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Effects of Organic and Inorganic Fertilizers, Cost Benefit-analysis on the Growth, Biomass Yield and Proximate Analysis of Amaranth (*Amaranthus quitensis* L.)

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ABSTRACT

Background: Africa is currently faced with food and nutritional insecurity and strategies to mitigate this problem include the increased production of vegetables through the utilization of organic manure and inorganic fertilizers, considering the input to output, in relation to availability and affordability. The objectives of this research were to determine the response of amaranth to organic, inorganic and biofertilizer sources and to determine the effect of fertilizer cost on production.

Methods: The experiments were conducted with three rates of NPK, Pig manure, supergro and control in a randomized complete block design. Data obtained were analyzed using Statistical analytical system. Cost benefit-analysis was also used to identify the best of fit in relation to cost among the fertilizers.

Result: Plant height varies significantly among the treatments at various weeks. 10 tonnes pig manure (OM10T) was significant for plant height (16.74 cm) at 2 weeks. Pig manure at 10 tonnes (OM10T) had significant differences for number of leaves at weeks of observation, while pig manure at 15 tonnes (OM15T) showed the highest chlorophyll content at 3 weeks. Proximate analysis revealed that levels of fertilizer treatments significantly influenced the nutritional composition of *A. quitensis* leaves. Pig manure at 5T/ha had the highest fat, protein, zinc, copper and iron contents. Analysis of variance (ANOVA) showed significant effects of fertilizer treatments on observed traits and proximate composition. Cost benefit ratio was best for pig manure and had the best returns for potential investors in amaranth production.

Key words: Amendments, Input-output return, Nutrients, Vegetable, Yield.

INTRODUCTION

The challenges in accessing certain indigenous vegetables and overall benefits of vegetable consumption remain a focus in research and public health nutrition education. Vegetables are consumed across societies and ethnic groups, regardless of socioeconomic status (Kaur and Kaur 2024). In sub-Saharan Africa, vegetables are a cost-effective source of proteins, vitamins, zinc and iron. Some countries have developed dietary recommendations to promote healthy living and disease prevention, emphasizing the importance of vegetable consumption, especially for individuals with lower household incomes (Kuo *et al.*, 2020; Hasan *et al.*, 2018).

Amaranth is an annual plant, which can grow up to a height of 0.5-3 m, depending on the species. The plants are bushy with thick stalks. The leaves are relatively broad and the blossom strands can reach a length of up to 90 cm. They can grow upright or prostrate. The genus *Amaranthus* contains about 70 species. *A. quitensis* stands out as the most commonly grown species in Africa. Its cultivation is feasible throughout the year, contingent upon water availability. *A. quitensis* is identifiable by its leaves, twice or thrice as long as they are wide, often featuring pointed tips. Amaranth boasts high nutritional value due to elevated levels of essential micro nutrients such as iron, manganese and zinc (Mlakar *et al.*, 2010). Additionally, it contains calcium, magnesium, carotene and niacin, with significant levels of Vitamin A and C. Amaranth typically grows in tropical forests, humid lowland areas, vegetable gardens and roadsides (Achigan-Dako *et al.*, 2014).

Amaranth serves as a vital vitamin source, particularly for vitamin A, crucial in preventing serious *utritional*

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deficiencies leading to blindness in numerous children in tropical regions. Additionally, the leaves are rich in vitamin C, K and folate, boasting three times more vitamin C, calcium, iron and 18 times more vitamin A compared to spinach. When contrasted with lettuce, *Amaranthus dubius* surpasses in vitamin A, calcium and iron content, with notable levels of carotene and essential micronutrients such as sodium, copper and manganese (Shukla *et al*., 2018). Alege and Daudu, (2014) revealed yields from 50 to 7200 kg/ha. Highest yields of 4600-7200 kg/ha are in South and Middle America, whereas in Africa crop yields are quite low, 50-2500 kg/ha. The yield depends on many factors, for example, low seed yields of 450-700 kg/ha on dry land were significantly increased to 900-2000 kg/ha by irrigation (Alemayehu *et al*., 2015).

Various experiments (Andini *et al*., 2013; Iren *et al*., 2016) have shown that well-decomposed organic manure and inorganic fertilizers at reasonable rate of whatever type is the best for amaranth cultivation, but the levels of application are not known to have been reported (Mahesh *et al.,* 2022). This study could contribute valuable insights into the optimal production practices for *Amaranthus quitensis*, which will help farmers make informed decisions on fertilizer selection, for increased production.

This study examined and determined the levels of application of both organic and inorganic fertilizers for *Amaranthus quitensis* production. Furthermore, a lot of research had published on the use of organic and inorganic amendments on vegetables, but many of such research did not indicate the cost-benefit analysis (CBA) for feasibility of the materials and methods used in relation to cost of input, services and output (benefit) of the project. This becomes imperative as research output is not only to be adopted by farmers but also industrial commercialization. The CBA involves the measurable financial metric, including revenue generated, potential cost of inputs and costs saved from the decision taken by the farmer or industrialist of different methods/materials to be used in executing the project (Johansson and Kristom, 2015). The CBA is expected to guide farmers and industrialists/ agripreneurs on the adoption of such organic or inorganic fertilizers used and found to be best fit, in terms of growth, yield and the economics of amaranth production. This study focuses to assess the impact of different fertilizers (Supergro, NPK 20-10-10 and pig manure) on the growth and biomass yield of *Amaranthus quitensis,* investigate how each fertilizer type influenced growth parameters with organic (pig manure), inorganic (NPK 20-10-10) and biofertilizer (Supergro) in the nutritional composition of *Amaranthus quitensis* and also carried out the cost-benefit analysis of the selected fertilizers to identify the best fit of use economically.

MATERIALS AND METHODS

This study was carried out at the Research Farm of the Federal University Oye-Ekiti (Ikole campus), Ekiti State, Nigeria with Longitude 07°N 48.550′ and Latitude 005°E 29.788′.

Total field size of 8.5 m × 23.5 m was laid out in a randomized complete block design (RCBD) with three replications in 2023/2024 and 2024/2025 cropping seasons. Plot size was 1.5 m × 1.5 m. Each fertilizer type was applied at 3-levels and control. The organic fertilizer (Pig manure) was applied at 5, 10 and 15 tonnes/ha, the inorganic (NPK) was applied at 200, 400 and 600 kg/ha and supergro was applied at 1000, 2000 and 3000 L/ha and control (no fertilizer) made a total of 10 treatments. The field was ploughed and harrowed to ensure the breaking of soil clods and equitable distribution of residual organic matter. The field was blocked and organic manure (Pig manure) and inorganic fertilizer (NPK) was applied manually to the plots, using hand trowel 2 weeks before planting the amaranth seeds. The biofertilizer (Supergro) (foliar) was applied 5 days after planting the amaranth seeds, only to the allocated plots. The acronyms used and the components of the treatments in this research are:

-OM5T= Pig manure at 5 tonnes per ha (10.5 kg N/ha, 2 kg P_2O_5 and 5.5 kg K_2O) (Gerard and Amy, 2020).

-OM10T=Pig manure at 10 tonnes per ha (21 kg N/ha, 4 kg P_2O_5 and 11 kg K_2O) (Gerard and Amy, 2020).

-OM15T= Pig manure at 15 tonnes per ha (31.5 kg N/ha, 6 kg P_2O_5 and 16.5kg K_2O) (Gerard and Amy, 2020).

-NPK200= NPK at 200 kg per ha (30 kg N/ha, 30 kg P_2O_5/ha and 30 kgK_2O/ha).

-NPK400= NPK at 400 kg per ha (60 kg N/ha, 60 kg P_2O_5/ha and 60 kgK_2O/ha).

-NPK600= NPK at 600 kg per ha (90 kg N/ha, 90 kg P_2O_5/ha and 90 kgK_2O/ha).

-SG1000L= Supergro at 1000l per ha (72 kg N/ha, 45 kg P/ha and 30 kg K/ha).

-SG2000L= Supergro at 2000l per ha (144 kg/ha, 90 kg/ha and 60 kg K/ha).

-SG3000L= Supergro at 3000l per ha (216 kg/ha, 135 kg/ha and 90 kg K/ha).

-Control (No fertilizer).

Amaranth seed was sourced from the National Institute of Horticultural Research (NIHORT) Ibadan, Nigeria.

Proximate analysis of the amaranth was carried out at the Crop and Soil Science Department laboratory, using the procedure of the Association of Officials of Analytical Chemists (AOAC, 2005) with the use of oven (model DHP-9032), Muffle furnace (UDIAN), Kjeldahl distillation (ZDDN-11) and nitrogen digester (Kjeldahl nitrogen digester).

Biomass yield

Plant biomass was determined using quadrant method (White, 1978).

$$\text{Biomass yield} = \frac{\text{Total fresh weight - Total dry weight (kg)}}{\text{Quadrant area (cm)}}$$

Data was collected on 5 plants at the middle of the row, on plant height, number of leaves, chlorophyll content and biomass yield. Plant height was collected with meter rule, number of leaves was collected by visual count, chlorophyll content was collected using chlorophyll meter (atLEAF digital chlorophyll meter) and biomass yield was determined by the use of weighing balance (XY3000C precision electronic balance). The datasets obtained in the seasons (2023/2024 and 2024/2025) were merged for robust, reliable and statistically significant findings. The averaged data was subjected to Proc GLM procedure in statistical analysis system (SAS, version 9.4) and analysis of variance (ANOVA) was used to separate means for agronomic traits, proximate values and significant difference was determined using Duncan multiple range test (DMRT) at $P<0.05$ and 0.01. Random sampling method was used in the collection of soil samples (before and after), using soil auger of 15 cm depth. The soil samples were homogenized for the physical and chemical analyzes (Table 1).

The valuation and forecasting methods of cost benefit analysis (CBA) was used for the purpose of this study. The cost benefit analysis was carried out using the dependent variables of the total cost.

$$(TC=X_1, X_2, X_3, X_4 \ldots X_n)$$

Where,

X_1 = Cost of seeds/kg.

X_2 = Cost of transportation.

X_3 = Cost of fertilizers/kg.

X_4 = Cost of labour/man day.

X_n = Other variable cost such as water supply *etc*.

Cost-benefit/Future value (FV) (CB) =

$$(P_1, P_2, P_3, P_4 \ldots\ldots\ldots P_n)$$

Where,

P_1= Revenue on marketable yield/kg.

P_2= Revenue of number of periods for harvest regime.

P_3= Revenue on seed harvested per Kg.

P_4= Annual inflation/deflation rate.

P_n= Customer satisfaction *etc.*

Hence, Cost benefit analysis ratio =

$$\frac{\text{Present value (PV) of benefit}}{\text{Present value (PV) of cost}}$$

RESULTS AND DISCUSSION

Table 1 showed the various components of the soil used for this experiment at basal and also after the amendment of the soil. The result revealed an increase in soil acidity, organic matter, organic carbon, total nitrogen, available phosphorus and exchangeable acidity. Table 2 revealed that plant height was significantly higher for pig manure (OM) at 10 and 15 tonnes/ha, pig manure at 10 tonnes per hectare (OM10T) ranged between 16.74 cm-31.15 cm at 2 weeks to 4 weeks respectively for plant height, pig manure at 15 tonnes per hectare (OM15T) ranged between 13.89 cm to 31.98 cm at 2 weeks to 4 weeks. Pig manure at 5 tonnes per hectare (OM5T) also showed significant difference to NPK and Supergro (SG) at the weeks of observation. Number of leaves (NL) was significantly higher for pig manure (OM) at 10 and 15 tonnes per hectare, which ranged from 9.22 to 12.66 and 7.89 to 11.44 respectively, to NPK and SG at the 3-levels of application. The increase in the soil acidity, total nitrogen, available phosphorus and exchangeable acidity as analyzed for the soil used for the experiment, indicated that the addition of organic or inorganic fertilizers can increase soil organic matter, acidity, nitrogen and exchangeable acidity, if such addition is not beyond what plant can utilize in the soil. This was also supported by Howe *et al*. (2024) who reported the influence of fertilizer and manure inputs on soil health. Pig manure treatment at 10 t/ha (OM10T/ha) produced the highest biomass yield of 5.26 kg/m^2, followed by pig manure at 15 tonnes/ha (OM15T/ha) with 4.98 kg/m^2, pig manure at 5 tonnes/ha (OM5T/ha) had 4.73 kg/m^2. NPK (400 kg/ha) and Supergro at 2 ml (SG2 ml) (2000l/ha) had 4.50 kg and 3.05 kg/m^2 respectively. Similar results were obtained by Olaniyi *et al.* (2008) who reported highest plant height and increased biomass yield in *Amaranthus* at higher organic manure and nitrogen application rates. The research was also in agreement with the report of (Olufolaji and Okelana, 2007) who reported that *Amaranthus* plants require high nitrogen content for their vegetative growth. Chlorophyll content was significantly higher for pig manure at 10 tonnes per hectare and pig manure at 15 tonnes per hectare which ranged 47.04 to 53.11 and 53.03 to 54.45 respectively, which was significantly higher than pig manure at 5 tonnes per hectare, NPK and SG at different levels. Biomass yield was significantly higher for pig manure at 10 and 15 tonnes

Table 1: Soil physical and chemical properties before and after from the experimental site.

Soil properties	Value	
	Before	After
pH	6.1	5.61
Organic matter (g/kg)	24.26	35.67
Organic carbon (g/kg)	15.16	22.12
Total nitrogen (g/kg)	0.61	1.2
Available P (mg/kg, ppm)	5.13	6.23
Exchangeable acidity (H^+, Al_3+)	0.27	0.41
Exchangeable cations (cmol/Kg)		
K	0.22	0.3
Ca	2.49	5.11
Na	0.22	0.31
Mg	0.99	1.21
Extractable micronutrients (mg/kg)		
Zn	1.69	1.7
Mn	44.12	115.32
Fe	101.62	110.5
Cu	1.97	1.98
Particle size distribution (g/kg)		
Clay	62	96
Silt	97	94
Sand	841	810
Textural class (USDA)	Sandy loam	Sandy loam

per hectare which ranged from 5.26 kg/m^2 and 4.98 kg/m^2 respectively. Increased number of leaves with pig manure at 10 tonnes/ha (OM10T/ha) confirmed the role of organic matter and nitrogen in promoting vigorous vegetative growth in leafy vegetables (Unagwu *et al.*, 2023).

Table 3 showed the mean performance of organic and inorganic amendment on proximate composition of Amaranth. Moisture was significantly highest for amaranth treated with pig manure at 10 tonnes per hectare and higher for pig manure at 15 tonnes and 5 tonnes respectively. Ash was highest and significantly different for supergro at 3000 litres (3000 L/ha) and supergro at 2000 L/ha. Protein was highest and significantly different for supergro at 1000 L/ha followed by supergro at 2000 L/ha and supergro at 3000 L/ha respectively. Zinc (Zn) and copper (Cu) were significantly difference and higher for pig manure at different levels of amendment in the vegetable biomass. Manganese (Mn) and iron (Fe) were significantly difference in the vegetable biomass for NPK at 200 and 400 kg per hectare. Lowest and significant protein percentage was also revealed by control (no fertilizer). Proximate analysis indicated that Supergro treatment at 3-levels had the highest protein and ash content in the sampled leaves of Amaranth. This agrees with the findings of Ogwu (2020) who also reported high protein content in amaranth treated with different organic based fertilizers. Proximate also revealed the varying content of micro nutrients in amaranth. This also agrees with Hoang *et al.*, (2019); Byrnes *et al.* (2017) who reported varying micro nutrients in amaranth. The result also aligned with (GNLD, 2017) findings that applying Supergro at specific rates enhances the nutrient content of amaranths. It also noted that using Supergro at rates that are too low or too high can impede nutrient formation in plants. This indicated that different fertilizer treatments significantly influenced growth parameters of amaranth plants. Chauhan *et al*. (2015) demonstrated that fertilization affects significantly the pasting profiles of amaranth. Salami (2011) also reported that vegetables provide essential proteins, minerals and vitamins helping to combat malnutrition by offering

Table 2: Mean performance of organic and inorganic amendment on the growth of amaranth.

Treatment	Observed traits in weeks of observation									
	PH2 wks	PH3 wks	PH4 wks	NL2 wks	NL3 wks	NL4 wks	CC2 wks	CC3 wks	CC4 wks	BY Kg
OM10T	16.74a	28.39a	31.15a	9.22a	10.77a	12.66a	47.04a	48.48ab	53.11ab	5.26a
OM15T	13.89ab	28.77a	31.98a	7.89ab	9.77ab	11.44ab	42.17ab	52.03a	54.45a	4.98a
OM5T	11.28bc	22.61ab	25.67ab	7.55ab	9.22abc	11.11abc	42.81ab	47.57ab	51.57ab	4.73ab
NPK400	8.78cd	16.33bc	18.57bc	6.00bc	7.88abc	10.55abc	37.81ab	44.85b	51.34ab	4.50ab
NPK200	7.22cd	13.89bc	16.07bc	6.33bc	7.55bc	9.55bc	39.87ab	43.36b	47.79b	3.50bc
NPK600	7.11cd	12.55bc	14.97c	6.44bc	8.00abc	9.75abc	37.75ab	47.47ab	50.92ab	3.38bc
SG2000l	7.33cd	12.85bc	14.95c	5.55bc	7.44bc	9.33bc	40.24ab	46.23ab	49.37ab	3.05c
SG3000l	5.96d	12.61bc	14.65c	6.22bc	8.00abc	9.89abc	35.51b	43.33b	49.12ab	2.95c
SG1000l	5.77d	9.82c	12.27c	4.78c	6.55c	8.33c	39.55ab	47.33ab	49.57ab	2.58c
Control	4.11e	6.45cd	9.23cd	4.76c	6.51c	7.95cd	30.02b	36.12bc	41.45bc	1.84cd

Mean in a column with the same letter(s) are not significantly different according to DMRT (P=0.05 and 0.01).

Legend: PH= Plant height; NL= Number of leaves; CC= Chlorophy content; BYKg= Biomass yield in Kg/m^2.

Table 3: Mean performance of organic and inorganic amendment on proximate composition of *Amaranthus quitensis.*

Treatment	Proximate composition (mg/100 g)									
	Mst%	Fat%	Ash%	PRT%	CF%	Car%	Zn	Cu	Mn	Fe
OM10T	80.39a	0.14f	3.71g	4.14h	5.09g	6.51d	2.28b	4.62b	2.74e	9.53g
OM15T	79.62b	0.15ef	3.77ef	3.98i	5.16fg	7.29b	2.20d	4.12c	1.56i	8.06i
OM5T	79.31c	0.16ef	3.72fg	4.77g	5.67d	6.36d	2.69a	5.29a	2.70f	11.74c
NPK400	78.60d	0.19d	3.93d	5.21e	5.24ef	6.82c	2.20d	3.20e	3.88b	12.20b
NPK200	76.72f	0.22c	4.20c	5.26d	6.20b	7.37ab	2.24c	3.34d	4.16a	9.84e
NPK600	78.68d	0.16e	3.81e	5.16f	5.28e	6.89c	2.15e	3.09f	3.45c	14.52a
SG2000l	76.52f	0.24b	4.27b	6.16b	5.91c	6.87c	1.10g	2.90h	2.56g	8.82h
SG3000l	75.55g	0.27a	4.37a	5.86c	6.36a	7.58a	1.04h	2.45i	1.98h	9.64f
SG1000l	77.45e	0.20d	4.26b	6.42a	5.68d	6.09e	1.24f	3.07g	2.96d	10.74d
Control	78.56d	0.14f	3.63gh	3.73j	6.51a	6.75c	1.33ef	3.01i	2.70f	9.57g

Mean in a column with the same letter(s) are not significantly different according to DMRT (P=0.05 and 0.01).

Legend: MST%= Moisture; FAT%= Fat; ASH%= Ash; PRT%= Protein; CF%= Crude fibre; CAR%= Carbohydrate; Zn= Zinc (mg/100 g); Cu= Copper; Mn= Manganese; Fe= Iron.

Table 4: Cost-benefit ratio for the fertilizers used in this study for the production of 1ha.

	NPK (Kg/ha)			Organic manure (Pig manure) (Tonnes/ha)			Supergro (L/ha)		
	200	400	600	5	10	15	1000	2000	3000
Present value of benefits	₦270,000	₦300,000	₦410,000	₦392,000	₦450,000	₦580,000	₦450,000	₦520,000	₦720,000
Present value of costs	₦180,000	₦200,000	₦320,000	₦185,000	₦280,000	₦200,000	₦5,000,000	₦10,000,000	₦15,000,000
Cost-benefit ratio	1.5	1.5	1.28	2.11	1.60	2.90	0.09	0.052	0.048

adequate nutrition, which has been used in years to treat various health issues. Mekonnen *et al*. (2018) reiterated that application of organic fertilizer during field cultivation of amaranth in South Western Ethiopia produced better growth and higher yield in comparison with the chemical fertilizer. Studies have shown that partial substitution of synthetic N fertilizer with livestock manure tended to decrease total Nr losses (Xia *et al*., 2018; Zhou *et al.*, 2019).

Significant differences in proximate composition (Table 3) indicated that the different fertilizer types and application rates significantly influenced the nutritional composition of the amaranth leaves. Talukdar (2011), also reported significant differences in grass pea at different salt levels. Control was significantly low in protein content and high in fibre, this reinforced the findings of Elbehri *et al.* (1993) who revealed that nitrogen significantly contributed to yield and protein levels of Amaranth.

Table 4 revealed the coefficient of the input-output ratio used (Cost-benefit ratio) for each of the fertilizers used in this study. The best cost-benefit ratio obtained in the amendments was for 15 tonnes of pig manure per hectare (>2) which indicated a more and highest profitable investment to be used by the farmers for amaranth production in Nigeria. It was also revealed that 5 tonnes per hectare of pig manure gave better investment ratio (>2) for a farmer in this experiment. NPK fertilizer at different levels in Kg/ha (200, 400 and 600) also revealed good profitable investment return in the cost-benefit ratio (>1). It was revealed in this analysis that supergro at different levels (L/ha) (1000, 2000 and 3000) in the production of vegetable had no profitable investment returns, as the cost-benefit ratio was very low (<0.9). Although, highest present value of benefit was recorded for supergro at 3000 litres/ha but this doesn't transcend to cost-benefit (the assurance of a supposed investor to have positive return on the investment) as more of the benefit had been eroded by high cost. The reduction in the present value of cost on 15 tonnes of pig manure per hectare revealed that the higher the organic manure to be applied the better for the farmer, as the variables revealed the reduction in the cost of transportation, application of the manure and lower rate for the truck loading of higher quantity. Sanni and Adenubi (2015) also reported the use of pig manure for increased yield and profitability in Okra production. The best cost-benefit ratio obtained in the amendments was for 15 tonnes of pig manure per hectare which indicated a more profitable investment to be used by the farmers for amaranth production. This was also confirmed by Kuwornu *et al*. (2018).

CONCLUSION

The addition of fertilizers to *Amaranthus quitensis*, either organic or inorganic will increase the plant growth, yield performance and affect the nutritional composition. Based on the findings, pig manure at 10 tonnes and 15 tonnes are recommended for plant growth and biomass yield of amaranth. It was confirmed that significant growth and yield was observed on the organic and inorganic amendment sources and also on the nutritional composition of amaranth. Pig manure at 15 tonnes and 5 tonnes per ha are economically feasible for high returns and profitability in amaranth production. This will help to solve malnutrition and establish economic realities in vegetable production in Africa.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All plant procedure for the experiments were done as approved by the International Plant Protection Convention (IPPC) and laboratory techniques were approved by the Association of Official Agricultural Chemists (AOAC).

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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