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The Effects of Organic Fertilizers and NPK on Growth and Yields of Cowpea (*Vigna unguiculata. L)* in Kano Plains Kisumu, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author OEBB designed the study, carried out the research, wrote the protocol, and wrote the first draft of the manuscript. Author RT performed the statistical analysis, assisted in writing. Author LO assisted in writing. All authors read and approved the final manuscript.

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ABSTRACT

Excessive use of inorganic mineral fertilizers as an agronomic practice has resulted in the depletion of soil organic matter of soils of many regions thereby rendering such soils infertile and unable to maintain sustainable production. The use of organic amendments provides the immediate strategy for compensating for soil carbon depletion thereby reducing land degradation. The purpose of this study was to evaluate the effects of six organic amendments on the growth and yield of Cowpea (*Vigna unguiculata L*) as compared to the conventional use of inorganic fertilizer NPK. The organic amendments were Boom Max, Ecoplanting, Evergrow, Dung slurry, Filter mud, and Market waste slurry applied to the soil at 8.33 t/ha against NPK (9:15:20) at 250 kg/ha. The experiment was laid

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in a RCBD. Data on growth and yields was collected on 10 tagged plants per plot. The results showed differences among treatments. Mature composts (Boom Max, Ecoplanting, and Evergow) resulted in a significantly ($p < 0.05$) higher germination percentage (53.49% on average) compared to that of Filter mud (41.50%) and the slurries (34.18% on average) while all the composts resulted in 25% higher number of branches on the average in season two as compared to the bio-slurries. In season three, Boom Max gave the highest germination percentage (41.02%) which was significantly higher than those of Evergrow (29.80 %), Filter mud and Dung slurry (27.18% on average) and NPK and Market waste slurry (5.64% on average) but not different from that of Ecoplanting. Five of the amendments had significantly better germination rates than NPK by an average of 20%. There were no significance differences ($P \leq 0.05$) in growth parameters between the mature composts and the NPK fertilizer, suggesting that the mature composts were equally efficient in nutrient supply to the crop as did the NPK fertilizer for plant growth. The application of organic amendments produced significant improvements in fresh leaf yields of the cowpea crop, with the highest yield recorded from the Boom Max applied plot (5781 kg on average), which was not different from others in seasons one and three but significantly different from that of NPK in season three. It can be concluded that depending on choice or type of amendment, organic manures are capable of producing similar or better results of crop growth and yields as the inorganic fertilizers.

Keywords: Organic; amendment; soil health; regenerative agriculture.

1. INTRODUCTION

Cowpea (*VignaunguiculataL*. *walp*) is a tropical annual herbaceous grain and fodder crop and the most prominent grain legume that belongs to the family Papilionaceae (Fabaceae), order Leguminosae and genus Vigna [1]. Cowpea is grown in eastern and southern Africa both as grain and leaf [2], where it may be grown for green or dried seeds and pods and leaves [3]. Africa is cited to be the probable origin of the species based on the large genetic diversity of cultivated and the wild types and has grown in various parts of the world, including tropical and sub-tropical regions covering Africa, Asia and the United States, Europe, and Central and South America [4]. It is important in warm marginal rainfall areas because it is well adapted to drought-prone areas, and has a short maturity period where the early maturing varieties provide food sooner than any other and a variety of uses which makes it an attractive alternative crop for farmers in arid and semi-arid regions where rainfall is low and unreliable [5]. Cowpea is a warm-weather, dual-purpose legume providing food for human consumption and fodder for livestock [6] and often grown for pasture, hay, silage and green manure. It is thus, a versatile and hardy legume crop, valued mainly for its seeds, pods, and leaves, and more than serves as feed fodder, hay, and silage for livestock and green manure and cover crop and an important component of crop rotation because of its ability to restore soil fertility [7], adaptable to areas with water scarcity and low fertile soils and surviving hot climates and dry semi- arid soils with little to no inputs [8].

Cowpea grain contains 23% protein and 57% carbohydrate, while the leaves contain 27-34% protein [9]. Due to its high adaptability to different environments, low input costs and high protein content, it is highly suited for cultivation in countries with protein deficiency. Among legumes, cowpeas are the most cultivated and most consumed especially in Asia and tropical Africa [10]. In addition to their importance in human food, cowpea is also useful for soil fertilization through symbiotic nitrogen fixation and are useful in providing nitrogen, especially in areas where poor soil fertility is a problem [11]; [12]therefore provides soil nitrogen to cereal crops, particularly maize, millet, and sorghum when grown in rotation or mixed in areas of poor soil. [13].

The nutritional value of cowpea is a rich source of protein, a good source of vitamins A, B and C and also contains a high rate of minerals [14], such as phosphorous, calcium and iron and [15]. The protein in cowpeas is rich in amino acids viz lycine and tryptophan as compared to cereal grains [16].

Cowpea grains show a wide range of total carbohydrate content (22.3 -66.5g $100g^{-}$) and the highest starch content among legumes with a good amount of dietary fibre and resistant starch [17]; [18]. The high starch content makes cowpeas suitable for the preparation of many processed products [19]. Cowpea is also rich in dietary fibre (16-20.9g $100g^{-}$) making its consumption useful in keeping the digestive system healthy and reducing the risk of diabetes and cardiovascular diseases [30]. A wide variation in sugar content (3.26-8.61g $100g^{-1}$) was reported in cowpea [20]. Cowpea grains are also rich in phenolic compounds, tannins, and flavonoids and show considerable antioxidant and radical scavenging activity [21].

Even though cowpea is commonly grown in Kenya due to the rise in demand and therefore consumption and market value, many production challenges has led to reduced productivity and production. Cowpea yield remains one of the lowest despite this dramatic increase in cowpea production among the food legumes in sub-Saharan Africa; remaining at 450kg/ha in 2006 - 2008 which is only 50% of the estimated yields in all other developing regions. Its yields are very low due to several constraints including poor soil (inadequate N, P, K, Ca, Mg, S and Organic Matter, use of low yielding variety of seeds as planting material, plant nutrients imbalances, low soil moisture content [13]; [22].

A positive response of cowpeas to both organic and inorganic fertilizers has been reported by several authors. It has also been established that cowpeas do not require a high rate of nitrogen fertilization because of their ability to fix their own [13]. The use of organic fertilizer is popular for reducing the environmental impacts of wastes while increasing organic matter and nitrogen in soils. Fertilizer is any material of natural or artificial origin (other than liming material) that is applied to soil or plant tissues to provide one or additional plant nutrients essential to the expansion of plants, maturity of time, size of plant parts and biochemical content of plants and seed capabilities [23].

To maintain consistency in high biomass productivity, soil nutrient management is essential, and fertilization is the only way to supply soil nutrients within a short period [24]. [25] Reported that fertilization costs accounted for 20-30% of the total production costs in biomass production. Soil fertility is the most important constraint limiting crop yield among resource-poor farmers in the developing world [26]. Fertilizers play an important role in increasing crop production [27]. It has also been proved that organic fertilizers improve crop qualities especially those of vegetables and fruits [28]; [29]. The use of chemical fertilizers and organic manure or fertilizer has both positive and negative effects on plant growth and the soil. Chemical fertilizers are relatively expensive, have high nutrient content and are rapidly taken up by plants [24]. However, the use of excess fertilizer can result in several problems, such as nutrient loss, surface and groundwater contamination, soil acidification and basification, reduction in useful microbial communities and increased sensitivity to harmful insects [30]. Organic manure has several shortcomings, including low nutrient content, slow decomposition and different nutrient compositions depending on its organic materials, compared to chemical fertilizers.

Organic farming is defined as a production system that avoids or largely excludes the use of synthetically compounded fertilizers [31] and depends mainly on organic recycling of biological and industrial waste nutrient energy. The system is based on the perception that tomorrow's ecology is more important than today's economy. It aims to utilize local resources present in abundance with enormous potential for application to maintain the long-term fertility of the soil. According to [32], organic fertilizer is an alternative to chemical fertilizer with no loss in crop yield and quality, and its use will avoid all forms of pollution, and reduce fossil fuel energy in agricultural practices while providing foodstuffs and maintaining a rural environment and preserving non-agricultural ecological habitats.

2. MATERIALS AND METHODS

2.1 Study Area

This investigation was conducted during the 2022 and 2023 cropping seasons at the field farm of the Great Lakes University of Kisumu (GLUK) agricultural farm. The site is located in Kibos within the Miwani West Sublocation of the Miwani ward of Muhoroni Subcounty of Kisumu County Kenya.

The area falls within the Lake Victoria lowlands and flood plains called the Kano plains, a vast lowland flat area experiencing a subhumid climate. The plain is mainly an extending lacustrine deposit characterized by montmorillonite clay with a blackish colour. The surface soil texture is clay with poor drainage.

The general aspects of the climatic conditions of the study area were done using climatological statistics of one full meteorological station, Kenya Sugar Research Institute in Kibos, Kisumu County. Climatic conditions of the study area are such that the mean maximum temperature ranges from about 27^0C to about 32^0C and the mean minimum temperature ranges from about

14^{0}C to 18^{0}C. The relative humidity (0900Hrs) East African Standard Time ranges from 56% to 75% with the peak being in May and July months of the year. The average annual rainfall ranges from 1100mm to about 1600mm and the climate is described as semi-humid and fairly warm with an altitude of about 1150m above sea level.

The experiment was set up in a randomized complete block design (RCBD) with three (3) replications. There were five treatments in the long rains and seven treatments in the short rains including control (T_1). The following were the treatments.

Each organic fertilizer was soil applied in furrows and soil incorporated before planting. Planting was done on the same day as incorporation. The layout, therefore, represented soil amendments with different types of organic fertilizers.

2.2 Vegetative Growth, and Yield

Data on plant growth were collected, that is germination percentage, plant height (cm), and number of branches as indicators from ten plants randomly selected and tagged from each treatment replicate. To evaluate crop yield, bi-weekly harvests were carried out on the leaves of the tagged plants from age 30 days from sowing until the plants were 75 days from sowing. Harvesting was therefore done four times at different growth stages. First, second, third, and fourth harvests were done at 30, 45, 60, and 75 days after sowing (DAS) the seeds respectively.

Different yields contributing data were recorded from ten plants which were randomly selected from each unit plot of every harvesting stage. The leaf-picking or leaf-peeling harvest method was used instead of a once-over harvest to prolong the growth and harvest period [33] and much higher harvest was obtained than by one harvest method, since nutrition is stored in the root production and supplied to the remaining young leaves. The growth of the young leaves is faster than that of seedlings started from seed.

2.3 Statistical Analysis

The data collected were then subjected to Analysis of variance (ANOVA) and procedures general linear model (PROC GLM) were used in the analysis using the SAS version (9.04.01M7P03062020).The effects of the organic amendments and NPK on germination percentage, number of branches, height (cm) as well as yields (g), were tested for level of significance using the F-test. Significant means at F-test were separated using the least significant difference (LSD) and all the analyses were performed at a 5% significance level. Additionally, Microsoft Excel software was used to develop tables and figures.

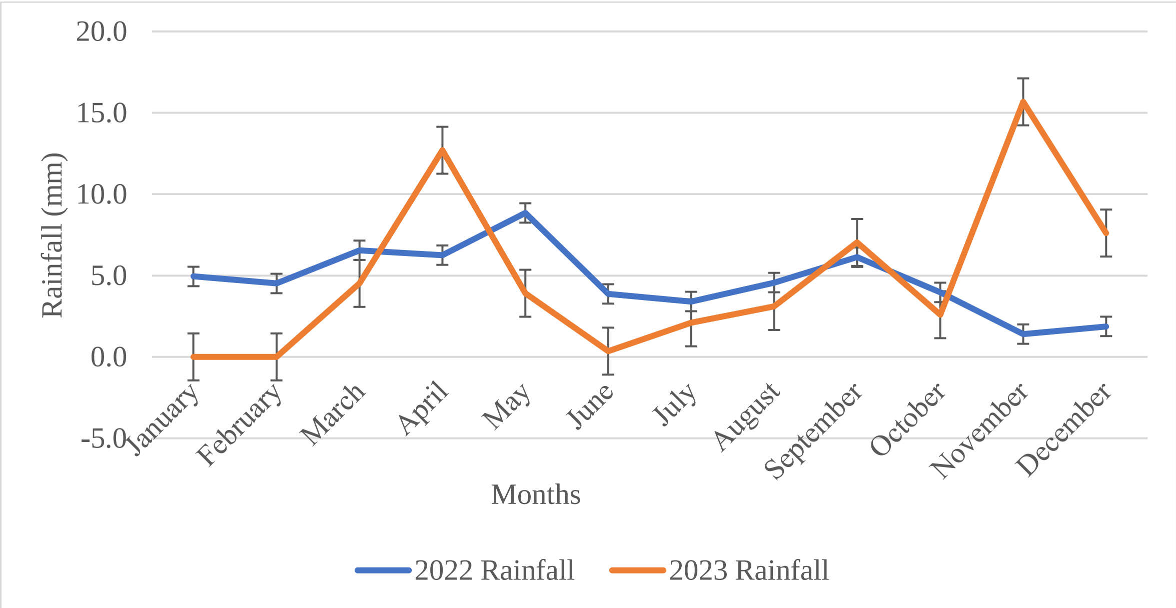

Fig. 1. The average rainfall distribution in the study area during the study period

Table 1. Treatment details

Long Rains 2022 Treatments	Short Rains 2022 treatments
T_1 = Eve @8.33t/ha per season	T_1= Ds @ 8.33 t/ha per Season
T_2 = Eco @8.33t/ha per season	T_6=MWS@8.33kg/ha per season
T_3 = Bx @8.33t/ha per season	
T_4 =Fm @ 8.33t/ha per season	
T_5 =NPK @ 250 kg/ha per season (9:15:20)	

Where; Eve =Evergrow, Eco= Ecoplanting, NPK = Nitrogen, Phosphorus and Potassium, DS = Dung slurry, Fm = Filter Mud, Bx = Boomax, and MWS = Waste Slurry Market

3. RESULTS AND DISCUSSION

3.1 The Effects of different Organic Amendments and NPK on the Germination Percentages of Cowpeas (*Vigna unguiculata L.*)

The germination percentages of cowpea (*Vigna unguiculata L.*) as affected by the various organic fertilizer amendments and NPK are presented in Table 2.

In season one (short rains of 2022), the germination rate averaged about 55.00% and was different from that of season two (long rains of 2023) which averaged about 46.40% and that of season three (short rains of 2023) which averaged about 22.63%. The seasonal differences must have arisen from the differences in precipitation levels, being higher and better during season one or the short rains of 2022 and season two or the long rains of 2023 (Fig. 1). During season one or the short rains2022, across the treatments the germination rates showed increase (ranging from 53.08% to 65.42%) compared to that of the inorganic NPK (39.64%). These results showed insignificant variation in cowpea germination with different treatments suggesting that the variations in germination among the treatments could be attributed to differences in soil organic matter contents as influenced by the various organic amendments causing variations on water imbibitions rates but which failed to attain significance.

During the second season (long rains of 2023), there were also differences in the rates of germination among treatments. Significant differences (P< 0.05%) were realized among treatments where Ecoplanting gave the best performance which was identical to inorganic NPK, Boomax and Evergrow but different from Filter mud, Dung slurry and Market Waste slurry. These results indicate that when moisture is adequate and no other factors are limiting, the 'mature' composts viz. Ecoplanting, Boomax and Evergrow showed significant effect on seed germination by increasing water-holding capacity of the soil media, initiating the imbibitions process and eventual seed germination. Similarly, with adequate moisture in the soil, the inorganic NPK did not create any barrier to flow of water to the seed for imbibitions and produced similar results as the composts. However the immature compost (Filter mud and the bio-slurries (Dung slurry and Market Waste slurry) showed that despite the adequate moisture content of the soil media their rate at which they were able to imbibe water was slower resulting in slower germination rates than the mature composts and NPK. The germination values ranged from 33.37 % to 64.00%. The highest germination rates were recorded in Ecoplantig (64.00%) which was statistically similar to that of the inorganic fertilizer NPK, Boomax and Evergrow but different from Filter mud, Dung slurry and Market Waste slurry. The least germination was recorded in case of Market Waste slurry which was identical with Dung slurry and Filter mud. During the third season (first rains of 2023) the germination percentages ranged from 45.17 to 5.57. The highest germination percentage was obtained from the Boomax (45.17%) application, while the lowest value (5.57%) was obtained from the Market waste slurry. The seed germination percentage was significantly (p< 0.05 %) affected by different types of organic amendments and ranged from 5.57% to 45.17% in this season. The highest seea germination percentage was recorded in Boomax which was statistically similar to Ecoplanting but different from Evergrow, Dung slurry, Filter mud, NPK and Market Waste slurry.

The results show that when soils have adequate moisture contents, soils amended with mature composts will perform as much as the inorganic fertilizers in terms of germination percentages and seedling vigour. This is indicated by the results from seasons one and two when rainfall enabled the soil to have adequate moisture for plant growth (Table 2). All the mature composts, Ecoplating, Boom Max, and Evergrow showed equal seed germination rates as compared to chemical fertilizer NPK. This may be explained by the fact that continuous organic amendments application improved the organic matter contents of the soils resulting into improved water- holding capacity, good tilth and aeration for germinating seeds and plant root development [34]. Mature composts are reported to have stable decomposed organic matter [35]. On the contrary, less organic matter from one immature compost (Filter mud) and the bio-slurries (Dung and Market Waste) applications meant compacted and compressed soils with reduced partial pressure of oxygen which slowed the germination. [36] Reported the oxygen concentration in the soil to depend on soil structure and compaction. Soil properties of organic matter, soil moisture, and other physical characteristics perform key roles in seed germination. Organic amendments together with inorganic fertilizers contain inorganic salts and when concentrations of such salts become high around the seeds may limit the water diffusion into the seed which is required for germination. According to [37], soil moisture should be such that moist soil is firmly in contact with the seed for timely germination of seed. [38] Reported that sufficient moisture must be present for germination to take place and that lack of water availability is the primary limitation affecting seed germination, since water is needed for respiration and growth. The amount of water available for germination is affected by type, amount and placement of fertilizer or amendment (METOS Online Store) and that when placed very close or with the seed, will reduce the amount of water available for seed germination as salts end up using some of the available moisture for dissolving itself into solution and very little or none reaches the seed, resulting into delayed or no germination at all. Salt contents of Evergrow, Dung slurry, Filter mud, NPK and Market Waste slurry must have used some of the available water to dissolve themselves thus limiting the amount reaching the seed for faster germination rate. Salinity thus reduces moisture availability by inducing moisture stress and creation of nutrient imbalance and ionic toxicity [39]. [40] Reported salinity to have caused delay in germination of six rice seed varieties by three to six days, thereby advocating strong negative relationship between salinity and seed germination.

This study suggests that organic fertilizers particularly from mature composts could be the most applicable and should be widely used in the agricultural industry for their favourable influences on seed germination rates, particularly under favourable environmental conditions. Under unfavourable moisture conditions or in dry areas, Boomax and Ecoplantng could be most useful as they are capable of holding more water than others to allow quicker germination of seed.

3.2 Number of Branches

Table 3. shows the various organic amendments' effects on the cowpeas' ability to grow or form branches.

During the second season (long rains or first rains of 2023) the number of branches as influenced by the various organic amendments ranged between 7 and 5 pieces per plant. The highest number of branches was obtained from Boom Max treatment with 7 pieces per plant, while the lowest number of branches was obtained from Dung and Market waste slurries. Boom Max treatment produced the highest number of branches per plant which was not different ($p < 0.05\%$) from those produced by Ecoplantng, NPK, Evergrow and Filter mud respectively, but significantly different from those produced by the Dung and Market waste slurries ($P \leq 0.05$). Among all the 17 essential nutrients for plant growth and development, nitrogen among other factors plays a determining role in shoot-branching regulation [41]; [42]; [43] and [44], and influence branching via various physiological and molecular mechanisms. Laboratory analysis of the six amendments revealed the nitrogen contents of them as 2.45%, 1.87%, 0.86%, 0.20, 0.02% and 0.01% for Ecoplanting, Evergrow, Filter mud, Market Waste slurry and Dung slurry respectively which corresponds to the outcome of this study. Similarly, results from the third season (short rains or second rains of 2023), all amendment treatments gave results that were not significantly ($p < 0.05\%$) different from other amendment types or which were statistically similar. These results indicate that the seedling growth character branching is highest and prominent when moisture is adequate and least with drought. This is confirmed from the results of season three when rainfall was minimal, when no significant differences were recorded, while in the second season, number of branches per plant showed significant differences. According to [45], biomas production is a function of the relationship between nitrogen and moisture availability, described as co-limitation [46] which means that plant growth response to water and nitrogen is greater than its response to each factor in isolation. Strategies to maximise plant growth should ensure availability of both resources equally. Moisture affects nitrogen nutrition through its influence on nitrogen uptake and on mineralization of organic nitrogen [45] and that transport of nitrogen in the soil and absorption by the roots is water dependent [45]. This co-limitation could explain the absence of branching in season three when moisture was inadequate.

These results indicated that the number of branch pieces per plant is soil moisture and nitrogen co-sensitive and must work together to promote branching as did occur in season two. On the contrary, with less rainfall in season three, all treatments did not show significant differences in the number of branches per plant.

3.3 Plant Height

The average height achieved from the various organic amendments during season two (long rains of 2023) was 13.44cm against season three (short rains of 2023) average of 25.40cm. The differences in the seasonal averages could have arisen from the cumulative residual effects of the nutrients contained in the amendments applied. During season two or the (long rains of 2023), all six applied organic amendments, and NPK gave results that were not significantly different ($P \leq 0.05$). The effects of the amendments on the plant height did not differ from that of the NPK standard on the plant height (Table 4). As a result of this study, plant height varied between 14.89 cm and 12.17cm in the second season. The highest plant height was obtained from Evergrow treatment, while the lowest value

Table 2. Vegetative growth of cowpeas as affected by different organic amendments and NPK

Growth		Germination (%)			
Fertilizers	**Season 1**	**Fertilizers**	**Season 2**	**Fertilizers**	**Season3**
Filter mud	65.42a	Ecoplanting	63.00a	Boom Max	45.17a
Evergrow	61.67a	NPK	51.48ab	Ecoplanting	36.87ab
Ecoplanting	55.21a	Boom Max	50.87ab	Evergrow	29.80b
Boom Max	53.08a	Evergrow	49.60ab	Dung slurry	18.90bc
NPK	39.64a	Filter mud	41.50b	Filter mud	16.36bc
Dung slurry		Dung slurry	34.99b	NPK	5.71c
Market W. slurry		Market W. slurry	33.37b	Market W. slurry	5.57c

Means covered by the same letters are not significantly different at ($P \leq 0.05$)

Table 3. The effects of the applied organic amendments on the number of branches

Growth		Number of branches	
Fertilizer	**Season2**	**Fertilizer**	**Season 3**
Boom Max	7a	Ecoplanting	6a
Ecoplanting	6ab	Boom Max	6a
NPK	6ab	NPK	5a
Evergrow	6ab	Evergrow	5a
Filter mud	6ab	Filter mud	5a
Dung slurry	5b	Dung slurry	5a
Market W. slurry	5b	Market W. slurry	5a

Means covered by the same letters are not significantly different at ($P \leq 0.05$)

Table 4. The effects of the applied organic amendments on plant height

Growth		Plant Height (Cm)	
Fertilizer	**Season 2**	**Fertilizer**	**Season 3**
Evergrow	14.93a	Evergrow	38.87a
NPK	14.89a	Ecoplanting	29.40b
Ecoplanting	14.13a	NPK	26.63b
Boom Max	12.93a	Boom Max	23.93bc
Dung slurry	12.83a	Dung slurry	19.41c
Filter mud	12.27a	Filter mud	18.67c
Market W. slurry	12.17a	Market W. slurry	17.87c

Means covered by the same letters are not significantly different at ($P \leq 0.05$).

was obtained from Market waste slurry treatment (Table 4). This result may be explained by the fact that under moist and warm conditions, mineralization is faster and organic amendments release nutrients faster, particularly nitrogen (both organic and inorganic nitrogen), and plants treated with organic amendments were able to perform equally with inorganic fertilizer NPK. On the other hand, results from season three (short rains of 2023) plant height ranged from 38.87 cm to 17.87cm. The highest plant height value was obtained from Evergrow application, while the lowest value was obtained from the Market waste slurry application. Evergrow-treated plants were the tallest and whose heights were significantly different from the rest (P≤0.05). The second in height were plants treated with Ecoplanting which was not significantly different from that of the inorganic fertilizer NPK. It is thought that this beneficial effect of Evergrow and Ecoplanting on the plant height of cowpea may be due to their ability to retain water which was available to transport nitrogen resulting from mineralization to the growing points of the plants in order to increase plant height.

This experiment is in agreement with that of [48], in an experiment on the growth and yield of broccoli (*Brassica oloracea L* varItalicaplenck cv top green) reported that among vegetative growth parameters the greater growth parameters may be attributed to the readily available nitrogen in high content. Similarly, [49], reported nitrogen from nitrate or ammonium forms from soil dominate the growth and development and that high-yield crop production relies heavily on nitrogen fertilization. All the above ground plant parts are systematically regulated by nitrogen status [50]; [51].

The growth of plants is a function of the photosynthesis activity of plants and the translocation of the photosynthates within the plant which ultimately depend on their capacity to utilize available nutrients [16]. Carbon (C) and Nitrogen (N) are key elements that form the basic components of the plant cells and control for biochemical functioning, growth and energy flow and nutrient recycling [52]. Carbon and Nitrogen are thus primary elements involved in the growth and development of plants and C:N ratio is an indicator of Nitrogen Use Efficiency (NUE) [53]. The fact that initial boost of nitrogen resulted in more plant height from mature composts as compared to mineral fertilizer NPK but which did not attain statistical significant levels in the second season but did in season three is supported by the c:n ratios of the various amendments (17.51, 14.82, 18.37,3.5, 830.00, and 2080.00) for Ecoplanting, Evergrow, Boomax, Filter mud, Dung slurry and Market Waste slurry respectively. Nitrogen is also known to contribute to cell elongation [16].

3.4 The Effects of different Organic Amendments and NPK on the Leaf Yields of Cowpea (*Vigna unguiculata L.)*

Table 5. shows the results of the effects of organic amendments and NPK on the leaf yields of cowpeas.

Yields were higher during the seasons of adequate rainfall (season one or (short rains of 2022) and season two or (the long rains of 2023) than from the third season or (short rains of 2023). The average yield level achieved was 6,881.86g, 3,260.19g, and 1,245.26g for the three seasons respectively per plot. The yields decreased in the order of season one or short rains 2022> season two or long rains 2023> season three or short rains 2023.

In season one fresh leaf yields ranged from 11,235.33g to 5,191.3g. The highest yield of fresh leaves was obtained from the Boomax application while the lowest value was obtained from the Filter mud application. Boomax had the highest yield outcome which was statistically significant to the rest (P≤0.05). It was distantly followed by the yield from the inorganic fertilizer NPK which was not significantly different from those of Evergrow. Ecoplanting, and Filter mud. Boom Max application therefore improved significantly the yield of cowpea and resulted in higher yield as compared to other amendments and NPK. In the second season, the fresh leaf yield values ranged from 4,238.67g to 1,866.67g. The highest yield value was obtained from the Boomax application while the lowest value was obtained from the Dung slurry. Boomax treatment once again significantly improved the cowpea yield as compared to other amendments and NPK. Next in performance was NPK whose performance was not significantly different from those of Evergrow, Ecoplanting, Filter mud and Market waste slurry but significantly different from that of Dung slurry. In season three, leaf yields ranged from 1,869.0g to 710.78g. The highest leaf yield value was obtained from the Boomax application while the lowest value was obtained from the inorganic fertilizer NPK. All the tested organic amendments and NPK showed no significant differences in their performance. Leaf yields per plot showed variation with amendment type or amendment source and the Boomax application recorded the highest yield in the three consecutive seasons and were observed to be the best in the three seasons. The reduced performance during the third season (short rains of 2023) and the lack of similarity and pattern, as was observed during the first season (short rains of 2022) and the second season (long rains of 2023), could be blamed on the inadequacy of rainfall (Fig. 1) as one of the soil factors that affect crop growth. Water is a principal constituent of the growing plants and helps in the chemical and biological activities of the soil including mineralization, nutrient availability and mobility in the soil [54]. Further, biomas production is a function of the relationship between nitrogen and water availability or co – limitation [46] as showed by the yield differences between the last season and the first two seasons. In addition, moisture affects nitrogen nutrition through its influence on nitrogen uptake and on mineralization of organic nitrogen [47].

Insufficient water availability translated into water shortage in the plant body bringing about a profound alteration to physiological processes including photosynthesis, which slowed down growth thereby reducing yielding potential [55], as was observed in season three [56]. Reported water to be a decisive factor for crop production because of its roles in nutrient uptake, transport, temperature regulation and several physiological processes such as photosynthesis.

The yields on average increased in the order Boomax> NPK> Evergrow> Ecoplanting> Filter mud>Market waste slurry>Dung slurry corresponding to the decreasing order of the C:N ratio among composts and increasing order between the digestates (Table 5) in all the two seasons when soil had adequate moisture but which changed to Boomax>Ecoplanting>Evergrow> Market Waste slurry > Dung slurry > Filter mud > NPK. The exceptions are those of the positions of the NPK and that of filter mud when rainfall was inadequate in the short rains of 2023 when the two performed poorer than in the previous two seasons. Therefore, the crops grown on digestate-amended plots had diminished yields compared to those grown on composts indicating that the high C:N ratios of the digestates (Market waste slurry and dung slurry) exceeding the ideal C:N ratio of 25:1 resulted in immobilization of inorganic nitrogen otherwise available for crop uptake and yields. This indicated that extra nitrogen was necessary for yields despite the application of adequate rates of nitrogen to all treatments. In addition, compared to the mature composts, the immature compost (Filter mud) and the two bioslurries (Market Waste slurry and Dung slurry) because of their unstable and immature organic matter contents were unable to store adequate moisture to mobilize and transport nitrogen to the growing plant sites since it is only the mature composts with stable, mature organic matter [35], which affected their fresh leaf output.

These reports compared well with those reported by [57] that compost can immobilize mineral nitrogen for only 30-70 days in the first season of application due to high C:N ratios after which organic nitrogen becomes increasingly available thereby pushing up the yields. In addition, compost has already been somewhat mineralized by the time of application and continues to decompose and slowly releases nutrients when added to the soil [58]: [36]; [57].

Boomax which exhibited the highest and undisputed supremacy in yields had several advantages over the others and NPK. According to [59] Boom Max is a vermicompost that contains plant growth-regulating materials such as humic acids, auxins, gibberellins and cytokinins responsible for increased plant growth and yields, and provides large particulate surface areas that provide many microsites for microbial activities.

Table 5. The effects of various organic amendments and NPK on Cowpea leaf yields (g)

Fertilizers	Season 1	Fertilizers	Season 2	Fertilizers	Season 3
Boom Max	11235.33a	Boom max	4238.67a	Boom Max	1869.00a
NPK	6548.42b	NPK	3805.00ab	Ecoplanting	1681.67a
Evergrow	5915.33b	Evergrow	3725.00ab	Evergrow	1666.00a
Ecoplanting	5515,00b	Ecoplanting	3589.33ab	Market W slurry	976.67a
Filter mud	5191.33b	Filter mud	2944.33ab	Dung slurry	923.33a
Dung slurry		Market W slurry	2652.33ab	Filter mud	889.33a
Market Wslurry		Dung slurry	1866.67b	NPK	710.78a

Means covered by the same letters are not significantly different at (P≤0.05).

During the two seasons when bioslurry was used as a fertilizer or an amendment, it did demonstrate itself as a soil conditioner but was unable to perform to the level of NPK under favourable climatic conditions. Both types of bio-slurry (Dung slurry and Market waste slurry) performed poorer than NPK and all other composts. This conforms to the reports of several researchers that although bioslurry is a potential fertilizer in agriculture, but has shortcomings relating to its bulkiness [60]; [61], and [62], the volume contributed by water is huge (about 93%) which limits its transportation and utilization, limited potential to meet the entire nutrient demand in agricultural fields and subject to nitrogen loss as ammonia volatilization, reduced rates of C:N ratio, and high pH [60]. [63] also reported that digestates of various feedstocks have higher ammonium Nitrogen (NH^{+}_{4} - N) to total Nitrogen, lower carbon contents, elevated pH values and lower C:N ratios. The authors also reported the process of anaerobic digestion through which various feedstocks pass exhibit low water soluble phosphorous probably caused by a shift of HPO_4^{2-} to PO^{3-}_{4} with possible precipitation of phosphorous complexes. the bioslurry as an alternative organic fertilizer may only be useful as an integration and not on its own. The levels of yields as compared to that of NPK could be related to the increase in the amount of soil organic matter contributed by each amendment to the soil as was suggested by [64] that organic application can have different effects on soil properties by adding 'less dense material' or by changing soil aggregates. [65] reported organic fertilizers to have enhanced soil fertility, plant growth and yields through sustainable health of the soil which relies on carbon-rich amendments that will feed the biological processes that are the core foundation [39] and support plant growth, yields and quality of crops [66,67] by rebuilding/rooting fertility and improving the physical, chemical and biological function of soils. Responses to cow dung by red amaranth (*Amaranthus hybridus*) and garlic (*Allium satirum L.)* to organic manure were reported by [68] and [69] respectively and are further evidence of the ability of organic amendments to improve soil conditions for crop production This result is consistent with those reported by [70] and [71] that yield responses to organic amendments vary by amendment type or amendment source. [72] Reported results indicating that organic amendments significantly improved the growth and yield of cowpea and maize (*Zea mays*) and where poultry manure was the most effective organic amendment in improving soil chemical properties as well as the growth and yield of cowpea. On another outcome, [73] reported a mixture of farmyard manure plus vermicompost and panchagavya to have recorded the highest yield of vegetable cowpea and declared the best treatment in two successive seasons.

4. CONCLUSIONS AND RECOMMENDATIONS

Organic amendments considerably influenced the growth and yield of cowpea crop by significantly increasing the germination percentage, plant height and the number of branches per plant ($P \leq 0.05$) which culminated into greater and or equal leaf yield to that of NPK fertilizer. It is therefore concluded that organic amendments as sole sources of nutrients need not necessarily give reduced yields as generally perceived if applied at the right dosage and under, and as the sole source of nutrients can give yields that are higher or comparable to those of inorganic fertilizers if the correct rate is applied and other environmental factors are favourable. As sources of organic matter, organic amendments are therefore indicators of soil quality and can affect many of the physical, chemical and biological processes that determine soil productivity by replenishing soil nutrients that maintains soil fertility. Based on the changes in the levels of extractable and available macro and secondary nutrients Boom Max amendment was declared the best treatment and which was followed closely by the other composts corresponding to the order of decreasing c:n ratio .The digestates, and Filter mud, because of their unfavourable C: N ratios were not able to perform to the level of the NPK fertilizer .In the case of inadequate moisture in the soil as was the case in season three, there appeared to be no significant differences ($P \leq 0.05\%$) in yield among all treatments despite significant differences in plant percentage germination and plant height between the composts on one hand and the NPK fertilizer and the digestates on the other.

This experiment was done in a black cotton soil (vertisol). It would be desirable to repeat the same under dissimilar conditions in order to confirm the validity of the above outcomes. Similarly, the results from Filter mud are those from uncomposted material. It would therefore befitting to include a mature alternative in the subsequent trial to expose its full potential.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTEREST

The authors declare that they have no-known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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