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Effect of poultry manure treated and untreated with effective microorganisms on growth performance and insect pest infestation on *Amaranthus hybridus*

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Poor soil fertility is a major cause of low yield of amaranth in Nigeria. Optimum productivity of the vegetable is also constrained by insect pests that cause reduction in yield and quality. Incorporation of effective microorganisms (EM) into organic matter is capable of positively influencing decomposition and mineralization. The present study assessed the effects of poultry manure treated and untreated with effective microorganisms on growth performance, yield and insect pest infestation on *Amaranthus hybridus*. The experimental design used was a randomized complete block design (RCBD) with 3 replications. The treatments consist of poultry manure treated with effective microorganism activated solution (PM + EMAS), poultry manure only (PM), and the control (C). Data were collected on shoot height, stem girth, number of leaves per plant, leaf area, total fresh leaf weight and mean pest number. The results from this study shows that incorporation of effective microorganisms into poultry manure significantly increased shoot height, stem diameter, leaf number, leaf area and fresh leaf weight. A significantly (P< 0.05) higher fresh weight (36.85 kg) of *A. hybridus* was obtained in plots treated with PM+EMAS. This was followed by plots treated with PM only (25.08 kg). The control had a significantly least fresh weight of 14.21 kg. Six insect species from 4 orders and 5 families were encountered on *A. hybridus* during the study period. They include *Zonocerus variegatus*, *Podagrica* spp., *Hymenia recurvalis, Nezara viridula*, *Psara bipunctalis* and *Sylepta derogata*. *Hymenia recurvalis* was the most prevalent pest recorded in the control plot (16.4). Generally, fewer number of pest species were observed in plots treated with PM+EMAS. The use of effective microorganisms in organic farming is a viable tool for curbing the menace arising from the use of synthetic fertilizers and pesticides.

Key words: *Amaranthus hybridus*, poultry manure, effective microorganisms, growth parameters, yield, pest infestation.

INTRODUCTION

Red amaranth (*Amaranthus hybridus*) is one of the cheapest and widely cultivated leafy vegetables in

Nigeria. Amaranth leaves are rich in calcium, phosphorus, folic acid, potassium, iron and vitamins A, B and C (AVRDC, 2003; Okpara et al., 2013; Oyedeji et al., 2014).

Nigeria ranks as the largest producer and consumer of*Amaranthus* spp. in Africa (Raemaekers, 2001). The world average yield of amaranth is estimated at 14.27 t ha^{-1} (FAO, 2007). The yield per hectare in Nigeria is low (7.60 t ha^{-1}) compared to what obtains in the United States (77.27 t ha^{-1}). Low soil fertility is a major cause of low yield of amaranth in Nigeria (Fasina et al., 2015; Shehu et al., 2015). Optimum productivity of the vegetable is also constrained by several insect pests that cause reduction in yield and quality (Aderolu et al., 2013).Insect pest infestation alone has been reported to account for 20 to 60% pre-harvest losses in vegetables in the developing countries (Sithanntham et al., 2003).

Most tropical soils exhibit rapid depletion of organic matter which causes an increase in the use of synthetic fertilizers that poses serious threat to soil and human health (Okito et al., 2004). To obtain high yield of amaranth, there is a great need to augment the nutrient status of the soil to meet the crop need (Dauda et al., 2005a). One of the ways of increasing the fertility of the soil is by boosting its nutrient content with organic matter such as poultry manure.

Poultry manure contains more plant nutrients than all other organic manures (Ali, 2005). Owing to its high organic matter content combined with available nutrients needed for improving plant growth, it is widely utilized as an excellent soil amendment. The manure is cheap and readily available. Decomposed poultry manure stimulates microbial activities which contribute to soil fertility restoration (Rahman, 2004).

Incorporation of effective microorganisms (EM) into organic matter is capable of positively influencing decomposition and mineralization. Effective microorganisms consist of mixed cultures of beneficial and naturally occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soil and plant (Muthaura et al., 2010). Research has shown that the inoculation of EM cultures to the soil plant ecosystem can improve soil quality, soil health and the growth, yield and quality of the crops (Kengo and Hui-lian, 2000). This ultimately leads to increase in the microbial diversity and activity in soils and plants (Zimmermann and Kamukuenjandje, 2008). Inoculation of EM cultures to the soil and plant ecosystem can improve soil quality and the growth, yield, and quality of crops. More importantly, EM helps to enhance crop quality and health to resist pest attack by improving their strength to withstand infestation. The present study therefore assessed the effect of poultry manure treated and untreated with effective microorganisms on growth performance, yield and insect pest infestation on *A. hybridus*.

MATERIALS AND METHODS

Study site

The research work was carried out at the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara State, Nigeria. The site lies between latitude 8°8' N and longitude 5°6' E of the equator. Annual rainfall ranges between 600 and 1500 mm with a distinct dry season from December to March (Ilorin Meteorological Bulletin, 2003). The mean annual temperature varies between 28 and 34°C.

Experimental design and treatment application

The land was cleared, ploughed and harrowed following which vegetable beds were prepared. A total land area of 40 m^2 was partitioned into nine plots, with each plot (vegetable bed) measuring 1 m × 3 m. Each plot was demarcated into three rows and separated from the adjacent bed by 0.5 m alley.

Fresh poultry manure (PM) collected from the Poultry Section of Landmark University Teaching and Research Farm was cured by allowing it to decompose for four weeks. It was thoroughly incorporated into three randomly selected vegetable beds at the rate of 30 $kgha^{-1}$ two weeks before planting and watered regularly to enhance mineralization.

Effective microorganism activated solution (EMAS) procured from Songhai Centre, Porto-Novo, Benin Republic was mixed with the decomposed poultry manure at the recommended rate of 5 ml per 2 kg of PM. This was applied at 30 kg ha^{-1} into three randomly selected beds two weeks before planting. The beds were watered regularly to enhance the mineralization of the poultry manure and the EMAS.

Seeds of *A. hybridus* obtained from the Teaching and Research Farm of Landmark University, Omu-Aran were drilled into the top-soil at a depth of 1 cm in each treatment. The experiment was laid out in a randomized complete block design (RCBD) with 3 replications. The treatments consist of PM treated with effective microorganism activated solution (PM + EMAS) andPM only. A control treatment without addition of PM or EMAS was also set up. Irrigation was carried out twice daily; morning and evening.

Data collection on growth parameters commenced two weeks after planting and was carried out at every 5 days. Ten plants were selected randomly from each row for data on shoot height, stem girth, number of leaves per plant and leaf area. Yield assessment was based on total fresh leaf weight at six weeks after planting. Shoot height was measured using a meter rule while stem diameter was determined with a vernier caliper. Leaf area expansion was determined according to Jose et al. (2000), using the formula:

$$A_L = 0.73\ (L_L \times W_L)$$

Where, A_L = leaf area, L_L = leaf length and W_L = maximum width

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Table 1. Effect of different treatments (poultry manure, PM; poultry manure with effective microorganism activated solution, PM+EMAS; and control, C) on the shoot height (cm) of *Amaranthus hybridus* at different number of days after planting (DAP).

Treatment	15 DAP	20 DAP	25 DAP	30 DAP	35 DAP
PM	8.26[b]	10.96[b]	17.45[b]	21.17[b]	23.68[b]
PM +EMAS	10.53[a]	13.83[a]	25.57[a]	35.02[a]	39.27[a]
C	7.27[c]	8.13[c]	11.28[c]	15.63[c]	17.23[c]

Values followed by the same letter within the same column are not significantly different (p ≤ 0.05).

Table 2. Effect of different treatments (poultry manure, PM; poultry manure with effective microorganism activated solution, PM+EMAS; and control, C) on the number of leaves of *A. hybridus* at different number of days after planting (DAP).

Treatment	15 DAP	20 DAP	25 DAP	30 DAP	35 DAP
PM	5.79[a]	7.48[b]	10.10[b]	13.70[b]	16.49[b]
PM +EMAS	6.35[a]	9.80[a]	13.64[a]	17.30[a]	22.37[a]
C	3.69[c]	4.63[c]	6.49[c]	8.64[c]	10.80[c]

Values followed by the same letter within the same column are not significantly different (p ≤ 0.05).

measured for all leaves on each plant

Insect collection was carried out very early in the morning and late in the evening. The upper and lower leaf surfaces of the vegetable in each treatment were carefully examined for insects and were collected by hand (insects on the plant surface) or with a sweep net (flying insects). They were put into vials, labeled according to the treatment in which they were found and taken to Landmark University Laboratory, where they were classified, counted and recorded according to treatment.

Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) and means separated using Duncan's multiple range test (DMRT) at 5% probability level.

RESULTS

Shoot height

The effects of PM and PM+EMAS treatments on shoot height of *A. hybridus* are shown in Table 1. At fifteen days after planting (DAP), plants in plots treated with PM + EMAS had a significantly (P ≤ 0.05) higher mean shoot height (10.53 cm), followed by PM plants (8.26 cm). Height of C-plants was significantly lower (7.27 cm). Similar trends of result were also recorded at 20, 25, 30 and 35 DAP.

Number of leaves per plant

At 15 DAP, there was no significant difference in the number of leaves produced by the vegetable in PM and PM+EMAS plots, although numerically higher values were recorded in the latter (Table 2). The control had significantly (P ≤ 0.05) lower number of leaves (3.69) among the treatments at 15 DAP. At 20, 25, 30 and 35 DAP, significantly higher numbers of leaves were recorded in PM + EMAS plots, followed by PM only. Significantly lowest leaf numbers were observed in C-plots.

Stem diameter

The effect of PM and PM+EMAS treatments on stem girth of *A. hybridus* is shown in Table 3. At 15 DAP, a significantly (P ≤ 0.05) higher stem girth (0.94 cm) was recorded in plots treated with PM + EMAS. This was followed by a stem diameter of 0.67 cm observed in PM plots while significantly least stem girth (0.43 cm) was observed in the control plot. Similar trend of result was also observed at 20, 25, 30 and 35 DAP.

Leaf area

At 15 days DAP, plants in plots treated with PM + EMAS had a significantly (P ≤ 0.05) higher leaf area (21.56 cm^2), followed by plants in plots treated with PM only (18.31 cm^2). The control had a significantly least leaf area (13.47 cm^2). Similar trends of result were also recorded at 20, 25, 30, and 35 DAP.

Table 3. Effect of different treatments (poultry manure, PM; poultry manure with effective microorganism activated solution, PM+EMAS; and control, C) on the stem girth (cm) of *A. hybridus* at different number of days after planting (DAP).

Treatment	15 DAP	20 DAP	25 DAP	30 DAP	35 DAP
PM	0.67[b]	0.96[b]	1.37[b]	1. 75[b]	2.03[b]
PM +EMAS	0.94[a]	1.17[a]	2.03[a]	2.61[a]	2.92[a]
C	0.43[c]	0.57[c]	0.82[b]	0.89[c]	1.75[c]

Values followed by the same letter within the same column are not significantly different ($p \leq 0.05$).

Table 4. Effect of different treatments (poultry manure, PM; poultry manure with effective microorganism activated solution, PM+EMAS; and control, C) on the leaf area (cm^2) of *A. hybridus* at different number of days after planting (DAP).

Treatment	15 DAP	20 DAP	25 DAP	30 DAP	35 DAP
PM	18.31[b]	20.76[b]	24.53[b]	36.86[b]	44.32[b]
PM +EMAS	21.56[a]	27.40[a]	32.92[a]	48.36[a]	57.06[a]
C	13.47[c]	15.18[c]	16.77[c]	20.34[c]	25.72[c]

Values followed by the same letter within the same column are not significantly different ($p \leq 0.05$).

Table 5. Effect of different treatments (poultry manure, PM; poultry manure with effective microorganism activated solution, PM+EMAS; and control, C) on the total fresh weight (kg) of *A. hybridus* at different number of days after planting (DAP).

Treatment	Mean fresh weight (kg)
PM	25.08
PM+EMAS	36.24
C	14.21

Values followed by the same letter within the same column are not significantly different ($p \leq 0.05$).

Fresh leaf weight

The effect of PM and PM+EMAS treatments on the total leaf fresh weight of *A. hybridus* is shown in Table 4. A significantly ($P \leq 0.05$) higher fresh weight (36.85 kg) of *A. hybridus* was obtained in plots treated with PM + EMAS. This was followed by plots treated with PM only (25.08 kg). The control had a significantly least fresh weight of 14.21 kg (Table 5).

Insect pest infestation

A total of 6 insect species from 4 orders and 5 families were encountered on *A. hybridus* during the study period (Table 6). They include *Z. variegatus*, *Podagrica* spp., *H. recurvalis, N. viridula*, *Psarabipunctalis* and *S. derogata*. *H. recurvalis* was the most prevalent pest recorded in the control plot (16.4). Generally, fewer number of pest species were observed in plots treated with PM + EMAS.

DISCUSSION

The results from this study show that incorporation of effective microorganisms into poultry manure significantly increased shoot height, stem diameter, leaf number, leaf area and fresh leaf weight. Increase in number of leaves in plants provided with adequate nutrition is a common occurrence in plants and can be attributed to increase in the photosynthetic activity of the plants (Muthaura et al., 2010).

The higher number of leaves, shoot height, leaf area, increased yield as well as reduced pest infestation on *A. hybridus* treated with EM recorded in this trial is in consonance with the findings of Reddy and Giller (2008) that reported successful control of sucking insects on legumes and cucurbits with EM preparation as well as improved growth in the leaves and stems of crops sprayed with different EM preparations, leading to yield increases of 15%.

Soil health is the key to producing good yield of crops. Vegetable crops have high nutrient requirement and application of nitrogen, a major component of poultry manure improves the yield of amaranth (Rahman, 2004). Research has shown that applying EM to the soil and plant ecosystem improves soil quality, soil health, and the growth, yield, and quality of crops. Application of EM to organic matter helps to improve biological activity through effective organic matter recycling. The organic matter recycled builds humus, the food for soil and plants. This

Table 6. Effect of different treatments (poultry manure, PM; poultry manure with effective microorganism activated solution, PM+EMAS; and control, C) on the mean pest number on *A. hybridus*.

Treatment	Common name	Order	Family	Scientific name	Mean number
PM					4.2
EMAS + PM	Grasshopper	Orthoptera	Acrididae	*Zonocerus variegatus*	1.8
Control					8.3
PM					7.8
EMAS + PM	Flea beetles	Colepotera	Chrysomelidae	*Podagrica*spp.	1.3
Control					6.5
PM					4.8
EMAS + PM	*Amaranthus* caterpillar	Lepidoptera	Crambidae	*Hymenia recurvalis*	0.7
Control					16.4
PM					1.8
EMAS + PM	Green vegetable bug	Heteroptera	Pentatomidae	*Nezaraviridula*	0.7
Control					4.6
PM					1.5
EMAS + PM	Leaf webber	Lepidoptera	Pyralidae	*Psarabipunctalis*	0.3
Control					4.1
PM					0.7
EMAS + PM	Cotton leaf roller	Lepidoptera	Pyralidae	*Syleptaderogata*	-
Control					3.3

process ultimately enhances nitrogen fixation, improves mycorrhizal activity, and hence, leads to more effective nutrient availability.

When effective combination of microorganisms makes contact with organic materials such as poultry manure, beneficial substances like vitamins, organic acids, minerals and anti-oxidants are secreted (Muthaura et al., 2010). As such, there is transformation in the micro-flora and macro-flora, leading to improvement in restoration of the natural health of the soil. This helps to improve plant growth.

In the present study, seedling emergence commenced three days after sowing in soils treated with EMAS + PM, while germination was observed after five days in the control plots. EM contains many micro-organisms, mainly lactic acid bacteria, yeast and phototrophic bacteria that speed up the decomposition of organic matter to promote germination (Reddy and Giller, 2008). Therefore, the early germination observed could be attributed to the presence of EM.

Vegetable crops are highly susceptible to pests and diseases during the growing phase. Incorporation of EM to organic matter performs two major functions. Firstly, it creates better growing conditions that leads to a stronger and healthier plant. Secondly, it inoculates leaf surfaces with beneficial microbes, thereby excluding pests and pathogens that compete with crops for space. EM acts as an insect repellant by creating a barrier around the plant, thereby protecting it from insect pest attack (Higa, 1998). Pests are suppressed or controlled through natural processes that enhance the competitive and antagonistic activities of the microorganisms in the EMAS.

Conclusion

The declining soil fertility, increased soil erosion and increasing food shortage are major factors affecting human health in Africa. Fertilizers are costly and beyond the reach of most resource poor farmers. The use of synthetic agrochemicals and fertilizers has caused adverse effects on human health and the environment. This observation has promoted the need to introduce novel farming methods capable of reducing health risks. The use of effective microorganisms in organic farming is a viable tool for curbing the menace arising from the use of synthetic fertilizers and pesticides.

Conflict of Interests

The authors have not declared any conflict of interest.

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