 37.10c | 42.50b | 49.08e |

*Treatment means within each column followed by the same letters are not significantly different from each other using Turkey's HSD at 5% level*

**Table 5. Effects of organic and inorganic fertilizers types and rates on number of leaves of cacao seedlings (Ibadan and Owena 2011 experiments)**

| Treatments (kg/ha) | | Ibadan experiment | | | Owena experiment | | |
|---|---|---|---|---|---|---|---|
| | | Months after planting | | | Months after planting | | |
| **Fertilizers** | **Rates** | **3** | **4** | **5** | **3** | **4** | **5** |
| Goat dung | 600 | 22.58abcd | 25.42abcd | 26.43adc | 9.13ab | 12.00ab | 16.33ab |
| | 400 | 17.42cdef | 21.83bcde | 22.84bcd | 12.12a | 13.67ab | 22.50a |
| | 200 | 23.42abc | 26.92abc | 27.29ab | 13.67a | 16.18a | 22.00a |
| | Control | 13.39ef | 14.93e | 15.54d | 7.56b | 9.15b | 7.22b |
| Organo-mineral fertilizer | 600 | 24.75ab | 28.33ab | 28.27ab | 13.27a | 15.15ab | 22.83a |
| | 400 | 26.92a | 32.00a | 33.10a | 10.85ab | 12.50ab | 21.08a |
| | 200 | 19.42bcde | 25.50abcd | 26.10abc | 11.58ab | 13.08ab | 17.83ab |
| | Control | 13.41ef | 14.93e | 15.52d | 7.57b | 9.18b | 7.30b |
| Organic fertilizer | 600 | 21.33abcd | 24.33abcde | 24.96abcd | 11.83ab | 14.75ab | 23.83a |
| | 400 | 18.83bcde | 23.08abcde | 23.66abcd | 11.08ab | 11.92ab | 16.08ab |
| | 200 | 21.63abcd | 22.88abcde | 24.63abcd | 9.83ab | 12.83ab | 20.25ab |
| | Control | 13.40ef | 14.94e | 15.51d | 7.56b | 9.16b | 7.25b |
| NPK 15: 15: 15 | 600 | 15.50def | 16.25de | 17.59cd | 9.52ab | 9.38b | 11.92ab |
| | 400 | 11.42f | 15.93de | 16.28d | 10.85ab | 12.77ab | 16.13ab |
| | 200 | 17.33cdef | 18.50cde | 19.05bcd | 4.50ab | 11.58ab | 15.50ab |
| | Control | 13.42ef | 14.94e | 15.53d | 7.60b | 9.17b | 7.25b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

Application of GD at 600 kg/ha gave the highest number of flowers at both 24 and 36 MAT relative to all other treatments in Owena experiment. At 24 MAT, GD applied at 600 and

400 kg/ha gave the highest number of cherelles followed by 200 kg/ha GD, but at 36 MAT, only 600 kg/ha GD gave the highest number of cherelles followed by 600 kg/ha OMF and 200 kg/ha GD. These yield results authenticate the importance of organic fertilizer in crop production, and that they are capable of enhancing yield of tree crops such as coffee [9,10], teak [11] and tea [12,13]. Recent findings indicated that leaf chlorophyll, K: Na and C: Na ratios of organic fertilizer treated crops were higher than NPK fertilizers. These high K and Ca

**Table 6. Effects of organic and inorganic fertilizers types and rates on stem diameter of cacao seedlings (Ibadan and Owena 2011 experiments)**

| Treatments | | Ibadan experiment | | | Owena experiment | | |
|---|---|---|---|---|---|---|---|
| | | Months after planting | | | Months after planting | | |
| **Fertilizers** | **Rates(kg/ha)** | **3** | **4** | **5** | **3** | **4** | **5** |
| Goat dung | 600 | 0.85a | 1.28a | 1.29b | 0.85a | 1.13ab | 1.56ab |
| | 400 | 0.74ab | 1.18ab | 1.19b | 1.03a | 1.11ab | 1.54ab |
| | 200 | 0.78a | 1.15ab | 1.14b | 1.09a | 1.19ab | 1.81a |
| | Control | 0.64ab | 0.94b | 1.29b | 0.91a | 1.03b | 1.09b |
| Organo-mineral fertilizer | 600 | 0.81a | 1.33a | 2.31a | 0.92a | 1.28a | 1.53ab |
| | 400 | 0.66ab | 1.25a | 1.33b | 1.09a | 1.16ab | 1.35ab |
| | 200 | 0.79a | 1.8a | 1.2ab | 0.71a | 1.10ab | 1.48ab |
| | Control | 0.65ab | 0.93b | 1.28b | 0.90a | 1.02b | 1.07b |
| Organic fertilizer | 600 | 0.74ab | 1.29a | 1.31b | 0.95a | 1.14ab | 1.56ab |
| | 400 | 0.57b | 1.27a | 1.29b | 1.07a | 1.15ab | 1.41ab |
| | 200 | 0.84a | 1.33a | 1.34b | 1.01a | 1.26a | 1.61ab |
| | Control | 0.67ab | 0.91b | 1.26b | 0.90a | 1.02b | 1.08b |
| NPK 15: 15: 15 | 600 | 0.65ab | 0.95b | 1.01b | 0.93a | 0.87b | 1.06b |
| | 400 | 0.56b | 0.94b | 0.95b | 1.01a | 1.12ab | 1.24ab |
| | 200 | 0.65ab | 1.09ab | 1.13b | 0.94a | 1.14ab | 1.45ab |
| | Control | 0.66ab | 0.95b | 1.29b | 0.91a | 1.04b | 1.09b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

**Table 7. Effects of organic and inorganic fertilizer types and rates on number of branches of cacao seedlings in Ibadan and Owena (2011 experiments)**

| Treatments (kg/ha) | | Ibadan | | | Owena | | |
|---|---|---|---|---|---|---|---|
| | | Months after transplanting | | | Months after transplanting (MAT) | | |
| **Fertilizers** | **Rates(kg)** | **3** | **4** | **5** | **3** | **4** | **5** |
| Goat | 600 | 0.58abc | 1.20ab | 2.04ab | 0.58b | 1.08ab | 2.00ab |
| Dung | 400 | 0.15c | 0.95ab | 1.46ab | 1.25a | 1.50ab | 3.42ab |
| | 200 | 0.92abc | 1.62a | 3.00a | 0.42b | 1.15ab | 3.50ab |
| | Control | 0.12c | 0.18c | 0.18b | 0.32bc | 0.36b | 1.25b |
| Organo- | 600 | 1.50ab | 1.60a | 2.74a | 0.75b | 1.33ab | 3.30ab |
| Mineral | 400 | 1.62a | 1.82a | 1.80ab | 0.92ab | 1.75a | 4.33a |
| Fertilizer | 200 | 0.28bc | 0.48bc | 1.10ab | 1.00a | 1.20ab | 3.17ab |
| | Control | 0.11c | 0.19c | 0.18b | 0.31bc | 0.36b | 1.23b |
| Organic | 600 | 0.67abc | 0.72ab | 1.75ab | 0.83ab | 0.84ab | 4.33a |
| manure | 400 | 0.37abc | 0.55ab | 1.05ab | 0.92ab | 0.73ab | 2.75ab |
| | 200 | 0.28bc | 0.39bc | 1.84ab | 1.17a | 1.17ab | 2.75ab |
| | Control | 0.11c | 0.18c | 0.17b | 0.31bc | 0.35b | 1.25b |
| NPK | 600 | 0.50abc | 1.50ab | 1.89ab | 0.92ab | 1.67a | 2.67ab |
| 15:15:15 | 400 | 0.37abc | 1.60a | 1.72ab | 0.58b | 1.83a | 2.43ab |
| | 200 | 0.45abc | 0.38bc | 1.36ab | 0.50b | 1.33ab | 4.25a |
| | Control | 0.12c | 0.19c | 0.19b | 0.33bc | 0.37b | 1.25b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

**Table 8. Effects of organic and inorganic fertilizer types and rates on plant height of cacao seedlings at 15, 16 and 17 MAT (Ibadan and Owena 2011 experiments)**

| Treatments | | Ibadan | | | Owena | | |
|---|---|---|---|---|---|---|---|
| | | Months after transplanting | | | Months after transplanting (MAT) | | |
| Fertilizers | Rates (kg/ha) | 15 | 16 | 17 | 15 | 16 | 17 |
| Goat | 600 | 59.42ab | 74.17ab | 92.58ab | 71.17abc | 88.17ab | 99.55a |
| Dung | 400 | 56.92ab | 77.58ab | 88.33ab | 69.77abc | 77.00ab | 79.00ab |
| | 200 | 57.08ab | 70.83ab | 80.33abc | 82.83a | 94.90a | 101.17a |
| | Control | 43.65b | 46.65b | 50.54c | 56.98c | 58.23b | 65.51b |
| Organo- | 600 | 61.23ab | 72.08ab | 90.75ab | 79.25ab | 81.95ab | 86.17ab |
| Mineral | 400 | 66.92a | 72.17ab | 81.50abc | 60.17bc | 67.97ab | 78.17ab |
| Fertilizer | 200 | 63.75a | 80.08ab | 90.50ab | 75.67abc | 83.59ab | 91.69ab |
| | Control | 42.56b | 45.98b | 51.11c | 56.12c | 57.90b | 64.01b |
| Organic | 600 | 66.08a | 81.92a | 95.42ab | 76.75abc | 82.17ab | 90.92ab |
| manure | 400 | 66.33a | 73.83ab | 109.83a | 71.08abc | 73.49ab | 89.00ab |
| | 200 | 63.75a | 71.75ab | 82.42abc | 67.75abc | 71.75ab | 73.50ab |
| | Control | 42.89b | 47.65b | 49.98c | 58.21c | 59.98b | 65.32b |
| NPK | 600 | 51.67ab | 67.67ab | 68.89bc | 70.83abc | 73.93ab | 83.33ab |
| 15:15:15 | 400 | 49.58ab | 54.50ab | 64.08bc | 68.52abc | 74.17ab | 78.92ab |
| | 200 | 51.67ab | 55.17ab | 68.33bc | 70.92abc | 73.82ab | 81.70ab |
| | Control | 44.78b | 46.58b | 50.42c | 57.42c | 58.83b | 64.51b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

**Table 9. Effects of organic and inorganic fertilizer types and rates on number of leaves of cacao seedlings in Ibadan and Owena (2011 experiments)**

| Treatments | | Ibadan | | | Owena | | |
|---|---|---|---|---|---|---|---|
| | | Months after transplanting (MAT) | | | Months after transplanting (MAT) | | |
| | Rates (kg/ha) | 15 | 16 | 17 | 15 | 16 | 17 |
| Goat | 600 | 31.25a | 43.75a | 48.17ab | 19.85ab | 32.05ab | 41.17a |
| Dung | 400 | 27.17ab | 33.00abc | 40.58abc | 24.78ab | 28.50ab | 33.08ab |
| | 200 | 28.27ab | 39.83ab | 44.92abc | 22.50ab | 28.00ab | 37.42ab |
| | Control | 15.54c | 15.32c | 19.34c | 11.76c | 15.32b | 17.54c |
| Organo- | 600 | 25.13abc | 36.00ab | 54.08ab | 24.00ab | 26.03ab | 39.75ab |
| Mineral | 400 | 32.27a | 37.72ab | 46.00abc | 22.33ab | 32.75ab | 36.36ab |
| Fertilizer | 200 | 24.92abc | 26.37abc | 29.83bc | 26.00a | 38.17a | 44.11a |
| | Control | 14.32c | 16.75c | 18.43c | 11.89c | 17.11b | 16.98c |
| Organic | 600 | 27.50ab | 39.25ab | 55.92ab | 26.75a | 33.42ab | 40.50ab |
| fertilizer | 400 | 24.33abc | 31.75abc | 61.33a | 26.25a | 26.86ab | 33.00b |
| | 200 | 25.30abc | 35.00ab | 41.42abc | 20.93ab | 16.02b | 20.50c |
| | Control | 15.90c | 16.09c | 20.32c | 12.98c | 17.21b | 18.56c |
| NPK | 600 | 16.25c | 23.33bc | 31.45bc | 14.92bc | 25.92ab | 33.50b |
| 15:15:15 | 400 | 16.00c | 26.92abc | 30.58bc | 17.81abc | 22.25ab | 23.72c |
| | 200 | 19.00bc | 29.17abc | 36.06abc | 18.42abc | 21.05ab | 30.42b |
| | Control | 15.54c | 16.75c | 19.50c | 12.83c | 16.25b | 17.56c |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

contents might have been responsible for the enhancement of growth, yield and yield quality for manured crops compared to NPK treatment [14,15]. It was also observed from the result of this study that flowers and cherelles produced did not translate to mature pods in all the treatments at 24 MAT, only GD applied at 600 and 400 kg/ha gave one pod each. This could be attributed to the fact that the cacao stems were too tender at 24 MAT for fruit bearing, incompatibility during cross pollination or as a result of adverse weather situation at the period

of flowering, and as a result of pest infestation. This observation was different from that of Murray [35], who observed that the increase in cacao yield due to fertilizer application was as a result of an increase in the production of cherelle per tree rather than a decrease in the amount of wilt. But at 36 MAT, GD applied at 600 kg/ha gave the highest number of pods, followed by

**Table 10. Effects of organic and inorganic fertilizer types and rates on stem diameter of cacao seedlings in Ibadan and Owena (2011 experiment)**

| Treatments | | Ibadan | | | Owena | | |
|---|---|---|---|---|---|---|---|
| | | Months after transplanting | | | Months after transplanting (MAT) | | |
| | Rates (kg/ha) | 15 | 16 | 17 | 15 | 16 | 17 |
| Goat | 600 | 1.43ab | 1.85abcd | 2.46abc | 17.3ab | 2.06ab | 2.26ab |
| Dung | 400 | 1.57a | 2.24a | 2.47abc | 1.85ab | 2.05ab | 2.42ab |
| | 200 | 1.23ab | 1.28de | 2.27abc | 2.11a | 2.34a | 2.38a |
| | Control | 1.18ab | 1.24e | 1.45c | 1.22b | 1.32c | 1.40b |
| Organo- | 600 | 1.47ab | 1.54bcde | 1.99abc | 1.70ab | 2.17ab | 2.60a |
| Mineral | 400 | 1.47ab | 1.59bcde | 2.09abc | 1.39ab | 1.65abc | 1.93ab |
| Fertilizer | 200 | 1.24ab | 1.61bcde | 1.97abc | 1.72ab | 1.86abc | 2.19ab |
| | Control | 1.17ab | 1.43e | 1.65c | 1.11b | 1,23c | 1.40b |
| Organic | 600 | 1.33ab | 2.09ab | 2.59ab | 1.71ab | 1.99abc | 2.07ab |
| manure | 400 | 1.39ab | 1.91abc | 2.79a | 1.58ab | 1.71abc | 1.99ab |
| | 200 | 1.35ab | 1.74abcde | 2.23abc | 1.68ab | 1.71abc | 1.86ab |
| | Control | 1.20ab | 1.24e | 1.65c | 1.22b | 1.23c | 1.34b |
| NPK | 600 | 1.06b | 1.54bcde | 1.97abc | 1.38ab | 1.64abc | 2.17ab |
| 15:15:15 | 400 | 1.04b | 1.45cde | 1.65bc | 1.37ab | 1.65abc | 1.89ab |
| | 200 | 1.12b | 1.97abc | 2.23abc | 1.35ab | 1.52bc | 1.81ab |
| | Control | 1.19ab | 1.26e | 1.56c | 1.23b | 1.25c | 1.39b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

**Table 11. Effects of organic and inorganic fertilizer types and rates on number of branches of cacao seedlings in Ibadan and Owena (2011 Experiments)**

| Treatments | | Ibadan | | | Owena | | |
|---|---|---|---|---|---|---|---|
| | | Months after transplanting (MAT) | | | Months after transplanting (MAT) | | |
| Fertilizers | Rates (kg/ha) | 15 | 16 | 17 | 15 | 16 | 17 |
| Goat | 600 | 4.50a | 8.33a | 8.83a | 2.43ab | 4.16ab | 4.42ab |
| Dung | 400 | 4.09a | 6.75a | 6.92ab | 4.37ab | 5.08ab | 5.42ab |
| | 200 | 4.25a | 7.42a | 8.08ab | 3.83ab | 4.92a | 5.42ab |
| | Control | 0.35b | 1.69b | 2.65c | 1.45b | 1.56b | 1.87b |
| Organo- | 600 | 5.14a | 8.75a | 7.83ab | 3.82ab | 4.19ab | 5.50ab |
| Mineral | 400 | 2.27ab | 4.92ab | 5.57abc | 4.65a | 4.73ab | 5.57ab |
| Fertilizer | 200 | 3.08ab | 5.28ab | 5.50bc | 3.68ab | 5.00ab | 5.07ab |
| | Control | 0.40b | 1.89b | 2.50c | 1.50b | 1.60b | 1.70b |
| Organic | 600 | 4.08a | 7.67a | 9.33a | 4.42a | 6.67a | 6.93a |
| Fertlizer | 400 | 2.33ab | 5.33ab | 7.00ab | 3.72ab | 4.49ab | 5.05ab |
| | 200 | 3.08ab | 6.28a | 6.5ab | 2.89ab | 4.14ab | 4.43ab |
| | Control | 0.34b | 1.87b | 2.50c | 1.49b | 1.60b | 1.74b |
| NPK | 600 | 3.75a | 5.83ab | 6.47ab | 4.03ab | 5.08ab | 5.52ab |
| 15:15:15 | 400 | 3.00ab | 5.33ab | 5.52abc | 2.95ab | 3.12ab | 3.83ab |
| | 200 | 3.33a | 4.63ab | 4.56bc | 4.83a | 5.27ab | 5.42ab |
| | Control | 0.37b | 1.95b | 2.53c | 1.52b | 1.63b | 1.75b |

*Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level*

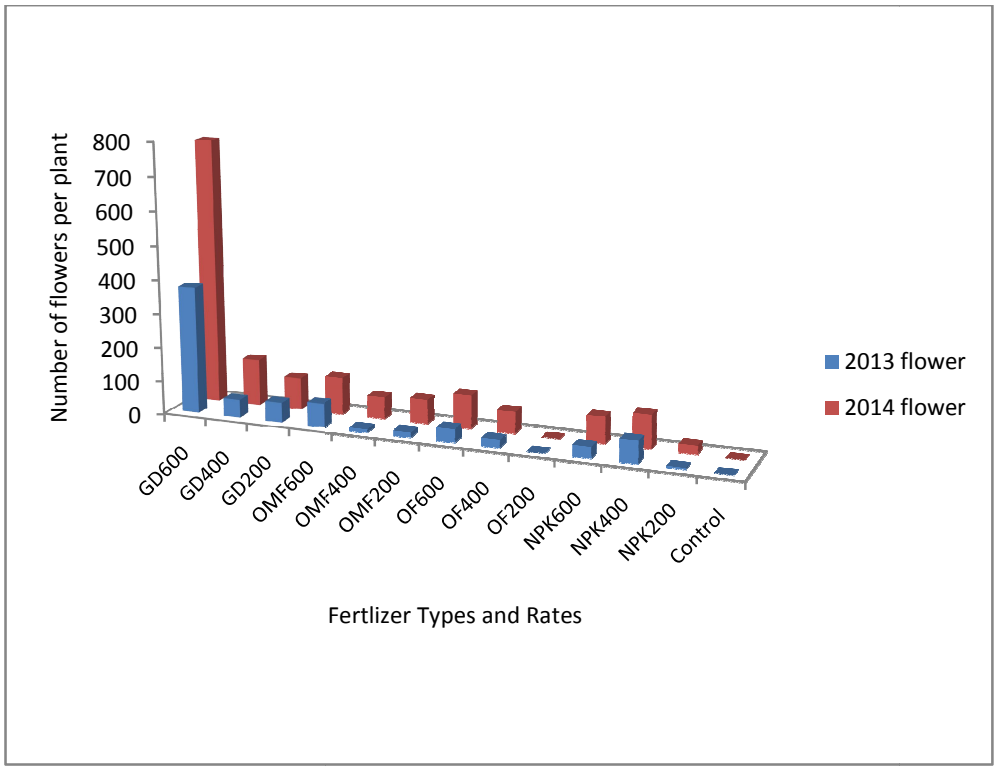


**Fig. 1. Number of flowers as influenced by organic and inorganic fertilizer types and rates at 24 and 36 MAT Owena (2011 experiment)**

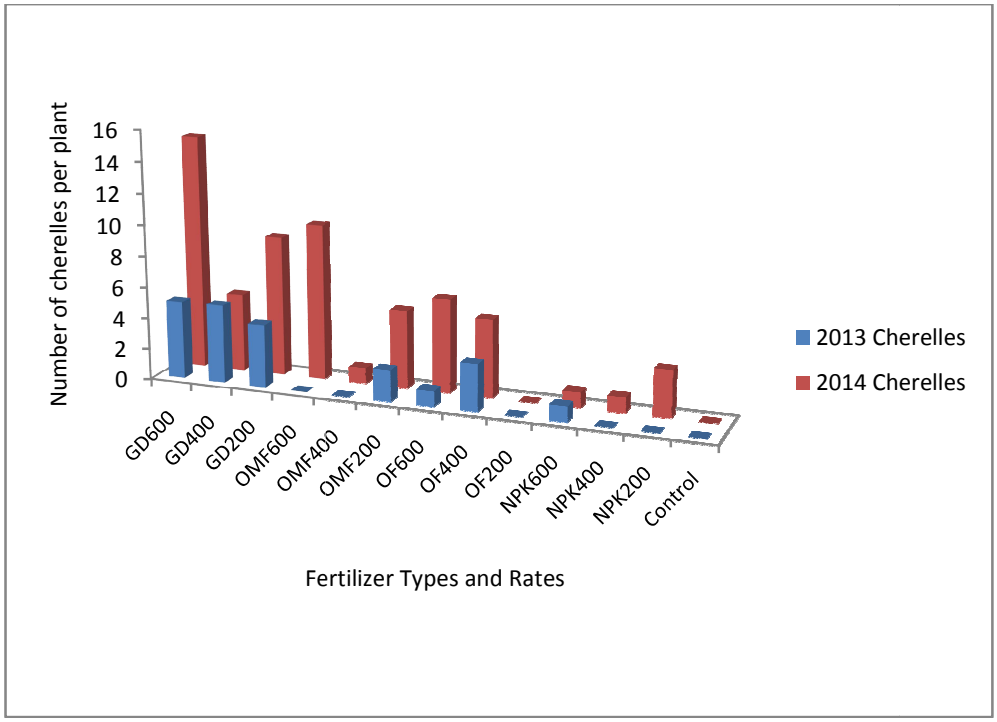


**Fig. 2. Number of cherelles as influenced by organic and inorganic fertilizer types and rates at 24 and 36 MAT Owena (2011 experiment)**

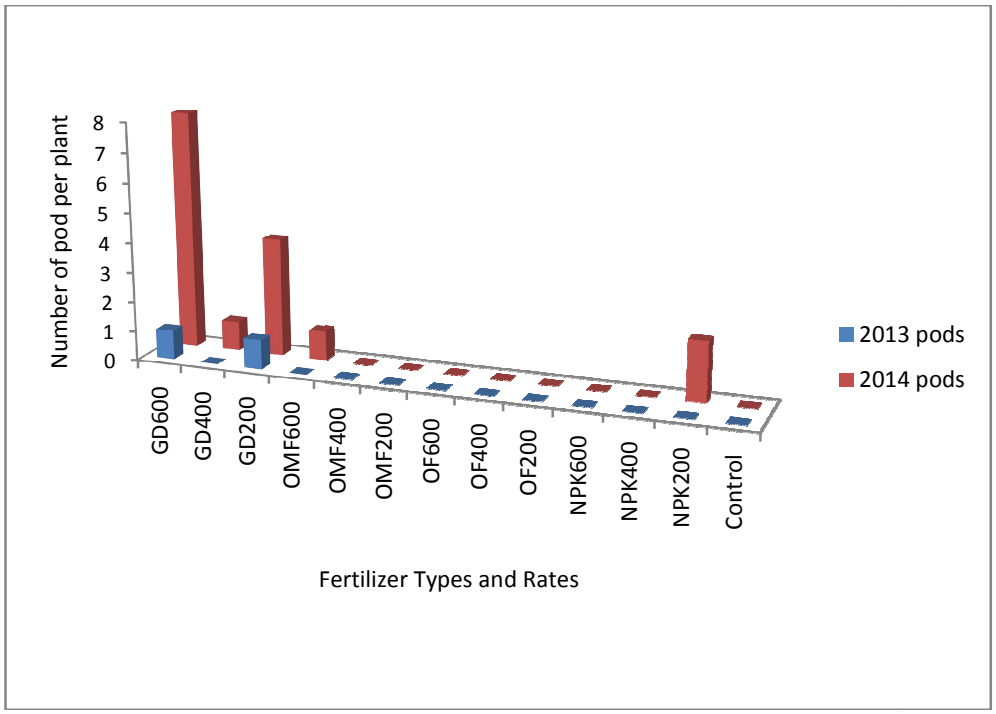


**Fig. 3. Number of pods as influenced by organic and inorganic fertilizer types and rates at 24 and 36 MAT Owena (2011 experiment)**

200 kg/ha GD. Ayeni et al. (2008) reported that soil OM, macro and micro nutrients and yield of maize were increased by cocoa pod ash. Adeyeye et al. [36] reported that wood ash amendment increased soil nutrients and yield of yam. During five years trial on the effect of fertilizer on the yield of cacao in Colombia, it was observed that the highest yield was produced with 150 – 90 – 200 kg/ha, N – $P_2$ $O_5$ – $K_2O$ treatment produced the greatest response with an average over the five year period of 620 - 802 kg dry bean/ha, more than double the yield produced by traditional farmer practices [37] this affirmed that adequate and balanced fertilization of cocoa is not only profitable but also sustains and build high yield over time. These contents might have been responsible for better plant growth, yield and yield quality for crops under organic treatments compared to NPK treatment [14,15].

## 4. CONCLUSION

Cacao (*Theobroma cacao L*), is an important perennial cash crop worldwide. The average cacao yield in the world and West Africa is about 0.5 t/ha while for Nigeria is around 0.4 t/ha. This suggests that yield in Nigeria is low compared to the world average. Low soil fertility and poor agronomic practices are among the causes of low cacao productivity in Nigeria. Therefore, the use of fertilizer to address low soil fertility problem in cocoa production cannot be over emphasized. Application of 600 kg/ha OF to cacao seedlings enhanced survival count (100 - 94.45%) at 12 MAT at Ibadan and Owena. Also, application of OF at 600 kg/ha significantly increased plant height at 15, 16 and 17 MAT relative to the control at Ibadan. At Owena, GD applied at 200 kg/ha gave higher number of leaves at 3, and 4 MAT, while 600 kg/ha OF significantly increased the number of leaves compared with the control at 5 MAT. The fertilizer treatments enhanced the growth parameters of cacao seedlings than the control in both locations, organic manures performed better than the organo-minerals (OMF), while the organo-mineral fertilizers were better than NPK. 600 kg/ha GD is recommended for optimum yield of cacao in Owena. Also, there were no yield parameters obtained for Ibadan at 24 and 36 MAT.

These results have clearly shown that organic fertilizers (GD, OF and OMF) supplied cacao nutrients, water availability and conservation. These attributes cumulated in improved growth, yield and nutritional status of cacao.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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