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Full Length Research Paper

Effects of fertilizer on the productivity of *Amaranthus cruentus* in an ultisol environment

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A field study was conducted at the Teaching and Research Farms of the University of Benin, Benin City, Nigeria in 2007 and 2008 to evaluate the effect of palm oil mill effluent and NPK fertilizer on the performance of *Amaranthus cruentus*. The trial involved three levels of palm oil mill effluent (0. 5 and 10 t ha^{-1}) and three levels of NPK (0, 150 and 300 kg ha^{-1}) using a factorial arrangement fitted into randomized complete block design and replicated three times. Results revealed that the effluent and NPK fertilizer had positive effects on dry matter partitions, relative yield, relative agronomic effectiveness and chlorophyll content of *A. cruentus*. Integration of 5 t POME and 300 kg NPK ha^{-1} had the optimum total dry matter (9.65 t ha^{-1}), relative yield (2.08), relative agronomic effectiveness (1.91) and total chlorophyll content (58.80 mg g^{-1}).

Key words: *Amaranthus cruentus*, chlorophyll content, dry matter, relative agronomic, effectiveness.

INTRODUCTION

In the intensive agriculture, nutrient management is gaining importance for sustainable production. *Amaranth cruentus* Linnaeus belongs to the family Amaranthacea. It is a heavy feeder of nutrients and its requirement can be fulfilled by supplying nutrients through organic fertilizer (organic wastes such as effluent} and inorganic fertilizers (NPK) to maintained soil and crop productivity on a sustainable basis. This arises from the fact that the most prominent constraint to amaranth production in this part of the world is low native fertility of the soil.

The use of inorganic fertilizer to sustain cropping was found to increase yield only for some few years but on long-term basic, it has not be effective (Ojeniyi, 2000). It often leads to decline in soil organic matter content, soil acidification and soil physical degradation, leading to increase soil erosion. On the other hand, inorganic fertilizers are beyond the reach of resource-poor farmers because of high cost and uncertain accessibility and organic inputs, which are often proposed as alternative to inorganic fertilizer composition and high labour requirement.

In Nigeria, huge amount of organic wastes such as palm oil mill effluent are generated as by product of palm oil and heaped on damp sites, posing potential environmental hazard. Incorporating these wastes materials into the soil for crop production is expected to be beneficial to the build up of organic matter layer that is needed for a steady supply of nutrients by tropical soils (Agboola and Omueti, 1982). However, due to high quantity needed, adequate quantity of an organic and inorganic waste may be obtained, hence the farmers are often apply organic and inorganic fertilizer combined. Complementary use of organic and inorganic fertilizers has been proved to be a sound soil fertility management strategy in many countries of the world (Lombion et al., 1991).

The nutrient use efficiency is a reflection of what a plant does with mineral nutrients once it is inside the plant. It is

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Table 1. Chemical composition of palm oil mill effluent (POME).

Nutrient	Composition
Organic carbon (%)	23.00
Ntitrogen (%)	1.80
Potassium (%)	3.50
Magnesium (%)	1.07
Calcium (%)	0.25
Sodium (Na)	0.13
Ash (%)	13
pH (H_2O)	4.80

Table 2. Physical and chemical properties of soils from the experimental site before Nigerian Institute for Oil Palm Research cropping with Amaranth.

Soil variable	Site	
	2007	2008
pH (H_2O) 1:1	4.35	4.57
Carbon (%)	0.56	2.82
Nitrogen (%)	0.06	0.05
Available P (mg kg^{-1})	10.47	30.7
C:N	43.60	60.000
Calcium (c mol kg^{-1})	1.04	1.84
Magnesium (c mol kg^{-1})	1.28	1.44
Potassium (c mol kg^{-1})	1.80	4.56
Sodium (c mol kg^{-1})	0.78	1.06
Clay (%)	5.60	8.20
Silt (%)	3.30	5.40
Sand (%)	91.10	86.40
Textural class	Sandy loam	Sandy loam

the ability of the plant to produce a higher yield from a soil that is supply with one or more of the limited nutrients. Therefore after application of nutrients (N, P and K), an evaluation of the nutrient use efficient (NUE) would indicate whether the amaranth utilized the nutrients as reflected by their performance, growth and yield in ultisol environment in Benin City.

The present study was conducted to evaluate the effect of palm oil mill effluent and NPK fertilizer application on the performance of amaranth in respect to dry matter partitions, chlorophyll content, relative yield efficiency and relative agronomic effectiveness.

MATERIALS AND METHODS

Field experiments were conducted during the 2007 and 2008 cropping seasons at the Teaching and Research Farms of University of Benin, Nigeria. Benin City is located between Latitudes 5° 4″ and 7°38″ and Longitude 5°4″ and 7° 38″ of the equator. Benin City is in rainforest agroecological zone of South-Central Nigeria. The dominant soil of the experimental area is ultisol (acid sand). The soils were well drained and have a low nutrient status.

Palm oil mill effluent (POME) was obtained from National Horticultural Research Institute (NIFOR), Benin City while the amaranth cultivar NH 84/445 was obtained from (NIHORT), Benin City Ibadan. POME was analyzed before application using Mylavarapus and Kennelley (2002) procedures and presented in Table 1.

The experiments were laid out in randomized complete block design with three replicates. Treatments consisted of three levels of POME (0, 5 and 10 t ha^{-1}) and three levels of NPK fertilizer (0, 150 and 300 kg ha^{-1}) that were combined factorially. The POME applied was thoroughly mixed with the soil and the left for two weeks to allow for mineralization. NPK fertilizer was applied one week after transplanting (WAT).

Seeds of *A. cruentus* were first sown in the nursery. Appropriate nursery management practices were carried out as at when needed to obtain healthy and uniform seedlings. After three weeks in the nursery, the seedlings were transplanted to well prepare beds and spaced 45 x 20 cm to achieve a plant population of 111,111 plants per hectares. Each plot size was 2.7 x 3.0 m and consisted of beds. Before transplanting in both years, surface soil samples (0 – 15 cm) were collected from 15 points for routine analysis using Mylavarapus and Kennelley (2002) procedures. The physical and chemical properties of the soils are presented in Table 2.

After transplanting crop, each plot was mulched with dry grasses/leaves to conserve soil moisture. Irrigation, weed, insect pest and disease control were carried out appropriately.

Data collection

All parameters were determined in-situ on five randomly sampled plants per plot. Five tagged plants were uprooted at 4, 8 and 12 WAT, separately into roots, stems and leaves, dried at 70°C for 72 h to constant weight (ISTA, 1993). From the summation of these partitions, total dry yield was obtained.

Five tagged plants were randomly selected from each plot for chlorophyll analysis. The process of chlorophyll determination involves grounding 0.04 g of leaves in a mortar in the presence of about 15 ml of 80% acetone solution. The resulting extract was filtered; the mortar was wash with 10 ml fresh 80% acetone solution until, it is colourless. Measurement of chlorophyll a and b were then made by direct determination of the absorbance at 663 nm and 645 wavelengths using a spectrophotometer.

Nutrient utilization efficiency was estimated through relative yield efficiency and the relative agronomic effectiveness using total dry matter yield (biological yield) at 12 WAT. Yield increase was calculated using the following formula:

$$\text{E.g. yield increase (\%) for treatment 2} = \frac{Yield\ (T2) - Yield\ (T1)}{Yield\ (T1)} + 1.00$$

For T3, T4, T5, T6, T7, T8 and T9 the same formula is used, where: T1 = control; T2 = 5 t POME ha^{-1}; T3 = 10 t POME ha^{-1}; T4 = 150 kg NPK ha^{-1}; T5 = 300 kg NPK ha^{-1}; T6 = 5 t POME ha^{-1} + 150 kg NPK ha^{-1}; T7 = 5 t POME ha^{-1} + 300 kg NPK ha^{-1}; T8 = 10 t POME ha^{-1} + 150 kg NPK ha^{-1} and T9 = 10 t POME ha^{-1} + 300 kg NPK ha^{-1}.

The relative agronomic effectiveness RAE) values of the NPK relative to the yields of the NPK relative to the yields obtained in the sole fertilizer treatment (T5) were calculated using the formula:

$$\text{RAE \% = for treatment T2} = \frac{Yield\ (T2) - Yield\ (T1)}{Yield\ (T5) - Yield\ (T1)}$$

For T3, T4, T5, T6, T7, T8 and T9, the same formula is used.

Table 3. Effects of POME and NPK fertilizer on the dry matter partitions of *A. cruentus* at 4 WAT.

POME (t ha^{-1})	Dry root yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})				Dry stem yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})			
	0	150	300	Mean	0	150	300	Mean
0	0.04	0.08	0.06	0.06	0.06	0.09	0.07	0.07
5	0.06	0.07	0.04	0.06	0.05	0.08	0.05	0.06
10	0.10	0.05	0.06	0.07	0.11	0.05	0.06	0.07
Mean	0.07	0.07	0.05	0.06	0.07	0.07	0.06	0.07
LSD (0.05) POME				ns				ns
LSD (0.05) NPK				ns				ns
LSD (0.05) POME x NPK				ns				ns
POME (t ha^{-1})	Dry leaf yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})				Total dry yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})			
	0	150	300	Mean	0	150	300	Mean
0	0.15	0.28	0.19	0.21	0.34	0.58	0.38	0.45
5	0.17	0.16	0.09	0.14	0.37	0.39	0.22	0.33
10	0.18	0.14	0.14	0.15	0.39	0.26	0.23	0.29
Mean	0.17	0.19	0.14	0.17	0.36	0.41	0.28	0.35
LSD (0.05) POME				ns				ns
LSD (0.05) NPK				ns				ns
LSD (0.05) POME x NPK				ns				ns

ns: not significant.

Analysis of variance was carried out on vegetative, growth and yield data recorded for each year of study, followed by combined analysis over two years. The Least Significant Difference (LSD) test was used for detecting significance differences between means at 5% level of probability. Linear correlations linking variables were also computed in GENSTAT programme, version 8.1(GENSTAT, 2005).

RESULTS AND DISCUSSION

Dry matter partitions

Evaluation of treatment combination on dry matter partitions at 4, 8 and 12 WAT are showed in Tables 3 to 5. Generally, there was no significant difference among the treatments at 4 WAT (Table 3). The lack of response may be as a result of the non-availability of nutrients, which may have been fixed in the soil.

However, at 8 WAT, there was significant difference among the treatments (Table 4) in respects of plant parts and total dry matter yield (biological yield). The total dry matter yield was highest (6.08 t ha^{-1}) from the application of 5 t POME ha^{-1} and 150 kg NPK ha^{-1} amended plots. Dry root yield showed a range of 0.69 t ha^{-1} and 1.54 t ha^{-1} for untreated plots and plots amended with a treatment combination of 5 t POME ha^{-1} and 150 kg NPK ha^{-1}, respectively. There were significant differences among the treatments. The untreated plots had the least in dry stem weight (0.72 t ha^{-1}) while the complimentary of 5 t POME ha^{-1} and 300 kg NPK ha^{-1} had the highest (2.02 t ha^{-1}). The untreated plots had the least in dry leaf weight (1.14 t ha^{-1}) while a complimentary application of 10 t POME ha^{-1} and 150 kg NPK ha^{-1}) had the highest dry leaf matter (2.96 t ha^{-1}) (Table 4).

At 12 WAT, a complimentary use of 5 t POME ha^{-1} and 150 kg NPK ha^{-1} still maintained the highest in dry root yield. Integration of 5 t POME ha^{-1} and 300 kg NPK ha^{-1} had the highest dry stem yield (2.86 t ha^{-1}) and dry leaf yield (3.37 t ha^{-1}) (Table 5). At 12 WAT, the mean values of total dry matter among different treatments were significantly influenced with POME either alone or in combination with NPK during both years of experimental trial. As expected, the control exhibited significantly the lowest total dry matter. The superior significance synergist effect observed with integrated 5 t POME ha^{-1} and 300 kg ha^{-1} and the most superior among all the treatments. The positive effect of POME on dry matter partitions does not collaborate with the reports of Oghoghodo et al. (2003) who observed a reduction in dry matter content in maize grown on soil treated with cassava mill effluent.

Relative yield and relative agronomic effectiveness

The relative yield efficiency among different treatments was significantly influenced compared to the untreated control since all treatment has mean values greater 1.00. The 5 t POME ha^{-1} and 300 kg ha^{-1} treatment combination (2.08 t ha^{-1}) was the most superior in terms

Table 4. Effects of POME and NPK fertilizer on the dry matter partitions of *A .cruentus* at 8 WAT.

POME (t ha^{-1})	Dry root yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})				Dry stem yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})			
	0	**150**	**300**	**Mean**	**0**	**150**	**300**	**Mean**
0	0.69	0.85	0.81	0.78	0.72	1.36	1.21	1.10
5	0.74	1.54	1.32	1.20	1.37	1.54	2.02	1.64
10	0.76	1.37	0.93	1.02	0.98	1.27	1.42	1.22
Mean	0.73	1.25	1.02	1.00	1.02	1.39	1.54	1.32
LSD (0.05) POME				0.286				0.361
LSD (0.05) NPK				0.286				0.484
LSD (0.05) POME x NPK				ns				ns

POME (t ha^{-1})	Dry leaf yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})				Total dry yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})			
	0	**150**	**300**	**Mean**	**0**	**150**	**300**	**Mean**
0	1.14	1.87	2.55	1.85	2.60	4.10	4.53	3.74
5	1.55	1.89	2.90	2.11	3.36	5.14	6.08	4.86
10	1.80	2.96	2.10	2.29	3.54	5.60	4.39	4.53
Mean	1.50	2.24	2.52	2.09	3.17	5.00	5.00	4.39
LSD (0.05) POME				0.735				1.263
LSD (0.05) NPK				0.786				1.263
LSD (0.05) POME x NPK				ns				ns

ns: not significant.

Table 5. Effects of POME and NPK fertilizer on the dry matter partitions of *A. cruentus* at 4 WAT.

POME (t ha^{-1})	Dry root yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})				Dry stem yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})			
	0	**150**	**300**	**Mean**	**0**	**150**	**300**	**Mean**
0	1.56	1.87	1.77	1.73	1.48	2.46	2.36	2.10
5	1.82	2.86	2.54	2.41	2.43	2.57	2.86	2.62
10	1.76	2.82	1.91	2.16	2.18	2.69	2.65	2.51
Mean	1.71	2.52	2.07	1.87	2.03	2.57	2.62	2.41
LSD (0.05) POME				0.613				0.503
LSD (0.05) NPK				0.617				0.531
LSD (0.05) POME x NPK				ns				ns

POME (t ha^{-1})	Dry leaf yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})				Total dry yield (t ha^{-1}) NPK fertilizer (kg ha^{-1})			
	0	**150**	**300**	**Mean**	**0**	**150**	**300**	**Mean**
0	1.91	3.06	3.13	2.70	4.64	7.39	7.26	6.54
5	2.36	2.78	3.37	2.84	6.63	8.20	9.65	8.16
10	1.99	3.26	2.79	2.68	5.93	8.77	7.36	7.35
Mean	2.09	3.03	3.10	2.74	5.84	8.12	8.09	7.35
LSD (0.05) POME				0.241				1.556
LSD (0.05) NPK				0.441				1.556
LSD (0.05) POME x NPK				ns				ns

ns: not significant.

of relative yield (Table 6). However, it was statistically comparable to plots treated with 10 t POME ha^{-1} and

Table 6. Nutrient utilization efficiency of amaranth as influenced by POME and NPK fertilizer application.

POME (t ha^{-1})	Relative yield efficiency				Relative agronomic effectiveness			
	NPK fertilizer (kg ha^{-1})				NPK fertilizer (kg ha^{-1})			
	0	150	300	Mean	0	150	300	Mean
0	1.00	1.59	1.57	1.39	0.00	1.04	1.00	0.68
5	1.43	1.77	2.08	1.76	0.76	1.36	1.91	1.34
10	1.28	1.89	1.59	1.59	0.49	1.58	1.04	1.04
Mean	1.23	1.75	1.74	1.57	0.42	1.33	1.32	1.02
LSD (0.05) POME				0.403				0.641
LSD (0.05) NPK				0.403				0.641
LSD (0.05) POME x NPK				ns				ns

ns: not significant.

Table 7. Chlorophyll content of amaranth as influenced by POME and NPK fertilizer application.

POME (t ha^{-1})	Chlorophyll a (mg g^{-1})				Chlorophyll b (mg g^{-1})			
	NPK fertilizer (kg ha^{-1})				NPK fertilizer (kg ha^{-1})			
	0	150	300	Mean	0	150	300	Mean
0	24.70	24.90	30.40	26.70	6.50	7.70	9.20	7.50
5	41.60	42.50	44.70	42.90	13.60	16.10	20.90	16.90
10	60.00	51.60	52.70	54.80	26.90	25.50	25.70	26.00
Mean	42.10	37.70	42.60	41.50	15.30	16.40	18.60	16.80
LSD (0.05) POME				10.345				10.674
LSD (0.05) NPK				10.378				9.875
LSD (0.05) POME x NPK				27.021				ns

POME (t ha^{-1})	Total Chlorophyll b (mg g^{-1})			
	NPK fertilizer (kg ha^{-1})			
	0	150	300	Mean
0	19.30	30.90	40.50	42.90
5	57.30	57.70	58.30	59.80
10	67.20	63.40	59.30	62.00
Mean	47.90	50.70	52.70	54.90
LSD (0.05) POME				20.258
LSD (0.05) NPK				10.654
LSD (0.05) POME x NPK				25.259

ns: not significant.

150 kg ha^{-1} and 5 t POME and 150 kg NPK ha^{-1}(1.36 t ha^{-1}) (Table 6). Relative yield efficiency tended to be higher with sole NPK fertilizer application than with sole POME application. The higher yield obtained in NPK amended plots could be attributed to the quick release of nutrients from NPK fertilizer to the soil and uptake by the crops. Improved relative yield efficiency obtained in POME amended plots might be due to its cumulative effect of nutrients released by the effluent to the soil. This observation implies the integration of POME and NPK fertilizer which provides additional benefits than sole use of POME or NPK.

Relative agronomic effectiveness for 5 t POME ha^{-1} and 150 kg NPK ha^{-1} was more superior compared to other treatments. However, it was at par with a complimentary use of 5 t POME ha^{-1} and 150 kg NPK ha^{-1}. Sole application of POME and NPK were better than control. The relative agronomic effectiveness showed statistical differences between control and other treatments.

Chlorophyll content

The mean chlorophyll content increased with increase in POME and NPK application rate up to the highest level (Table 7). The mean value of total chlorophyll obtained from plots amended with sole 10 t POME ha^{-1} was statistically comparable with other treatments which were significantly difference from untreated control. The consistency in chlorophyll content among the treatments indicates that the effluent is effective in promoting germination, growth, and chlorophyll and protein control. This observation collaborated with the views of Orhue et al. (2005) who reported that chlorophyll content of maize plant was positively enhanced by brewery effluent.

Conclusion

Total dry matter, relative yield, relative agronomic effectiveness and chlorophyll content indicated that the addition of POME and NPK fertilizer had significant influence than the control. Integration of 5 t POME ha^{-1} and 150 kg NPK ha^{-1} has been confirmed in this study to be the optimum treatment combination as alternative to sole use of inorganic fertilizer.

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