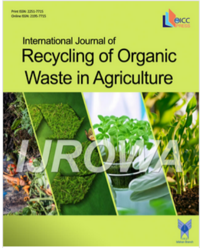

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Growth response of *Amaranthus hybridus* after amendment with bio-organic fertilizer developed from food wastes

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Original Research

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Abstract:

Purpose: In order to reduce food insecurity, the use of organic fertilizers is steadily gaining traction in crop development, especially in areas where the continued use of inorganic fertilizers poses serious environmental problems in addition to being extremely expensive for local farmers. The study looked at how *Amaranthus hybridus* responded to being amended with bio-organic fertilizer made from food waste.

Method: Food waste was gathered from food vendors; processed, sun-dried and blended. Dry cow dung was added to the waste mixture (ratio, 1:4), after which was liquefied with Greek yoghurt, Baker's yeast in water, and cassava effluents, and then left to biodigest in a biodigester for 50 days. Removal, dewatering, and sun drying followed. After 1%w/w of the developing fertilizers was added to the soil, 0.05g of *A. hybridus* seeds were sown by broadcast.

Results: Results after 7 weeks revealed significant improvements in plant output, especially in soils treated with yeast-based fertilizers. In these soils, plant height as well as leaf area and number increased by more than 40% in comparison to the control, which had no soil amendments. The 1% w/w yeast-based fertilized plants showed no chlorosis or other physical foliar anomalies in comparison to other treatments. Similar to how plants sowed in the yeast-based bio-organic fertilized soils had 11.24 g of total dry weight while plants sown in the control had 2.17 g.

Conclusion: This study therefore concluded that organic fertilizers, especially those augmented with Baker's Yeast, have the potential to enhance the growth and yield of vegetables.

Keywords: *Amaranthus hybridus*; Organic fertilizer; Waste-to-wealth; Cassava effluents; Vegetable

1. Introduction

Although vegetable gardening continues to happen mainly at the home levels alongside just a few farmers growing the crop on a large scale for commercial purposes, the growing of vegetables across the continent of Africa is roughly as old as peasant farming itself. This might be because crops like cereals, root and tuber crops, as well as legumes, receive a lot of attention. Cereals and tubers form the bulk of food consumed in the tropics but they are deficient in minerals and vitamins compared to the body requirement to guarantee good healthy living. In Nigeria, one of the most commonly grown vegetables is the Amaranth (Afolabi et al., 2020). Apart from its rich fibre contents, the vegetable is known for its nutraceutical importance. Afolabi et al. (2020) also reported that the plant has significant medicinal values; a decoction of the entire plant has been reported to be effective in the management of dysentery and inflammation. The plant has also been widely used as an emollient as well as a vermifuge. Therefore, given these importance, cultivation is widespread in Nigeria (Afolabi et al., 2020). To enhance productivity and improve yield, fertilizers are usefully utilized (Ikhajiagbe and Akendolor, 2016; Ogwu, 2019). According to Ogwu (2019), the use of various soil amendments and additions such as fertilisers might impact the proximate and phytochemical content of amaranthus. Oyedeji et al. (2014) demonstrated that applying NPK fertiliser to *Amaranthus* species in farms increased

their protein content, ash content, and crude fibre.
It is important to state that a continual dependence on chemical fertilizers may be accompanied by a fall in organic matter content, increased soil acidity, degradation of soil physical properties and increased rate of erosion due to instability of soil aggregates (Olowoake and Adeoye, 2010). Preserving soil organic matter content is one strategy necessary for the maintenance or improvement of soil fertility. This is achieved by using organic fertilizer sources. Given that Amaranths also require a high organic content and with adequate nutrient reserve for optimum yield, a reliance or organic fertilizer would obviously suffice (Ilupeju et al., 2015). Research has shown that organic based fertilizers are less leached into groundwater than the chemical fertilizer (Adeoye et al., 2015). Consequently, from the aforementioned, the use of organic fertilizer has gained appeal in increasing agricultural output in Nigeria, especially as it is less likely to damage ground water than chemical fertilizers when they are leached. It promotes soil fertility while also increasing farmer income through increased production.
Organic fertilization is widely encouraged due to its suitable nature and ability to recycle organic matter. Arguably among the most remarkable instruments for modern agriculture is bio-organic fertilizer, which is viewed as a blessing from the scientific community in order to transform garbage into useful materials through value addition. These fertilizers are safe for the surrounding ecosystem and frequently aid in some kind of decontamination of the soil environment from accumulated chemical fertilizers. In the agricultural sector, these developed organic fertilizers are used as a substitute forchemical fertilizers that are not eco-friendly and can destroy soil fertility in the long term (Owamah et al., 2014). Bio- organic fertilizers are preparations containing latent cells of effective microorganisms that assist theabsorption of nutrients by crop plants when applied via seed or soil by their interactions in the rhizosphere (Yasar et al., 2017).
The use of organic fertilizers not only enhances soil physicochemical property, it also enhances soil microbiota, especially because of the myriads of microbial contents it comes with; some of which are plant growth promoters. And it is increasingly important in promoting crop production, restoring soil fertility, and inhibiting soil diseases (Huang et al., 2014; Ikhajiagbe and Chijioke-Osuji, 2015).
Since important soil nutrients are stored in organic form, bio-organic fertilizers are likely to outperforms synthetic fertilizers when it comes of providing an extensive range of nutrients as well as organic matter that crops require. It is therefore imperative to supplement nutrients to soil to boost plants growth and yield (Adeoye et al., 2015; Ilupeju et al., 2015). Apart from the problem of possible negative impact due to continual use on soils, the cost of provision of inorganic fertilizers may not be too friendly for farmers. Given that inorganic fertilizers are easily leached into soils particularly in areas of significant rainfall, this puts more cost on procurement and effective use. The gradual release fertilizers dissipate slowly, prolonging the deposition of nutrients to reduce eventual contamination. Knowing how much or at what rate soil nutrients should be administered at any given time is critical to ensuring plant morphological growth and physiological performance; it is also required to increase sustainable production growth and plant yield per hectare. It is essential to use bio-organic fertilisers, which are significantly less likely to leach into the groundwater system than chemical-based ones, thus leading to nutrient loss. This suggests therefore that using organic fertiliser benefits Nigerian farmers, the majority of whom are from the poor economic class, by increasing crop yield.
Currently, food waste is thrown out alongside other garbage from the community at landfills or municipal garbage dump sites. Annually, Nigerians throw away no fewer than one hundred and eighty kilograms of food as waste, amounting to an aggregate of thirty-seven million tons of food. Despite the high organic content in the food waste, the practice of dumping it in landfills is not beneficial or healthy for the environment. The leaching of chemical substances into soil, land area reduction, odour creation, microbial contamination, and the release of greenhouse gases are all effects of landfill practice. The concept of value addition has always been known to be a huge strategy for waste management. Conversion of wastes to biogas or organic fertilizers is sure on way to achieving value addition.
The utilization of food wastes, which are totally organic, in the development of organic fertilizers rely on the degradation of organic materials by degrading microorganisms to release nutrients tied up in the wastes, including nitrogen, potassium, phosphorus, magnesium, calcium, as well as organic carbon. The resultant product from the degradation, mostly referred to as the digestate, is a product of the anaerobic breakdown of biological material including is made up of microorganism-generated biomass, partly-degraded organic and inorganic substances. Digestate can be used as a biofertilizer for fertilization of farmlands, as an organic fertilizer or raw material for biofertilizer production. The target technology is anaerobic digestion. Digestate is preferable since it has a greater quantity of readily bioavailable nutrients than non-digested ones. The use of digestate as the developed organic fertilizer will not only provide farmers in Nigeria and Africa with a new strategy which is helpful for achieving the targeted goal of food security in Nigeria by increasing high productivity yield of food grains (Food and Organization, 2012), it will also curb the dependency on chemical fertilizer which have adverse effect on soil and the environment for crop fertilization (Owamah et al., 2014). The aim of the study was to explore the potential impact of organic fertilizer on development of *Amaranthus hybridus*; these organic fertilizers would be developed from food wastes randomly collected from the waste dump of local restaurants, vegetable and fruits sellers around the main campus of the University of Benin, Nigeria.

2. Materials and methods

Study area

This project was carried out in a well-ventilated screen house at the Department of Plant Biology and Biotechnology in the University of Benin, Benin City, Nigeria.

Food waste materials

Food waste materials used in the development of the bio-organic fertilizer includes, Vegetables such has, carrots, cucumbers, spinach, watermelon peels, onion peels and peas. Fruits peel such as, orange peels, Pineapple peels and other plant crops such as Yam peels, potato peels, plantain peels, egg shells and dried leaves. These were collected over a period of three weeks from local vendors and from Uselu market in Ugbowo, Benin City. Probiotics used in the development of bio-organic fertilizer: cow dung, cassava effluent, yeast (*Saccromycese cerevisae*), Yoghurt (unsweetened).

Research methodology

Organic fertilizer development

The food waste collected from vendors and the market were sorted to remove any unwanted material and further sorted into the various types of waste for easy identification and mixing. The sorted food waste was shredded to reduce the sizes to allow easy drying and grinding. The food waste was then laid in the sun for four weeks to properly dry and turn to chips to aid easy blending. After drying, the food waste was weighed individually before taking to the mill, this was to identify proportions to mix together and in their various ratios.

The dried food waste was taken to a local mill and blended into different proportions based on the type of waste collected. After blending, the food waste was given a good mix in a large bowl. Oven-dried cow dung that was finely grounded was added in the ratio 1:4.

Having obtained the food wastes, they were sun-dried to constant weight and blended to enhance surface area. They were subsequently mixed in the ration presented on Table 1 below.

Probiotics application

Selected probiotics including cassava effluent, Baker's yeast and Unsweetened yoghurt have been found to to be very beneficial for crop overall growth and development (Souza Vandenberghe et al., 2017); and hence introduced in proportions. These were therefore introduced into the measured ground dried waste.

<u>Cassava substrate</u>: Cassava roots were purchased from a local farm in Ekosodin, Benin City; peeled, washed and cut into bits and then soaked for three days for biodigestion to occur, it released this alcohol-like smell on day three.

Baker's yeast was purchased from a baking store which contained a significant amount of *Saccromyces cerevisae* this was based on manufacturer's description. Also purchased was unsweetened Greek yoghurt from a supermarket. In the fourth preparation, no probiotic was added other than water. Amount of distilled water added to all types of probiotics used was 2000 mL. This was necessary to mix all ingredients into a paste. However, since the retting liquid from the soaked cassava was pure liquid, no additional distilled water was added (Table 2).

Anaerobic digestion

After introduction of probiotics (with water) into the food waste-cow dung mixture, the mixture was placed in an air-tight container (biodigester), and was left for 50 days to biodigest. It was kept under ambient temperature (29±3°C). A vent was made that permitted intermittent gas release through a pipe into water in order to prevent air from entering the digester when the vent was opened, allowing for the escape of organic gas produced as a result of the decomposition of the biomass in the digester. Once a week, vents would be opened in under two seconds.

Mineralization

After 50 days in the digester, the respective contents were removed, dewatered, and then sun dried to constant weight. Thereafter, Potash was added as a supplement at the rate of 1 % w/w.

Screening and curing

The fertilizer was screened using a sieve (2 mm mesh) to remove debris or large lumps of fertilizer leaving only a very fine powdery fertilizer which was good for planting for easier absorption by plants.

Phytoassessment of bio-organic fertilizer developed

Soil samples were collected at 3 random areas within pooled random depths (0 - 15 cm), within a fallow area. Soils were analyzed for soil physicochemical parameters according to methods described by Metson (1961), Neson and Sommer (1982), and APHA (1985). Enumeration and isolation of bacterial and fungal isolates in the bio-organic fertilizer-

Table 1. Organic food waste used in the bio-organic fertilizer development.

Food waste	Dry weight (g)
Orange peels	1800
Onion peels	500
Plantain peels	1000
Pineapple peels	400
Watermelon peels	200
Yam peels	300
Potato peels	180
Mixed vegetables	300
Egg shells	50
Dried leaves	200

Table 2. Proportion of materials used to develop the bio-organic fertilizer with by adding with the food waste.

Materials	Quantity	Treatment code
Wastes used:		
Organic food waste	1600 g	-
Cow dung	400 g	-
Total quantity used	2000 g	-
Probiotic addends:		
Retting cassava water	2000 mL	F-Cassava
Baker's Yeast	300 g*	F-Yeast
Unsweetened Greek Yoghurt	500 g*	F-Yoghurt
Volume of water	2000 mL	F-Water

*mixed in 2000 mL distilled water

impacted soils according to the methods outlined by (Taiwo and Oso, 2004; Cheesebrough, 2006).

Planting of vegetables

The collected top soil to be used in the experiment were filtered through 2mm-mesh sieve toremove large particles and debris, and then distributed into Experiment bowls (radius, 18 cm; height, 20 cm). Soils per bowl amounted to 5.79kg per dried weight. Seeds were then amended with the bio-organic fertilizers at three different concentrations on weight-weight basis (0.01, 0.02, and 0.1% respectively). The setup was allowed to attenuate for 2 days with constant turning of the soil-fertilizer mix. Thereafter, seeds of *Amaranthus hybridus* were obtained from the National Institute for Horticultural Research, NIHORT, Ibadan. Seeds were sown by broadcast all over the soil surface, at the rate of 0.05g per bowl. Surface area of soil in the bowl was 1017. 8cm2.The control soil was not amended. Weeds were controlled manually by hand picking weeds from the bowls. Soil is constantly wetted with tap distilled water (pH range, 6.7 - 7.2) every other day with 200 mL, to maintain soil moisture.

Data collection and analyses

Changes in plant morphological characteristics were determined. Growth parameters of the plant such as plant height, leaf area, and extent of leaf and stem colouration, leaf colour were recorded. To obtain shoot and root dry mass, the fresh shoot samples were sun-dried to constant weight. Internode reading in this study was distance between nodes at the 5th leaf (L5) and 6th leaf (L6) from the soil level. Rhizoacidity readings were done by using litmus paper to check acidity from crushed roots (Ikhajiagbe et al., 2022). This was necessary to determine level of acid exudation from roots of plants. This is a parameter that identifies capacity for acidification of rhizosphere of the test plant for plant growth promotion. Data collected were subjected to analysis of variance (ANOVA) while treatment means were compared using Duncan Multiple Range Test (DMRT).

3. Results and discussion

For physicochemical characteristics (Table 3), results show that pH values for Cassava-based bio-organic fertilizer varied between 3.2 and 3.9 (Fig. 1). The Yeast-based bio-organic fertilizer was 4.3 on day 20 and 4.2 on day 40, the pH also became steady on day 50. The Yoghurt-based bio-organic fertilizer the pH showed decrease, it showed 4.5 on day 20 and 4.1 on day 50. The water-based bio-organic fertilizer varied between 4.0 and 3.8 on day 20 and 50 respectively showing an increase in acidity. Generally, the bio-organic fertilizer showed acidity at day 50 when it was removed from the bioreactor and dewatered. The bacterial count of the dry food waste before it was employed in the development of the bio-organic fertilizer was 6.50 × 10^4 Cfu/g; it was 11.75×10^4 Cfu/g in the cow dung (Table 4). However, 50 days after exposure in the digester, the bio-organic fertilizer made with Yoghurt had the highest bacterial count of 9.50 × 10^4 Cfu/g, followed by the Yeast-based bio-organic fertilizer which showed 6.50 × 10^4 Cfu/g. The Cassava based fertilizer and water-based fertilizer showed bacterial counts of 1.83 × 10^4 Cfu/g and 0.90 × 10^4 Cfu/g respectively. The cassava-based fertilizer had the lowest bacterial count.

The bacteria present in the cow dung and dry food waste which were used as key ingredients in the development of the bio-organic fertilizer included *Serratia maracescens* and *Escherichia coli* which was present in both materials. The cow dung had the presence of *Proteus mirabils*, *Pseudomonas aeruginosa* and *Klebsiella oxytoca* before biodigestion and the dry food waste had *Bacillus subtillis* also present before biodigestion (Table 5). After biodigestion and dewatering, *Bacillus subtillis* was present in all fertilizer types and *Klebsiella oxytoca* absent in all. The fungal species present in the cow-dung and food waste was

Table 3. Physicochemical characteristics of soil used in the study.

Characteristics	Mean±SD (n=3)
pH (H_2O)	6.31±0.56
Organic carbon (%)	1.86±0.52
Total organic matter (%)	3.21±0.93
Total nitrogen (%)	0.57±0.17
Avail. phosphorus (ppm)	4.85±0.98
Potassium (Cmole/kg)	0.56±0.25
Ca (Cmole/kg)	5.32±1.22
Mg (Cmole/kg)	2.75±0.72
Na (Cmole/kg)	0.43±0.08
Exchangeable acidity (Cmole/kg)	0.17±0.03
ECEC (Cmole/kg)	9.14±1.23

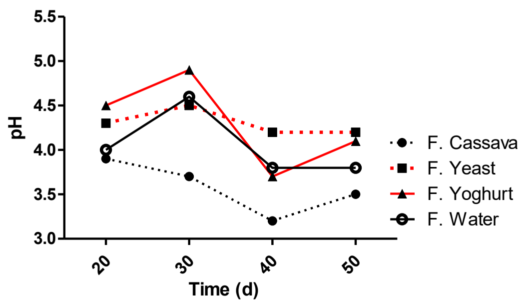

Figure 1. pH analysis after 50 days during biodigestion of bio-organic fertilizer.

Table 4. Bacterial counts of Bio-organic fertilizer microbial analysis.

Code	× 10^4 Cfu/g	$\log_{10}$ (cfu/g)
Materials before biodigestion		
Dry Food waste	6.50±2.12	4.80±0.4
Cow dung	11.75±1.06	5.07±0.04
Bio-organic fertilizer after biodigestion		
F-Cassava	0.90±0.14	3.95±0.07
F-Water	1.83±0.11	4.26±0.003
F-Yeast	6.50±1.41	4.81±0.10
F-Yoghurt	9.50±0.71	4.98±0.03

Table 5. Bacterial and fungal composition of the bio-organic fertilizer.

Isolates	Materials for the fertilizer before biodigestion		Bio-organic fertilizer after biodigestion			
	Cow dung	Dry Food waste	F-Cassava	F-Water	F-Yeast	F-Yoghurt
Bacterial isolates						
Bacillus subtillis	-	+	+++	+	+++	+++
Enterobacter cloacae	-	-	-	-	+	-
Proteus mirabilis	+++	-	-	-	+	++
Serratia marcescens	+	+++	+	-	-	+
Escherichia coli	+	+	++	+	-	-
Pseudomonas aeruginosa	+	-	-	++	+	++
Klebsiella oxytoca	+	-	-	-	-	-
Fungal isolates						
Aspergillus niger	-	+	+	+	+	+
Aspergillus fumigatus	+	+	-	+	+	-
Rhizopus stolonifera	+	+	+	-	+	+
Trichoderma sp.	+	-	-	+	-	+
Penicillium sp.	-	+	+	-	+	+

+ shows the comparative degree of proliferation of isolate on growth medium after 48 hours; - Absent

Aspergillus fumigatus, *Rhizopus stolonifera* before biodigestion (Table 5). The nutrients composition of the bio-organic fertilizer after 50 days of biodigestion showed the Yoghurt-based fertilizer having the highest percentage of Nitrogen (11.61%), followed by Yeast-based fertilizer (6.73%) (Table 6). The magnesium content was higher in the yoghurt-based bio-organic fertilizer (3.12Cmole/kg) compared to 1.98 Cmole/kg in the cassava effluent-based fertilizer.

Biofertilizers are generally defined as an organism-based composition of micronutrients and carbon substrates such as bacteria, cyanobacteria, fungi, and algae that can nourish and enhance soil quality (Ma et al., 2020). In order to disperse microbiological inoculants into the specific targeted plant part, especially the stem, root system, or floral parts, transport or carrier elements such slurries, granular particles, powdery substances, and liquid blends are now employed in the production of biological fertilizer bioformulation. To improve the makeup and variety of microorganisms that are helpful in the soil's biota, useful and relevant microbial inoculants can be incorporated into food waste formulations for organic fertilizer development. That way one uses "one stone to kill two birds". These are usually incorporated in the form of powders or liquid broths (produced in medium). In the current study, cassava effluents that are rich in microorganisms, as well as yoghurt and Baker's yeasts which are probiotics are carried via liquid media and added unto the food waste materials to be used in the organic fertilizer formulation. This study worked on the development of bio-organic fertilizer using market friendly materials to introduce microorganisms into the fertilizer, the materials used led to the development of a Cassava-based fertilizer, Yeast-based fertilizer, Yoghurt-based fertilizer and Water-based fertilizer. At 7 weeks, significant changes in plant height was reported in *A. hybridus* sown in soils amended in 0.1% w/w yeast-based bio-organic fertilizer (91. 7 cm) and 81.6 cm in those sown in bio-organic fertilizers biodigested using only water (Table 7). Compared to the leaves in the control soil (115.4 cm^2), yeast-based bio-organic fertilizer (0.1% w/w) significantly enhanced leaf area to 172.8 cm^2. The extent of foraged leaves was seen in most of the treatment which ranged from 1-5 leaves being foraged by insects. The control treatment and yeast had no foraged leaves on the fifth week of growth. See Plates 1 - 4.

Fertilizer is one of the most vital inputs contributing to crop production because it increases productivity and improves yield quantity and quality. The objective of this study was to carry out a qualitative growth assessment on a vegetable (*Amaranthus hybridus*) that was grown on soil amended with organic fertilizer. When compared to the no-fertilizer control condition, the use of bio-organic fertilizer resulted in increased growth. Plant height is a significant factor of a plant's capacity to compete for light and is crucial in defin-

Table 6. Nutrient composition of bio-organic fertilizer.

Type of fertilizer (n=3)	Bio-organic fertilizer				p value
	F-Yeast	F-Water	F-Cassava	F-Yoghurt	
Nitrogen (%)	$6.73^a \pm 0.02$	$5.34^a \pm 1.02$	$5.44^a \pm 2.03$	$11.61^b \pm 2.42$	0.054
Phosphorous (%)	$4.45^c \pm 1.52$	$2.24^c \pm 1.82$	$15.57^b \pm 3.24$	$20.02^a \pm 5.21$	***0.002***
Potassium (%)	$39.26^a \pm 2.13$	$36.86^a \pm 4.24$	$37.55^a \pm 5.21$	$38.11^a \pm 2.91$	0.184
Ca (Cmole/kg)	$6.81^a \pm 1.27$	$4.03^b \pm 0.26$	$4.83^b \pm 1.93$	$5.89^{ab} \pm 1.28$	0.351
Mg (Cmole/kg)	$3.01^{ab} \pm 0.09$	$2.05^b \pm 0.24$	$1.98^b \pm 0.72$	$3.12^a \pm 0.24$	***0.016***

Table 7. Plant above-ground morphological characteristics at 7 weeks after sowing.

Experiment	Plant height (cm)	Leaf area (cm^2)	No. of leaves	Stem girth at 5 cm from base (cm)	No of primary stem branches	Internode (cm)
Control	60.7 ±3.2	115.4 ±14.2	43 ±4	0.8 ±0.1	0	4.2 ±0.6
0.01%F-Cassava	60.3 ±4.1	101.2 ±23.1	38 ±5	0.7 ±0.1	0	4.2 ±0.3
0.01%F-Water	70.7 ±5.3	119.8 ±24.2	50 ±2	0.7 ±0.3	0	5.5 ±1.3
0.01%F-Yeast	43.2* ±1.4	84.6 ±11.5	31* ±4	0.6 ±0.3	0	3.9 ±1.2
0.01%F-Yoghurt	54.9 ±6.3	71.4* ±14.2	33 ±2	0.7 ±0.4	0	3.5 ±1.1
0.02%F-Cassava	66.7 ±3.2	98.1 ±21.4	40 ±6	0.8 ±0.2	0	4.4 ±0.5
0.02%F-Water	51.6 ±5.3	85.4 ±15.3	39 ±4	0.6 ±0.2	0	3.2 ±0.8
0.02%F-Yeast	80.5 ±4.6	132.2 ±15.3	47 ±3	1.2* ±0.2	4*	4.1 ±0.8
0.02%F-Yoghurt	48.5 ±2.7	53.5* ±26.3	26* ±6	0.9 ±0.2	0	5.8* ±0.6
0.1%F-Cassava	69.8 ±8.5	121.8 ±21.4	40 ±2	0.8 ±0.4	0	4.4 ±0.8
0.1%F-Water	81.6* ±3.1	107.8 ±34.2	50 ±5	1.3* ±0.2	19*	4.4 ±1.3
0.1%F-Yeast	91.7* ±3.7	172.8* ±11.5	58* ±6	0.6 ±0.3	0	3.9 ±1.3
0.1%F-Yoghurt	71.6 ±9.3	105.7 ±25.2	43 ±3	0.8 ±0.4	0	7.5* ±0.9
LSD(0.05)	20.3	43.2	12	0.4	3	1.4
p-value	0.028	0.004	0.061	0.103	0.138	0.183

*Means (n=5) on same column with asterisks superscripts differ significantly from the control ($p<0.05$)

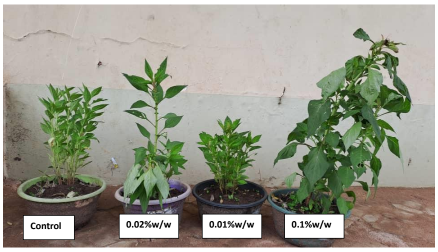

Plate 1. *Amaranthus hybridus* germination at week seven with yeast-based fertilizer.

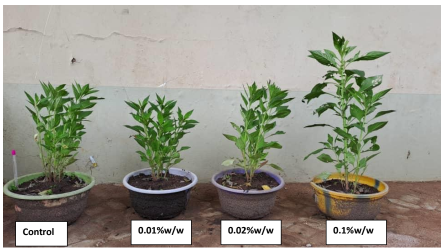

Plate 2. *Amaranthus hybridus* germination at week seven with water-based fertilizer.

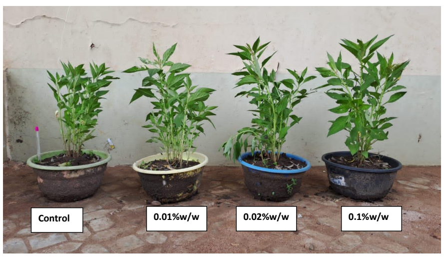

Plate 3. *Amaranthus hybridus* germination at week seven with cassava-based fertilizer.

Plate 4. *Amaranthus hybridus* germination at week seven with yoghurt-based fertilizer.

Plate 5. Rhizoacidity test of plant root samples.

ing the plant's morphological growth response to a growth stimulant or a stressor. The increase in plant height indicates a considerable beneficial response to bio-fertilization. The capacity for exudation of organic acids from the roots of plants is usually considered an important factor in plant-growth enhancement (Table 8). These acids lower soil pH around the rhizosphere, thus making it conducive for proliferation for plant-growth promoting rhizobacteria like Pseudomonads. In the study, the degree of redness of the litmus paper was used to adjudge the magnitude of acidity in the roots. Plants exposed to organic fertilization sowed more rhizo-acid magnitude than those in the control soil. See Plate 5.

Table 8. Plant root characteristics at 7 weeks after sowing.

Experiment	Primary root length (cm)	Root weight (g)	Rhizo-acidity	Total plant weight (g DW)	Shoot weight (g DW)	Total no. Dried leaves weight per plant	Shoot/ root ratio
Control	19.7 ± 4.7	0.48 ± 0.11	+	2.17 ± 1.02	0.87 ± 0.67	0.82 ± 0.19	1.81 ± 0.88
0.01%F-Cassava	29.2* ± 5.3	0.39 ± 0.15	++++	1.47 ± 0.25	0.78 ± 0.35	0.30* ± 0.04	2.01 ± 1.25.
0.01%F-Water	26.1 ± 5.1	1.65* ± 0.37	+	5.19* ± 1.53	3.01* ± 0.95	0.40* ± 0.14	1.81 ± 0.92
0.01%F-Yeast	26.3 ± 4.7	2.96* ± 0.74	+++	5.62* ± 2.13	1.71 ± 0.38	0.95 ± 0.32	0.57* ± 0.24
0.01%F-Yoghurt	20.9 ± 6.3	0.40 ± 0.15	+++	2.81 ± 1.13	2.07 ± 1.02	0.34* ± 0.25	5.17* ± 1.93
0.02%F-Cassava	26.8 ± 3.8	0.96 ± 0.14	++	3.92 ± 0.28	2.34* ± 0.73	0.62 ± 0.22	2.43 ± 1.02.
0.02%F-Water	25.3 ± 8.2	0.89 ± 0.22	++++	3.59 ± 0.57	2.36* ± 0.83	0.34* ± 0.09	2.65* ± 0.92
0.02%F-Yeast	18.2 ± 11.4	0.60 ± 0.35	+++	2.12 ± 1.23	1.28 ± 1.13	0.33* ± 0.03	2.01 ± 0.62
0.02%F-Yoghurt	17.9 ± 5.6	0.40 ± 0.05	++++	3.36 ± 1.47	2.26* ± 1.02	0.76 ± 0.25	5.65* ± 1.33
0.1%F-Cassava	58.0* ± 6.7	0.76 ± 0.33	++++	3.09 ± 0.27	1.37 ± 0.83	0.96 ± 0.42	1.80 ± 0.64
0.1%F-Water	27.9 ± 8.4	6.22* ± 1.32	+++	2.07 ± 1.45	0.99 ± 0.22	0.78 ± 0.35	3.31* ± 1.03
0.1%F-Yeast	24.8 ± 10.2	0.72 ± 0.23	++++	11.24* ± 4.24	7.16* ± 1.23	2.42* ± 0.67	1.83 ± 0.63
0.1%F-Yoghurt	24.3 ± 5.3	0.31 ± 0.09	++++	2.84 ± 1.15	1.35 ± 0.24	0.77 ± 0.32	1.87 ± 0.79
LSD(0.05)	8.4	0.62		2.3	1.25	0.42	0.71
p-value	0.103	0.183		0.029	0.007	<0.001	0.046

+ magnitude of acidity (the higher the + sign, the higher the acidity as shown in the litmus paper)
*Means (n=5) on same column with asterisks superscripts differ significantly from the control ($p<0.05$)

Total plant weight at 7 weeks after exposure to treatment regimen shows that better outcomes (11.24g) in the plants sown in the yeast-based fertilizer compared to those in the control soil (2.17g). Similar increases in total foliar yield expressed as total dry weight of leaves per dry weight was reported in this same treatment. Whereas shoot-root ratio was higher in plants exposed to bio-organic fertilizers at 0.02%w/w concentrations, shoot-root ratio in those plants in the soils enhanced with 0.1%w/w yeast-based bio-organic fertilizers was 1.83, which was minimally different from the control (1.81, $p>0.05$) (Table. 8). No physical anomalies, ranging from foraging by herbivorous insects or caterpillars, or chlorosis or other forms of physical foliar anomalies were recorded in the 1% w/w yeast-based fertilized plants (Table 9). However, the total number of senesced leaves was 13, amounting to 30.23% of its entire foliage ($p>0.05$). The most significant foliar loss due to senescence was in 0.1%w/w Cassava-based organic fertilized plants as well as those exposed to 0.1% w/w Water-based fertilizers. Fig. 2a-c shows changes in foliar colour in response to application of treatment regimen. Foliar colour varied with time from green yellow to lawn green, and from dark sea green to dark green. Based on their nutritional content; three primary nutrients—nitrogen, phosphorus, and potassium—are present in the organic fertilizers developed in the study. This suggests the food waste and cow dung is rich in nutrients and has the potential to increase soil microbes and nutrient state when used together as a fertilizer especially in nutrient depleted soils. Anaerobic digestate potentials have been discovered in several research as an efficient replacement

Table 9. Plant morphological anomalies recorded at 7 weeks after sowing.

Experiment	+No. of leaves with evident foraging	+No. of leaves with chlorotic spots	+Total no. of senesced leaves	Percentage senesced leaves (%)	Visible morphological anomalies in the stem
Control	25 ± 4	1 ± 1	13 ± 4	28.10 ± 8.21	None
0.01%F-Cassava	20 ± 6	0	11 ± 6	30.82 ± 5.34	None
0.01%F-Water	14* ± 3	0	22* ± 5	41.24 ± 9.24	None
0.01%F-Yeast	22 ± 6	0	17 ± 3	32.34 ± 11.27	None
0.01%F-Yoghurt	26 ± 6	1 ± 1	14 ± 4	39.24 ± 13.5	None
0.02%F-Cassava	14* ± 4	0	8 ± 2	18.23 ± 9.25	None
0.02%F-Water	29 ± 5	0	7 ± 3	17.24 ± 5.25	None
0.02%F-Yeast	29 ± 8	0	7 ± 2	24.32 ± 11.25	None
0.02%F-Yoghurt	16 ± 4	1 ± 0	11 ± 5	42.31± 10.53	None
0.1%F-Cassava	19 ± 3	4* ± 1	22* ± 4	51.24* ± 12.47	None
0.1%F-Water	9* ± 3	1 ± 0	33* ± 4	64.32* ± 9.52	None
0.1%F-Yeast	24 ± 6	0	14 ± 6	30.02 ± 11.66	None
0.1%F-Yoghurt	12* ± 5	0	13 ± 3	30.23 ± 6.83	None
LSD(0.05)	11	2	8	15.21	-
p-value	0.015	0.332	0.078	0.192	-

+mean and standard error expressed to the nearest integer

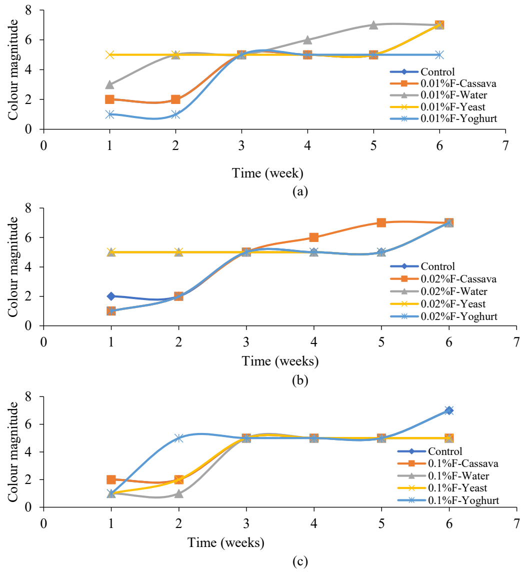

Figure 2. Leaf colour readings (colour code) for plants during the first 6 weeks following exposure to (a) 0.01% (b) 0.02% (c) 0.1% bio-organic fertilizer respectively. Key on the y-axes (foliar colours); 1 Green yellow, 2 Lawn green,3 Dark sea green, 4 Lime green, 5 Olive drab, 6 Dark Olive green, 7 Green, 8 Dark green.

for inorganic chemical fertilizers, which are known to have negative environmental consequences. Nitrogen percentage was found to be highest in the yoghurt-based fertilizer, this further emphasizes the proactive action of the microbes which led to a faster release of nutrients while in the bio digester. Generally, the NPK results were good enough as in the case for organic fertilizers (Akanni et al., 2011; Maria et al., 2017).

The phytoassesment of *Amaranthus hybridus* used in the study compared growth parameters between soil fertilized with organic fertilizer and unfertilized soil (control). The assessed growth metrics of the plants may be utilised to evaluate how well they responded to the various treatments. Comparing the outcome on soil only to that on soil treated with organic fertilizer, the *Amaranthus hybridus* plant performed better (Siswanti and Khairunnisa, 2021).

The progressive increase in height, number of leaves and leaf area of *A. hybridus* tested with organic fertilizer showed favourable nutrient mineralization of the fertilizer as a result of the influence of the mineral component on the organic content of the fertilizer (Adeoye et al., 2015).

Plants grown in the yoghurt-based fertilizer significantly enhanced the production of leaves and maintained the trend observed in plant height at week 5 and at harvest. Over-reliance on inorganic fertilizers, particularly in the tropics are on the rise, this has resulted in a decline in soil fertility, environmental degradation and even a contribution to the release of greenhouse gases. Organic fertilizers, such as biofertilizers with great microbial potential, are therefore necessary for adequate supply of nutrients to plants and also function as an amendment to increase soil humus, coupled with its eco-friendliness compared to inorganic fertilizers (Sun et al., 2015).

4. Conclusion

In the study, the application of bio-organic fertilizer was shown to enhance plant growth and development. This study is even more important particularly in areas where farmers do not have the financial capability to obtain fertilizers for their crops. Apart from this, the utilization of bio-organic fertilizers has been reported previously as one of several methods of reducing carbon footprint in the environment, thus contributing to a more sustainable and healthier environment. In this study, the yeast-based bio-organic fertilizer showed promising effects on plant overall growth and yield enhancements. Not only were leaf sizes enhanced, there was the significant increase in plant biomass due to the application of this bio-organic fertilizer. Local traders in Amaranths would make more money selling broader-leafed vegetables than thinner ones; hence, this considerable increase in leaf area and biomass benefits crop economics greatly. This therefore has implications for the development of bio-organic for enhancing food security. In general, the usage of bio-organic fertilizers improved crop plant overall turnover. The fact that the technology was cheap and easily affordable and deliverable puts it right at the doorsteps of poor farmers who deliberately require this technology not only to enhance their turnover, but perhaps as an indirect weapon to defeat food insecurity.

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Authors' Contributions
BI and FOE conceived of the research. BI designed the study; Data collection was by FOE under supervision by BI; Data analyses and interpretation were conducted by BI & JSA; JSA and FOE did the Literature search and wrote the first draft; All authors read and approved the final draft for publication.

Availability of data and materials
The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests
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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