GROWTH PERFORMANCE, YIELD AND NUTRITIONAL QUALITY OF *AMARANTHUS CRUENTUS* L. UNDER REPEATED APPLICATIONS OF POULTRY MANURES

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ABSTRACT

This study investigated the growth performance, yield and nutritional quality of *Amaranthus cruentus* with a view to determining the changes that take place in the proximate composition of the test crop under repeated applications of different poultry composts in pot culture. A factorial combination of four treatments, namely; 100 % Broilers' Manure Compost (BMC), 100 % Layers' Manure Compost (LMC), 100 % Cockerel Manure Compost (CMC) and 33.33 % BMC + 33.33 % LMC + 33.33 % CMC otherwise referred to as Mixed Manure Compost (MMC) were applied at four levels each and replicated three times. The levels of application were (t ha^{-1}): 9.0, 6.0, 3.0 and 0, which served as the control. The results showed that the growth parameters; such as plant height, stem girth, number of leaves and leaf area of plants increased with increase in compost applications. The highest leafy productivity (leaf + shoot) mean yield of 24.19 t ha^{-1} was significantly ($p < 0.05$) different from 9.73 t ha^{-1} obtained with 9 t ha^{-1} of CMC during the two consecutive cropping. The control treatment gave the significantly ($p < 0.05$) highest values of crude fiber (16.78%), total ash (13.08%) and vitamin C (5.75%) when compared with other treatments. Comparable but lower values were obtained during the second cropping. Despite increased soil fertility brought about by repeated application of poultry manures to soil, reduced leafy productivity and quality of *A. cruentus* obtained may be attributed to ecotoxicological effect of the compost on the soil.

Keywords: *Amaranthus cruentus*, Compost, Nutritional Quality, Organic Waste, Plant Health, Poultry Droppings.

INTRODUCTION

Amaranthus cruentus L. commonly known as Amaranth belongs to the family Amaranthaceae. It is a leafy vegetable commonly cultivated in Nigeria and other West African countries (Olorode, 1984). It has a growing period of 5 to 6 weeks thus making it an advantage for the rural and peri-urban farmers in Nigeria to keep cultivating it two or more times on the same piece of land in a year (Adewole and Igberaese, 2011). Till now, the bulk of vegetables consumed in Nigeria are supplied by subsistence farmers. Apart from *A. cruentus* uses as a vegetable, its grains can also be cooked as a cereal, popped like popcorn, toasted or even ground into flour for baking (Railey, 1999). Vegetable supply to areas of high demand has remained low and seasonal as most of the subsistence farmers continue to rely on natural rainfall.

The current high demand for vegetables in the cities and towns has stimulated the growth of market gardening along perennial rivers and streams in major towns and cities in Nigeria. Some farmers rely on irrigation water from streams, wells and boreholes to cultivate vegetables all year round. Organic production of vegetables have become good source of employment for young school leavers and are also preferred in quality to conventional ones (Dipeolu *et al*., 2009).

Some of the problems encountered by amaranth growers in Nigeria are the low soil fertility and lack of capital to buy chemical fertilizers for optimum crop productivity (Olufolaji *et al.,* 1990; Adeyemi *et al*.**,** 1987). Most African soils are inherently low in organic carbon, slightly acidic and relatively sandy. Studies by Ayoola and Adeniyan (2006) revealed that the use of inorganic fertilizers has not been helpful in agriculture. Adeoye *et al*. (2005) had advocated the use of properly amended organic manures to the resource-poor-farmers for the cultivation of *A. caudatus,* another popular amaranth leafy vegetable in Nigeria.

The production and consumption of poultry products will continue to increase relative to the world's growing human population for improved life quality (Williams *et al*., 1999; Zhang *et al*., 2007). Consequently, environmental impacts of waste by-products of poultry industries are of increasing importance worldwide and the disposal of these wastes is a major environmental problem related to intensive livestock production. The use of animal residues such as poultry manure for the growth and yield of vegetable and other crops had been advocated to compensate for the export of soil nutrients because of their low cost and availability (Moyin-Jesu, 2002).

Zublena *et al.* (1990) earlier observed that poultry manure in crop husbandry must be done with sound soil fertility management practices to prevent soil nutrient imbalance and associated animal and human health risks, as well as surface-water and groundwater contamination. Therefore, addition of poultry manures to soil for enhanced fertility must be done with caution. But, the poultry manure quantity and quality depends on the type of bird and quality of feeds (Snijders and Wouters, 2003). Also, the production stage and type of the bird determine the feed rations. For example, Cheeke (1991) gave a starter diet of 24% protein, grower diet of 20% protein, and finisher diet of 18% protein; while layer diets was 16% protein.

Agro-industrial wastes such as poultry manures; if converted to organic fertilizers could minimize the environmental hazard they may pose (Ayeni, 2010). Presently in Nigeria, vegetable farmers always have heaps of poultry droppings around them that they need not pay money for their collection and usage. This free access is therefore being abused. The repeated use of poultry manures as bio-fertilizers on the same piece of land, irrespective of the type and quality of the droppings for the cultivation of *A. cruentus* is on the increase. Currently, there is a dearth of information on the growth performance, yield and nutritional quality of *A. cruentus* after repeated application of different type of poultry manures to soil. This study, therefore, sought to assess the agronomy and proximate composition of A. cruentus under repeated application of different composted poultry manures.

MATERIALS AND METHODS

The experiment was conducted in the screenhouse of the Faculty of Agriculture, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. The seeds of *A. cruentus* were obtained from the National Horticultural Research Institute, Ibadan, Nigeria. The broilers' and layers' droppings were obtained from the Teaching and Research Farm, OAU, Ile-Ife while the cockerels' droppings were obtained from a private farm in Ile-Ife and thereafter, composted. Each of the poultry manure was allowed to decompose aerobically in windrows for 60 days, ground, sieved and bagged. The pot experiment was a factorial combination of four treatments, namely; 100 % Broilers' Manure Compost (BMC), 100 % Layers' Manure Compost (LMC), 100 % Cockerel Manure Compost (CMC) and 33.33 % BMC + 33.33 % LMC + 33.33 % CMC otherwise referred to as Mixed Manure Compost (MMC). Each manure treatment was applied at four levels and replicated three times. The levels of application were (t ha^{-1}): 9.0, 6.0, 3.0 and 0, which served as the control. Two weeks after the application of the composted poultry manures into the 3 kg of exhaustively cropped soil in each pot, five seeds of *A. cruentus* per pot were planted into 48 pots.

The *A. cruentus* stands were regularly wetted with distilled water during the growing period. The plants were thinned to three stands per pot at two weeks after sowing. The growth parameters of *A. cruentus* such as plant height, number of leaves, stem girth and leaf area were measured weekly till 5 weeks after planting (WAP). Total harvesting of *A. cruentus* was carried out by uprooting at 6 WAP and a repeat experiment was carried out on the same soil in the pots. The pre-soil used for pot experiments was analyzed for physico-chemical characteristics. The shoots of *A. cruentus* were oven-dried at 70 °C for 48 hours for proximate analyses.

Soil Sampling, Sample Preparation and Analysis

Surface soil sample was collected from an exhausted crop land; air dried for 7 days, and sieved using a 2 mm mesh sieve to remove debris and stones. Soil pH was potentiometrically determined in 1:1 soil-water ratio (Mclean, 1982). Soil organic carbon was determined using Walkey-Black method (Nelson and Sommers, 1982). Total nitrogen of the soil was determined by the macro-Kjeldahl method of Bremner and Mulvaney (1982). Available phosphorus in the soil was determined using Bray P1 method (Olsen and Sommers, 1982).

The exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were determined using 1 M Ammonium acetate buffered at pH 7.0 as extractant (Thomas, 1982). Ca^{2+} and Mg^{2+} concentrations in soil extracts were read using Buck Scientific 210/211 VGP (East Norwalk, Connecticut, USA) Atomic Absorption Spectrophotometer (AAS) while Na^{+} and K^{+} concentrations were read on Gallenkamp flame photometer. The exchangeable acidity (H^{+} + Al^{3+}) in the soil was extracted with 1 M KCl using Thomas (1982) and the extract titrated with

0.05 M NaOH using phenolphthalein as indicator (Odu *et al.*, 1986).

Poultry manure analysis

The total nitrogen present in the composted poultry manures were determined by the macro-Kjeldahl method (Bremner and Mulvaney, 1982) while the available phosphorus was determined using Bray P1 method (Olsen and Sommers, 1982). After digestion with 1 M ammonium acetate, the concentration of potassium was determined by reading with the flame photometer. Calcium ions and Mg^{2+} in compost extracts were read using AAS. The results of the pre-planting of the soil analysis and composted poultry manures used are presented in Table 1.

Proximate analysis

The shoots of *A. cruentus* were collected per treatment pot using clean knife from all the replicates and weighed. The plant shoots were rinsed with distilled water, oven-dried at 70°C for 48 hours and ground using the Thomas stainless-steel milling machine. Nutritional contents of *A. cruentus* (crude protein, fat, carbohydrate and vitamin C) as well as crude fiber, total ash and moisture contents were determined (AOAC, 1990).

Statistical Analysis

The data obtained were subjected to descriptive and one-way analyses of variance to test for their treatment effect. Test of significance for differences in means was statistically compared using Duncan's multiple range tests at 5% level of probability.

Table 1: Properties of the soil and composted poultry manures used during the experiments

Property	Soil	BMC	LMC	CMC	MMC
Soil pH (1:1 soil-water)	6.60	Nd	Nd	Nd	Nd
Organic carbon (g kg^{-1})	12.58	Nd	Nd	Nd	Nd
Total nitrogen (g kg^{-1})	0.73	0.31	0.29	0.39	0.36
Available P (g kg^{-1})	3.67	0.44	0.33	0.31	0.37
Exchangeable acidity (cmol kg^{-1})	0.50	Nd	Nd	Nd	Nd
K (cmol kg^{-1})	0.30	2.17	1.22	0.92	0.83
Ca (cmol kg^{-1})	0.64	1.85	3.37	1.85	2.98
Mg (cmol kg^{-1})	0.90	0.65	1.39	0.39	0.85
Na (cmol kg^{-1})	0.42	Nd	Nd	Nd	Nd
Zn (mg kg^{-1})	Nd	0.03	0.03	0.03	0.03
CEC (cmol kg^{-1})	2.26	Nd	Nd	Nd	Nd

Legend:
BMC = Broilers' Manure Compost
LMC = Layers' Manure Compost
CMC = Cockerel Manure Compost
MMC = Mixed Manure Compost
Nd = Not determined

RESULTS AND DISCUSSION

Vegetative growth characteristics

Plant height of A. cruentus

The effects of different poultry manures at different levels on the mean plant heights of *A. cruentus* measured at weekly intervals are represented in Figure 1(a-h). Significant difference ($p < 0.05$) was observed among different poultry manures fertilization and at different rates from the 3rd WAP during the first cropping. However, the observed plant heights were lower from the 2nd WAP during the second cropping.

The residual effect of previous poultry manures applied in the 1st cropping with the 2nd cropping manure application may have caused early response of the test crop. The positive performance of poultry manure on the growth response of *A. cruentus* may be due to the balanced nutrients the manure contained (Okokoh and Bisong, 2011). The mean plant height was directly related to the quantity of poultry manure fertilization. Makinde *et al.* (2010) earlier obtained

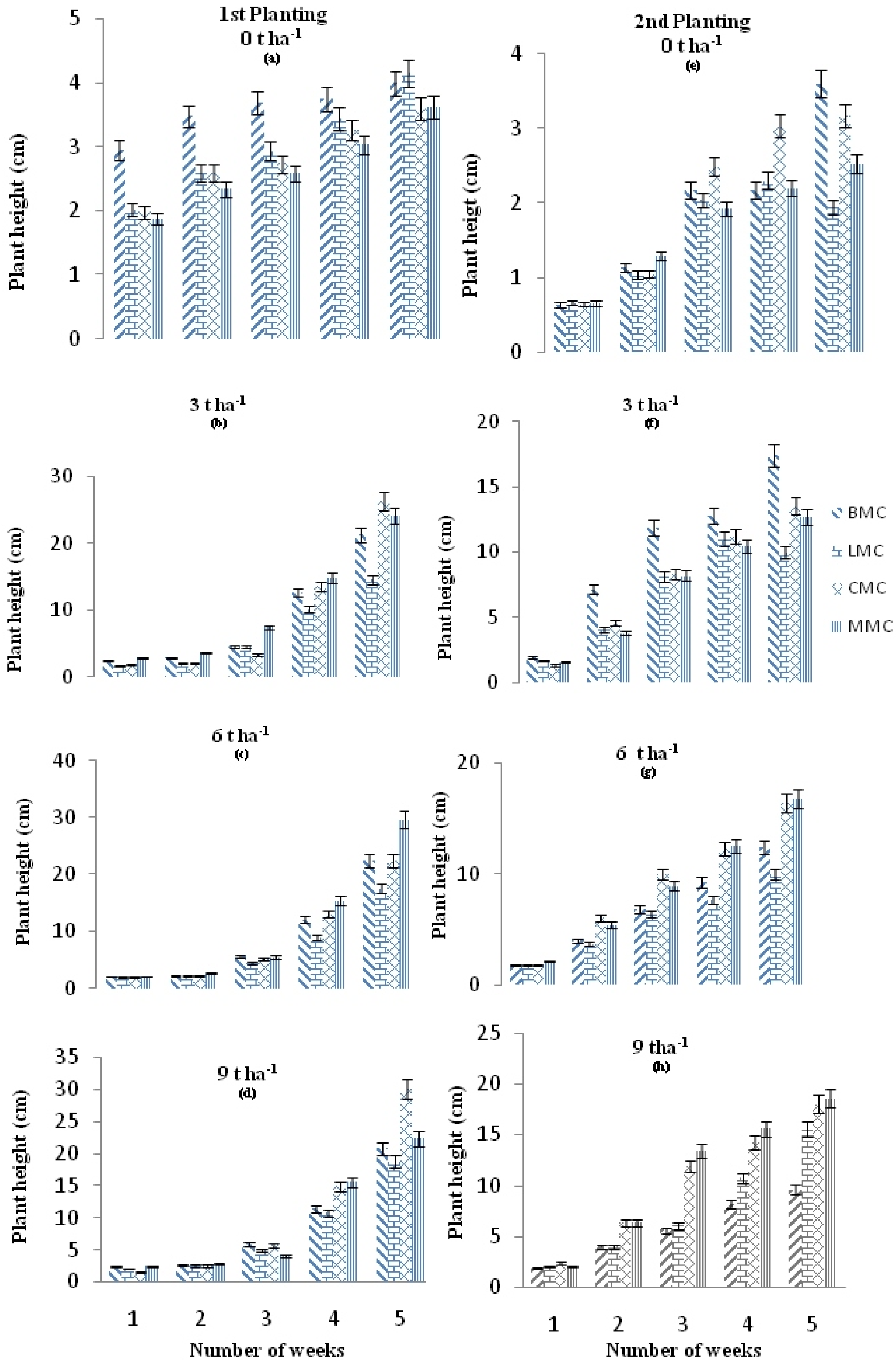

Figure 1: Mean Plant Height of *Amaranthus cruentus* under Different Poultry Composts. Vertical bars represent the SE. **Legend:** BMC = Broilers' Manure Compost, LMC = Layers' Manure Compost, CMC = Cockerel Manure Compost, MMC = Mixed Manure Compost.

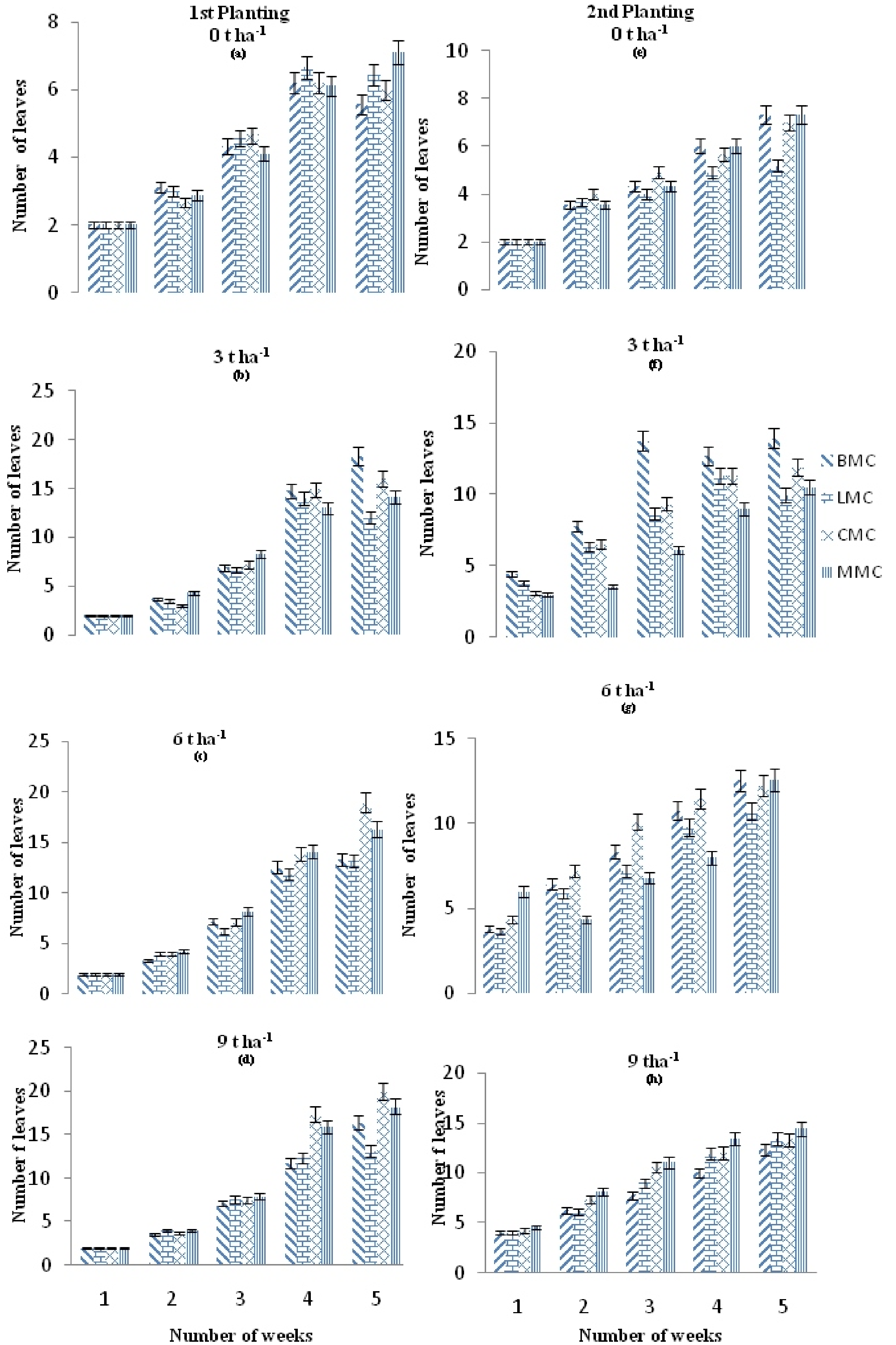

Figure 2: Mean number of leaves of *Amaranthus cruentus* under different poultry composts. Vertical bars represent the SE.. **Legend:** BMC = Broilers' Manure Compost, LMC = Layers' Manure Compost, CMC = Cockerel Manure Compost, MMC = Mixed Manure Compost

similar increase in plant height of *A. cruentus*, though with increased organomineral fertilizer applications in *Orthic luvisol* and *Dystric fluvisol* soils.

Stem girth of A. cruentus

The effects of different poultry manures at different levels on the mean stem girth of *A. cruentus* measured at weekly intervals are represented in Figure 2(a-h). Stem girth measurement was carried out from the 3rd WAP to prevent damage to the stems at the tender stage. Cockerel Manure Compost gave significant highest values in all the treatment rates during the first cropping and also at 3 t ha^{-1} during the second cropping. Okokoh and Bisong (2011) however, obtained highest stem girth value of *A. cruentus* when combination of 15 tonnes of poultry manure and 30 kg Urea-N ha^{-1} was applied to soil *in-situ*.

Number of Leaves of A. cruentus

The effects of different poultry manures at different levels on the mean number of leaves of *A. cruentus* measured at weekly intervals are represented in Figure 3(a-h). Significant difference ($p < 0.05$) was observed among different poultry manures fertilization and at different rates from the 4th WAP during the first cropping. Makinde (2007) obtained similar trend in the number of leaves of *A. cruentus* when 100% agro-waste and combination of agro-waste with NPK fertilizers were compared. However, from the 1st WAP during the second cropping, the number of leaves of *A. cruentus* was lower when compared with first cropping. The residual effect of previous poultry manures applied in the 1st cropping with the 2nd cropping manure application may have caused early response of the test crop. CMC gave significant highest values in all the treatment rates during the first cropping while it was MMC during the second cropping.

Leaf area of A. cruentus

The effects of different poultry manures at different levels on the mean leaf area of *A. cruentus* measured at weekly intervals are represented in Figure 4(a-h). Leaf area measurement was carried out from the 3rd WAP as no appreciable difference was noticed before this time. Significant difference ($p < 0.05$) was observed among different poultry manures fertilization and at different rates from the 4th WAP during the first cropping. However, reduced leaf area of *A. cruentus* was obtained from the 3rd WAP during the second cropping. The previous work of Richert and Salomon (1998) gave similar increased leaf area of lettuce and cabbage crops when broiler poultry manure was used as the bio-fertilizer. Cockerel Manure Compost gave significant highest values in all the treatment rates during the first cropping while highest leaf area values obtained with Mixed Manure Compost application during the second cropping were still much lower when the corresponding treatment rates were compared. Increase in organic-N brought about by manure applications may be attributed to the leaf area increase.

Yield of *A. cruentus*

Mean fresh yield and reduction factor of *A. cruentus* under different poultry composts are presented in Table 2. The results showed that the higher the quantity of manure applied, the higher was the total biomass produced per pot. The highest mean yield of 24.19 t ha^{-1} obtained with CMC was significantly ($p < 0.05$) higher than 18.29 t ha^{-1} obtained with MMC at 9 t ha^{-1}. Layers' Manure Compost gave the least mean yield. As the levels of poultry manure added to the soil increased, increased plant nutrients in their available forms may have accounted for yield increase. Oworu *et al.* (2010) and Okokoh and Bisong (2011) gave similar results of increased leafy productivity of grain amaranth when the combination of poultry manure and urea-N fertilization was compared with conventional fertilizer application.

The results of poultry manure composts analyzed were rich in N, P, K, Ca and Mg (Table 1). The significant positive response observed on the yield performance of *A. cruentus* could be attributable to higher values of nitrogen in CMC and MMC. Comparable results, though at low magnitude were obtained during the 2nd cropping. Soil nutrients antagonism and soil ecotoxicological effect arising from indiscriminate fertilizer use as suggested by Adewole and Adeoye (2008) could cause this low yield. The order of increase was: CMC > MMC > BMC > LMC for the treatment rates during the 1st cropping, while no specific order was obtained with the repeated application.

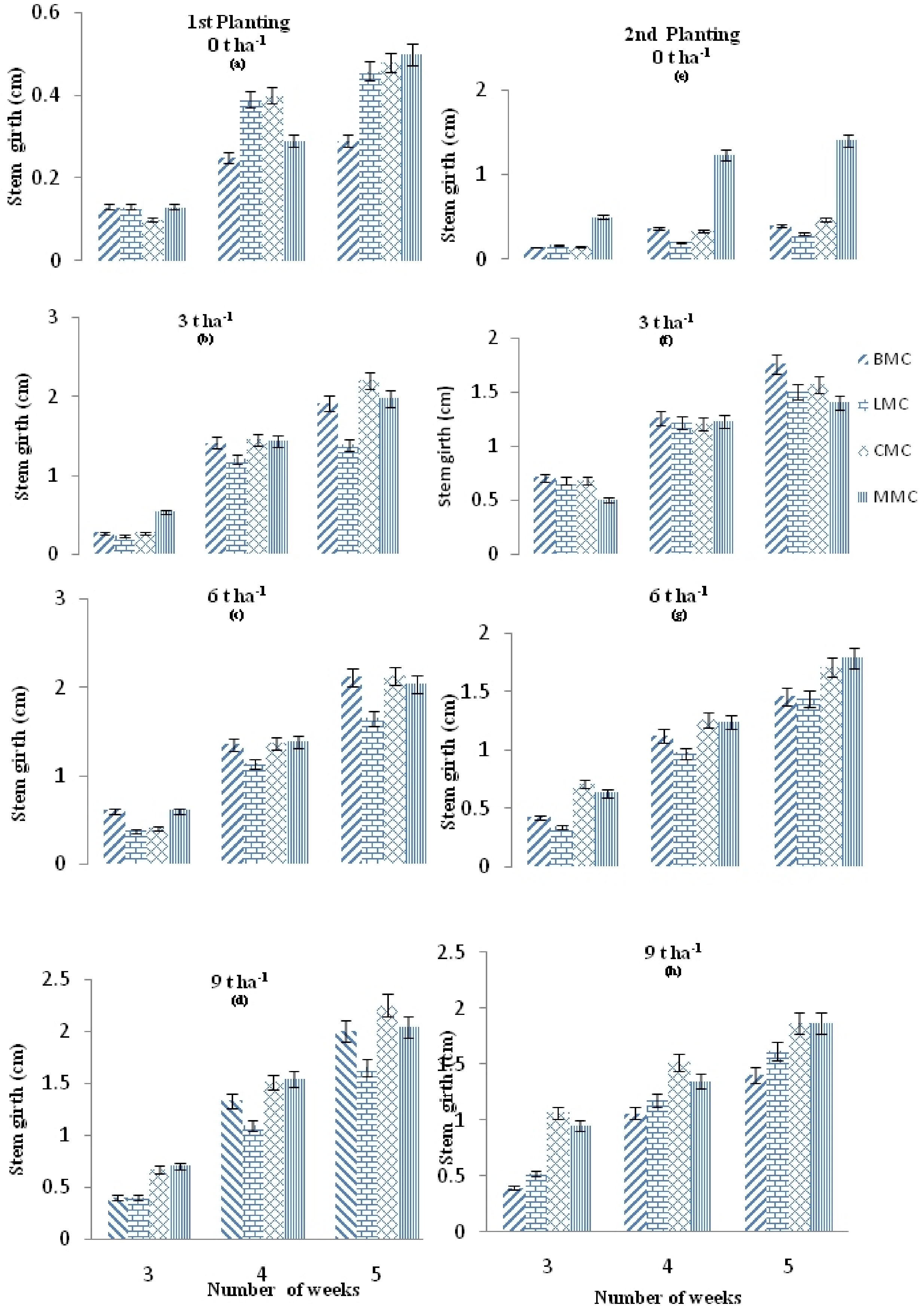

Figure 3: Mean stem girth of *Amaranthus cruentus* under different poultry composts. Vertical bars represent the SE. **Legend:** BMC = Broilers' Manure Compost, LMC = Layers' Manure Compost, CMC = Cockerel Manure Compost, MMC = Mixed Manure Compost

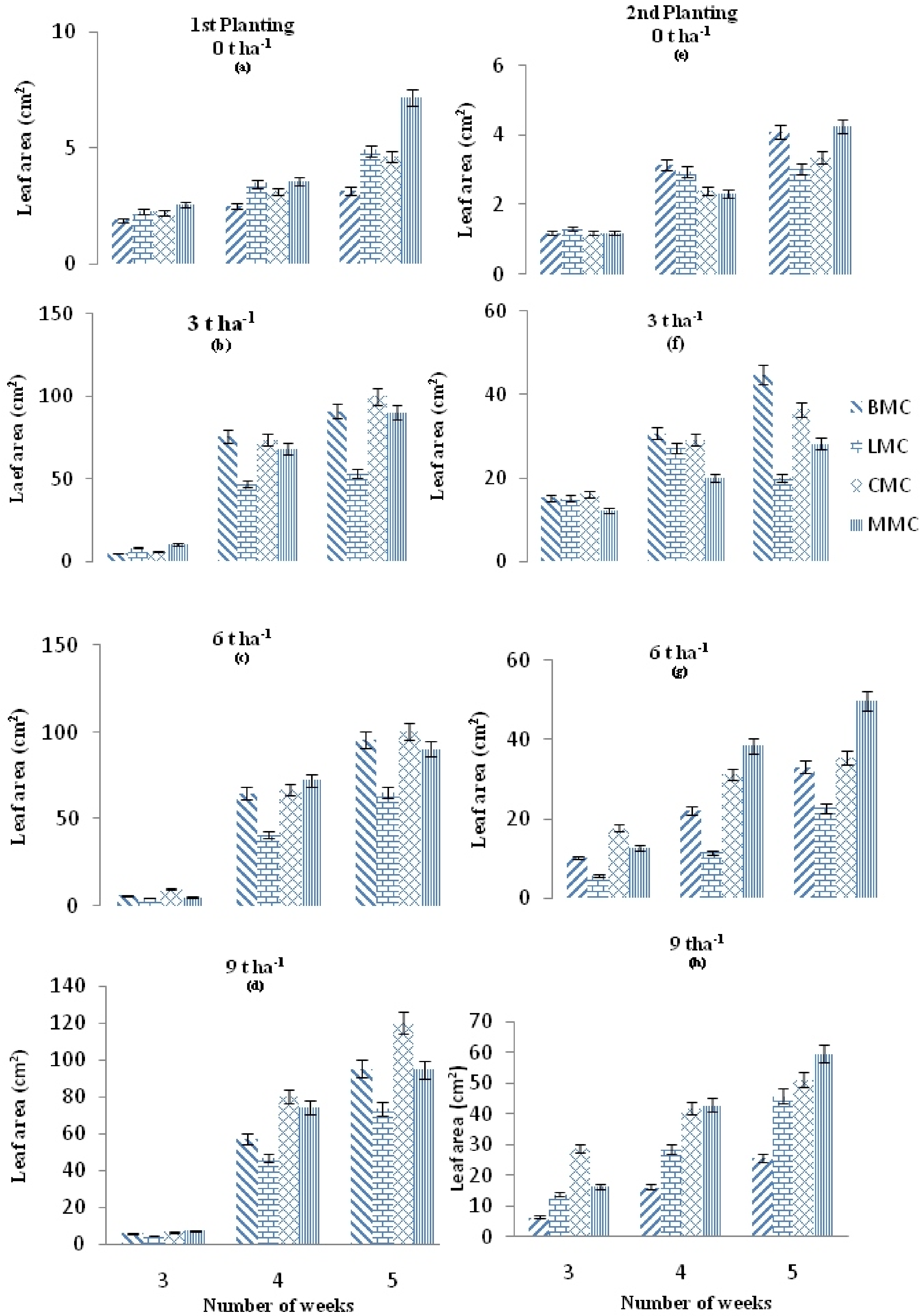

Figure 4: Mean leaf area of *Amaranthus cruentus* under different poultry composts. Vertical bars represent the SE. **Legend:** BMC = Broilers' Manure Compost, LMC = Layers' Manure Compost, CMC = Cockerel Manure Compost, MMC = Mixed Manure Compost

Table 2: Mean yield (t ha^{-1}) and reduction factor (%) of *A. cruentus* under different poultry composts

Treatment	0	3	6	9
		First planting		
BMC	0.42a	14.94b	15.73b	17.11b
LMC	0.40a	7.06a	8.17a	10.74a
CMC	0.41a	15.90c	20.29c	24.19d
MMC	0.40a	15.62c	15.98b	18.29c
		Second planting		
BMC	0.22a	2.85a	5.82a	6.29 a
LMC	0.21a	2.83a	5.63a	8.15b
CMC	0.20a	5.78c	7.81b	9.73c
MMC	0.20a	3.66b	8.25c	8.83b
		Reduction factor		
BMC	47.62	80.92	63.00	63.24
LMC	47.50	59.92	31.09	24.12
CMC	51.22	63.65	61.51	59.78
MMC	50.00	76.57	48.37	51.72

Means with the same letter in each column are not significantly different at $p < 0.05$

Legend:

BMC = Broilers' Manure Compost

LMC = Layers' Manure Compost

CMC = Cockerel Manure Compost

MMC = Mixed Manure Compost

Table 3: The effect of poultry composts on the nutritional quality (in %) of *A. cruentus* during the two cropping periods

Treatment	CP	EE	CF	TA	MC	CHO	Vit C
			1st cropping				
CT	15.48c	5.56a	16.78b	13.08b	7.85b	58.04a	5.75c
BMC	13.94b	4.66a	15.94a	12.06a	8.53b	70.81c	4.02b
LMC	15.49c	5.26a	15.99a	11.57a	6.89a	60.79a	3.16a
CMC	15.22c	4.65a	14.48a	11.76a	6.84a	64.53a	2.66a
MMC	12.36a	4.16a	15.48a	11.26a	5.62a	66.60b	1.26a
			2nd cropping				
CT	13.28a	3.56a	13.38a	8.76a	7.81a	66.58b	2.84b
BMC	15.66b	6.23b	15.14b	12.08b	7.12a	58.91a	3.86b
LMC	14.83b	5.94b	17.29b	12.26b	7.58a	59.39a	1.74a
CMC	15.57b	5.81b	16.41b	13.28b	6.92a	58.42a	6.32c
MMC	15.57b	5.80b	16.41b	13.28b	6.92a	58.41a	6.32c

Mean with the same letter in each column are not significantly different at $p < 0.05$

Legend: CT= Control, BMC = Broilers' Manure Compost, LMC = Layers' Manure Compost, CMC = Cockerel Manure Compost, MMC = Mixed Manure Compost, CP = Crude Protein, EE = Ether Extract, CF= Crude Fiber, TA = Total Ash, CHO = Carbohydrate, MC = Moisture Content, Vit.C = Vitamin C.

Yield Reduction Factor of *A. cruentus* after Successive Cultivation

By the end of second successive cultivation, the yield reduction factors were: LMC, 24.12%; MMC, 51.72%; CMC, 59.78% and BMC, 63.24% with 9 t ha^{-1} manure applications (Table 2). The implication of this was that the residual effect of LMC with the new application during the 2^{nd} cropping was most efficient, while BMC was the least in vegetative production of *A. cruentus.* The continuous use of poultry manures as an alternative cheap source of nitrogen supply for amaranth production as suggested by Oworu *et al.* (2010) must therefore be done with caution.

Vegetable Quality and Nutritional Value

The effects of the different treatments on the nutritional quality of *A. cruentus* are presented in Table 3. During the first cropping, crude fiber, total ash and vitamin C contents obtained with manure applications were significantly ($p < 0.05$) lower than values obtained with the control treatment. Hence, poultry manures have direct effect on the quality of *A. cruentus*. Okokoh and Bisong (2011) recently suggested integrated nutrient management approach for enhanced yield and quality of *A. cruentus.* Lumpkin (2003) also, was of the opinion that organically produced vegetables were of higher qualities than those produced using conventional methods. However, with the repeat experiment, CMC and MMC had significantly ($p < 0.05$) higher vitamin C value when compared with other treatments and these values were still lower than those obtained during the first cropping. Additional manure fertilization may have caused ecotoxicological problem to the soil and hence influenced negatively, the nutritional Chemistry of the test crop. Increased soil fertility brought about by treating the soils with poultry manures, reduced the leaf productivity of *A. cruentus* and the good quality of the crop (Table 3).

CONCLUSION

The study concluded that with single application of poultry manures to soil during a production cycle of *A. cruentus*, enhanced growth performance and leaf productivity in the order CMC > MMC > BMC > LMC were obtained. However, the repeat production of *A. cruentus* on the same soil with arbitrary application of poultry manures led to reduced growth performance, yield and quality of *A. cruentus*.

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