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Efficacy of Palm Oil Mill Effluent (POME) in the Improvement and Sustainable Production of Leaf Amaranths (*Amaranthus hybridus* L)

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ABSTRACT

Improved production of leaf vegetables becomes imperative due to their ability to act as supplements in the usual starchy diets of Africans. To make this task achievable, the use of POME is adopted because it is reportedly rich in essential nutrients, and more environmental friendlier than inorganic fertilizers. In this study, five treatments consisting of fresh POME were applied at the rate of 0, 15, 30, 45, 60 t/ha, and NPK 15-15-15 at 400 kg/ha was used for compares. Bed preparation, and other necessary agronomic practices were carried out. There were twenty-four beds of 2 m × 4 m size, arranged in a randomized complete block design field experiment, replicated four times. The treatments were randomly applied to prepared plots, and growth parameters (number of leaves, stem girth, plants height), and total marketable yield (MY) were measured at 5, 6, 7 and 8 weeks after sowing (WAS). Data collected were subjected to analysis of variance (ANOVA) and their means separated, using Duncan Multiple Range Test (DMRT) at 5%. Fresh POME applied at higher rates was significantly effective in improving agronomic parameters and marketable yield of *Amaranthus hybridus*. Marketable yield, at (t/ha) was in the order: 60 t/ha-8.93>45 t/ha-8.72>NPK-7.50>30 t/ha-5.90>15 t/ha-4.81>Control-2.23. This study concluded that 60 t/ha of fresh POME could be effective in alleviating the challenges encountered in leaf vegetable production, and would reliably act as an alternative to inorganic fertilizers. However, application of POME at 45 t/ha could also be useful where application at 60 t/ha is unattainable.

Keywords: Leaf vegetables, improved production, soil fertility, fertilizers, organic nutrient sources

Introduction

If the soil remains un-replenished with nutrients, crop yields will deteriorate over time. The use of fertilizers, whether organic or inorganic, containing primary and secondary macronutrients and micronutrients becomes necessary. Research has shown that organic fertilizers are more environmentally friendly than inorganic fertilizers (Anikwe, 2000; Omolayo *et al.*, 2011; Fawole, 2015; Adeyemi and Omotoso, 2023). Organic fertilizers and compost, if properly used,

can be beneficial for improving soil fertility and promoting sustainable vegetable and crop production (Adedeji *et al.*, 2019; Adeyemi and Omotoso, 2023).

Palm Oil Mill Effluent (POME) is a highly potent pollutant, having a low pH, reportedly caused by the presence of organic acids components, produced through incomplete degradation of palm fruits before processing (Osemwota, 2010). POME discharged from a mill is harmful to the environment, equally polluting streams and rivers (Okwute and Isu,

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2007), if improperly disposed (Adeyemi, 2022). The palm oil industry, contributes greatly to the total pollution in oil palm nations, thus necessitating the need to investigate the effectiveness of the wastes, the effluent in particular, as soil additives, for soil fertility maintenance and restoration. This would aid the efficient use of the wastes for sustainable crop production and efficient soil use, rather than remaining a major pollutant in those palm oil producing countries, Nigeria in particular (Gobi and Vadivelu, 2013).

Amaranth plants are typically annuals or short-lived perennials (Ogwu, 2020). Amaranths are high yielders of leaves, easy to grow and harvest, and simple to cook. Both the leaves and the seeds are highly nutritive and have been used as good sources of dietary fibre and minerals, and are high-protein sources. The leaves can be consumed raw fresh or prepared like spinach which could be added to salads or soups (Petruzello, 2017).

Amaranthus serve the dual purpose as affordable sources of essential nutrients and energy, and as a means to improve income and generate more employments (Ogwu, 2020). Developmental, growth and yield responses of amaranths, *Amaranthus hybridus*, to varied rates of raw/untreated POME therefore becomes essential, to enlighten the farmers on the adoption and use of POME as a form of organic fertilizer, as it is very economical, easy to get, effective, and environmentally friendly.

Materials and Methods

The Study Site

The selected site for the experiment was a fallow land in a tropical rainforest environment at the Teaching and Research Farm of the Faculty of Agricultural Sciences, within Ekiti State University, along Iworoko road, Ado Ekiti, positioned between latitude 7°15' and 8°5'N, and longitude 4°45' and 5°13' E, in south-western Nigeria. The experiment which was conducted on a typical loamy sand, in the year 2024, was rain-fed.

The Treatments

The six (6) treatments used in the study, consisting of fresh POME and NPK 15-15-15 were applied at 0, 15, 30, 45, and 60 t/ha and 400 kg/ha respectively. NPK 15-15-15 at 400 kg/ha. The treatments were replicated four (4) times, resulting in a total of 24 beds.

The Parameters Measured

The Agronomic metrics measured on the field included; plants height, number of leaves, stem girth, and total marketable yield. The stipulated values were measured at 5th, 6th, 7th and 8th week after sowing (WAS).

Chemical Analysis of the Organic Waste

Fresh POME was collected from the palm oil mill at Are-Ekiti Road, Afao, Ekiti State. Samples from the organic waste material were prepared and air-dried. The samples of the material were ground in stainless steel Wiley mill and analyzed for pH in water at 1:2 ratio, total carbon by chromic acid wet digestion method, total N by the micro-Kjeldahl method, total P, Ca, Mg, K and Na by wet digestion using concentrated nitric, perchloric and sulphuric mixture acid in a ratio of 25: 5: 5 respectively; P was determined by vanadomolybdate method; Ca, Na and K were determined by flame photometry while Mg was determined by atomic absorption spectrophotometry (Udo *et al.*, 2009).

Planting, Weeding and Harvesting

The six treatments were randomly assigned to the different plots (beds of 2 m × 4 m size) laid out in a randomized complete block design (RCBD). The treatments were applied to the beds one week before sowing the leaf amaranth seeds to allow for the curing of the organic waste, as the waste was fresh POME and had not been composted. Amaranth seeds were sown at a seeding rate of 3 kg/ha by broadcasting on the organically treated plots. The inorganic fertilizer, NPK, was applied to the designated plots/beds at

400 kg/ha by broadcasting two weeks after sowing the amaranth seeds. Weeding was done by uprooting only once at 4 weeks after sowing. Harvesting was done at 5, 6, 7, and 8 weeks after sowing by uprooting the vegetables. Sample seedlings were picked for measurements of the stipulated growth parameters. Marketable yield was obtained by rinsing the uprooted vegetables to remove the attached sands, and then weighing.

Data Analysis

Data generated were subjected to statistical analysis using ANOVA, and the means were separated using Duncan’s multiple range test (DMRT) at $\alpha_{0.05}$.

Results and Discussion

Chemical Properties of the Organic Waste

Table 1 shows the results of the chemical analysis of fresh POME. Fresh POME is acidic with a pH value of 4.70. The organic carbon in POME is 70.70 g/kg. The recorded nitrogen (N) value was 4.80, while the phosphorus content was 48.90 g/kg. The calcium content was 12.46 g/kg, magnesium was 5.62 g/kg, and potassium was 2.45 g/kg. The high values of the exchangeable bases recorded from the chemical analysis of POME is an indication that though POME could be acidic (Bello *et al.*, 2013), it would still retain its high nutrient contents for plant uptake, an indication of its good ability for soil restoration and maintenance/management.

Number of Leaves

Table 2 shows the effect of POME on the quantity of leaves produced by the differently treated vegetables. At 5 WAS, POME applied at 60 t/ha produced the leafiest vegetables (124.66), which differed significantly from NPK, which produced the fewest leaves (56.64). However, at 6 WAS, there were no significant differences in the number of leaves recorded from the vegetables from the treated plots, but POME applied at 45 t/ha gave the highest number of leaves (84.65). At 7 WAS, NPK and POME applied

Table 1. Chemical properties of the organic waste (POME)

Parameters	Values
pH (H ₂ O)	4.70
Organic C (g/kg)	70.70
Nitrogen (g/kg)	4.80
Available P (g/kg)	48.90
Calcium (g/kg)	12.46
Magnesium (g/kg)	5.62
Potassium (g/kg)	2.45
Sodium (g/kg)	0.94
Moisture (g/kg)	7.84
Fat (g/kg)	2.59
Ash (g/kg)	7.20
Protein (g/kg)	3.21
Crude fibre (g/kg)	20.50
Carbohydrate (g/kg)	58.66

at 60 t/ha produced the leafiest vegetables (40.00) which were significantly different from the vegetables from plots treated with POME applied at 45 t/ha, which produced vegetables with the fewest leaves (15.00). The highest values recorded for the number of leaves in the study were obtained from POME applied at 60 t/ha (124.66), POME applied at 45 t/ha (84.65), NPK, and POME applied at 60 t/ha (40.00), and NPK (48.00) at 5, 6, 7, and 8 WAS, respectively. The organically-treated plots gave higher number of leaves than the inorganic NPK at 5 WAS, an indication that POME compares well with NPK in fast release of sufficient nutrients for plant utilization when needed, to aid crop performance. Values recorded from NPK (56.64), POME applied at 60 t/ha (49.00), POME applied at 45 t/ha (15.00), and POME applied at 30 t/ha (14.66) were the least number of leaves recorded for each week, respectively. The outperformance of POME applied at 60 t/ha corroborates the findings

Table 2. Effect of the Varied Rates of Pome on the Number of Leaves of *Amaranthus Hybridus*

Treatments	5 WAS	6 WAS	7 WAS	8 WAS
Control	94.66ab	64.65a	36.66a	42.66a
NPK	56.64a	80.00a	40.00a	48.00a
A	124.66b	49.00a	40.00a	16.30c
B	92.65ab	84.65a	15.00b	21.65bc
C	82.00ab	57.66a	26.00ab	14.66bc
D	72.00ab	75.66a	22.65ab	25.00abc

NOTE: Means followed by the same letters in a column do not differ significantly at 0.05

Legend

Control- soil alone

NPK- inorganic fertilizer

A- POME applied at 60 t/ha | B- POME applied at 45 t/ha | C- POME applied at 30 t/ha | D- POME applied at 15 t/ha

of Md. Amirul *et al.* (2022), who submitted that the plant height, numbers of branches, numbers of leaves, canopy coverage area, growth rate, fresh weight and dry weight of Brazilian spinach were positively influenced by the use of POME.

Stem girth

Table 3 shows the effect of POME applied at different specified rates on the stem girth of leaf amaranth, as observed in the study. Though there were no significant differences in the stem girth values obtained at 5, 6 and 7 WAS, the organically-treated plots produced the thickest vegetables. At 8 WAS however, plots treated with NPK had the thickest stem (5.72 cm), which was significantly different from the vegetable stems measured from plots treated with POME applied at 30 t/ha, which had the thinnest stem (2.98 cm). The stems of the vegetables were thinner with the increase in number of weeks on the field. This might mean the fixation of nutrients in POME, thus reducing the amount of nutrients available for uptake and utilization by the vegetables. Paillat *et al.* (2020) opined that for the nutrients in organic fertilizers to be available for plants, organic fertilizers need first to be mineralized by heterotrophic microbes into simple organic compounds. However, it was observed that the organic treatments competed well with NPK at each week of the study, as higher stem girth values

were obtained from the organically treated plots.

Plant height

Table 4 describes the effect of the different rates of POME on the height of the leaf amaranth at 5, 6, 7, and 8 WAS. There were observable significant differences in the plant height of the leaf amaranth. There were no significant differences in the height of the vegetables at 5 WAS, however, the organic treatment applied at 45 t/ha produced the tallest vegetables (51.70 cm), while the shortest vegetables at 5 WAS were also harvested from organically-treated plots at 15 t/ha. The inorganic fertilizer (NPK) produced the tallest vegetables at 6 WAS (56.03 cm), and were significantly different from the organic fertilizer applied at 60, 45 and 15 t/ha respectively. Plots treated with POME applied at 60 t/ha produced the shortest plants (34.36 cm). The organic nutrient source (POME) applied at 30 t/ha gave the highest plant height value at 7 WAS (33.70 cm), and it differed significantly from the height of vegetables (22.70 cm) harvested from plots treated with 45 t/ha of the organic waste at the same week. Vegetables harvested from plots treated with 45 t/ha of POME which produced the shortest vegetables at 7 WAS, also significantly differed in height from the vegetables harvested from the plots assigned to the control and NPK plots. At 8 WAS, NPK had the

Table 3. Effect of the varied rates of POME on the stem girth (cm) of *Amaranthus hybridus*

Treatments	5 WAS	6 WAS	7 WAS	8 WAS
Control	8.12a	6.34a	3.95a	4.75ab
NPK	7.25a	5.64a	3.68a	5.72b
A	9.58a	5.61a	4.82a	3.02ab
B	9.15a	5.54a	5.72a	5.45ab
C	9.45a	4.24a	4.45a	2.98a
D	7.12a	5.64a	5.82a	4.85ab

NOTE: Means followed by the same letters in a column do not differ significantly at 0.05

Legend

Control- soil alone

NPK- inorganic fertilizer

A- POME applied at 60 t/ha | B- POME applied at 45 t/ha | C- POME applied at 30 t/ha | D- POME applied at 15 t/ha

Table 4. Effect of the varied rates of POME on the plant height (cm) of *Amaranthus hybridus*

Treatments	5 WAS	6 WAS	7 WAS	8 WAS
Control	38.70a	49.03bc	26.36a	22.03a
NPK	37.03a	56.03c	29.70a	32.36a
A	50.70a	34.36ab	26.03ab	22.36a
B	51.70a	42.03ab	22.70b	23.36a
C	42.36a	43.36abc	33.70a	19.70a
D	35.70a	35.70ab	28.03ab	28.20a

NOTE: Means followed by the same letters in a column do not differ significantly at 0.05

Legend

Control- soil alone

NPK- inorganic fertilizer

A- POME applied at 60 t/ha | B- POME applied at 45 t/ha | C- POME applied at 30 t/ha | D- POME applied at 15 t/ha

tallest plants of 32.36 cm, which did not significantly differ from the other treatments. The tallest plants (56.03 cm) in the study were harvested from the NPK at 6 WAS, while the shortest plants (19.70 cm) were from POME applied at 30 t/ha at the fourth week of harvest. Palm oil mill effluent applied at higher rates gave higher values of all parameters measured, at the earlier weeks of the experiment. This might mean that there were desirable amounts of nutrients in POME, which were readily made available for uptake and utilization by the vegetables, before the onset of

nutrient fixation whose effect was observable between weeks 6 and 8 of the study. The results obtained here corroborates the earlier submission of Adeyemi *et al.* (2021) who observed the quick-releasing ability of poultry manure, which is an indication that some organic nutrient sources could also be termed as quick releasing sources of plant nutrients, as in inorganic fertilizers. Akparobi (2009) observed that seedlings of amaranthus which were treated with manure at a rate of 35 t/ha had the highest mean values of measured parameters, and thereafter submitted that it should

be recommended for farmers growing amaranthus in rainforest agroecological zone.

Marketable Vegetable Yield

Table 5 shows the effect of NPK fertilizer and POME at different rates on the yield of *Amaranthus hybridus* at 5, 6, 7, and 8 (WAS). The highest yield value of 12.85 t/ha recorded for the leaf amaranth vegetables at 5 WAS came from plots treated with 60 t/ha of fresh POME, which was not significantly different from 45 t/ha of fresh POME, but differed significantly from other treatments. The yield value of 2.03 t/ha from plots designated as control was the lowest. At 6 WAS, plots treated with the organic nutrient source applied at 60 t/ha yielded significantly more vegetables (10.00 t/ha) than the control (1.58- the lowest yield) and POME-treated plots at 15 t/ha which yielded 3.75 t/ha of amaranthus vegetables. The largest quantities of marketable vegetables at 7 WAS were yielded by POME-treated plots at 60 t/ha (8.61 t/ha), though not significantly different from plots treated with POME applied at 45 and 30 t/ha which yielded 6.25 and 5.48 t/ha respectively, but was significantly higher than the quantities of vegetables harvested from the control, NPK and POME at 15 t/ha plots. The least yield at 7 WAS, obtained from the control plots (2.50 t/ha), meaning that the control plots remained the

least productive plots. Yield values recorded for the organically treated plots at higher rates of 60 and 45 t/ha were observed to be higher at 5 and 6 weeks, following the same trend as with the inorganic fertilizer used. However, a decrease in agronomic parameters and yield values was observed across weeks of sowing. The higher yield values recorded for the organically treated plots at higher rates of 60 and 45 t/ha at 5 and 6 weeks, following the same trend as with the inorganic fertilizer, confirms the findings of Agboola *et al.* (2019). The decrease in the agronomic parameters and yields also observed across weeks of sowing could be associated with the fixation of nutrients in the organic source, making the nutrients unavailable for uptake and utilization by crops. Additionally, it might be due to the fact that more seedlings were harvested in the earlier weeks. The maturing period of *Amaranthus hybridus* might be too short for the mineralization of the immobilized nutrients in the plots treated with lower rates of organic fertilizers, and the amount of readily available nutrients for immediate release, and utilization by the vegetable seedlings would definitely be lower than in the higher rates. Organic fertilizers were reported to be effective when considering the lifespan of crops, indicating that they also have potential for the cultivation of long-term vegetables (Fawole *et al.*, 2021). The higher marketable shoot yield values for the various rates of the organic waste,

Table 5. Effect of varied rates of POME on the Yield of *Amaranthus hybridus* (t/ha)

Treatments	5 WAS	6 WAS	7 WAS	8 WAS
Control	2.03d	1.58c	2.50b	2.23b
NPK	7.25bcd	7.00ab	3.36b	7.50ab
A	12.85a	10.00a	8.61a	8.93a
B	8.23ab	7.33ab	6.25ab	8.72a
C	3.74bcd	7.14ab	5.48ab	5.90ab
D	2.39cd	3.75bc	3.54b	4.81ab

NOTE: Means followed by the same letters in a column do not differ significantly at 0.05

Legend

Control- soil alone

NPK- inorganic fertilizer

A- POME applied at 60 t/ha | B- POME applied at 45 t/ha | C- POME applied at 30 t/ha | D- POME applied at 15 t/ha

recorded at 8 WAS corroborates the submissions of Fawole *et al.* (2019) and Fawole *et al.* (2021), that some organic nutrient sources could be used for effective production of short-term crops, while some could be adopted for the effective production of long-term crops. It is also an indication that more nutrients, especially nitrogen from the organic sources, were available for utilization by amaranth (Tovihoudji *et al.*, 2015). Organic fertilizers can be used in long-term viable production of crops, and vegetables putting into consideration the life span of such crops and vegetables. The lower values of agronomic parameters recorded from the inorganically treated plots at 6 and 7 weeks into the experiment could mean that the depletion of the supplied nutrients from the inorganic fertilizer had already commenced, indicating the non-residual characteristic of inorganic nutrient sources (Fawole, 2015). The depletion of the soil nutrient however, could be due to leaching, as earlier reported by Mathowa *et al.* (2012). POME applied at higher rates, especially 60 t/ha, will be beneficial for the production of early maturing crops and vegetables.

The highest growth parameters and yield values for the study which were recorded from the organically treated plots, is an indication that POME, at any rate, could be useful, and is adoptable for the production of vegetables and crops, considering the lifespan of such vegetable or crop, whether early or late maturing. The findings from this study showed that POME compared very well with NPK, and could therefore serve as a replacement for the inorganic fertilizer. Omotoso and Salami (2020) and Eyitayo (2015) earlier concluded that POME could serve as an alternate source of nutrient to synthetic fertilizers, for leaf amaranth production, and also as a renewable fertility management approach for production of crops. Furthermore, it confirmed the effectiveness of palm oil mill effluent in soil fertility restoration and/or management, and sustainable production of crops and vegetables, if properly disposed and managed (Momoh, 2019; Adeyemi, 2022).

Conclusion

The study investigated the utilization of fresh palm oil mill effluents (POME) to improve the production of *Amaranthus hybridus*. Palm oil mill effluents is a by-product of palm oil mill industries, and have been reported to be rich in plant nutrients, and more environmental friendlier than any chemical or synthetic fertilizer. However, POME could be hazardous to crops, aquatic inhabitants, soil microbial community and the environment at large, if improperly managed. The need therefore arises, to look at the effectiveness of palm oil wastes (especially the effluent) as soil additives, for soil fertility maintenance and restoration, to aid sustainable crop production and efficient soil use, rather than remaining a major pollutant. The study concluded that:

- i. High values of the exchangeable bases were recorded from the chemical analysis of POME, meaning that though POME could be acidic, it would still retain its high nutrient contents for plant uptake, an indication of its good ability for soil restoration and maintenance/management.
- ii. POME competed well with NPK; giving values higher than NPK, in the measured parameters.
- iii. Palm oil mill effluent applied at higher rates gave higher values of all parameters measured, at the earlier weeks of the experiment, thus indicating the presence of desirable amounts of nutrients in POME, which were readily made available for uptake and utilization by the vegetables, before the onset of nutrient fixation.
- iv. The highest growth parameters and yield values for the study which were recorded from the organically treated plots, confirmed that POME could be useful, and is adoptable for the production of vegetables and crops.

Palm oil mill effluent, applied at 60 t/ha could serve as an alternative source of nutrient to mineral fertilizer

for leaf amaranth, and also as a sustainable fertility management strategy for crop production, and it is therefore recommended for improved and sustainable production of Amaranth. Where application of 60 t/ha of POME is not attainable, application at 45 t/ha could be adopted.

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