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ORIGINAL RESEARCH

Growth and proximate composition of *Amaranthus cruentus* L. on poor soil amended with compost and arbuscular mycorrhiza fungi

Oyeyemi A. Dada[2] · **Francis Imade**[1] · **E. M. Anifowose**[2]

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Abstract

Purpose The study was carried out to examine growth, shoot yield, dry matter and proximate composition of *Amaranthus cruentus* on poor soil augmented with compost or AMF either singly or in combination.

Methods The experiment was arranged in completely randomized designed in six replicates with four treatments. Four treatments: comprised control and three other amendment types derived from the application of compost made from cattle dung and maize stover, arbuscular mycorrhiza fungi singly or in combination with compost. The treatments were applied a week before sowing to allow for proper mineralization. Growth characteristics, chlorophyll content, ascorbic acid content and proximate composition were assessed.

Results The results revealed that the compost supplied sufficient plant nutrients needed for improving biological and economic yields of *Amaranthus cruentus* . Application of compost significantly ($P \leq 0.05$) influenced growth, dry matter and fresh shoot yield of *A. cruentus*. Applying of combination AMF and compost to nutrient limiting soil had no significant ($P \geq 0.05$) effect on yield and yield components of *A. cruentus*. Proximate composition of *A. cruentus* was significantly enhanced in pots augmented with compost better than pots amended with the combination of AMF and compost.

Conclusions Application of compost to nutrient deficient soil promoted growth, fresh shoot and dry matter yield of *A. cruentus*. Similarly, proximate composition of the crop was appreciably influenced by compost application.

Keywords *Amaranthus cruentus* · AMF · Compost · Proximate composition

Introduction

Amaranthus collectively known as amaranth is a leafy vegetable of high dietary value produced and consumed most parts of sub Sahara Africa, particularly in Nigeria (Tindall 1983). Amaranthus has diverse health advantages such as therapeutic value on cardiovascular diseases (Martirosyan et al. 2007), rich in phytosterols which reduce the cholesterol levels and also prevent cancer (Su et al. 2002).

The genus *Amaranthus* has received considerable research attention in many countries because of high nutritional value of some species that are important source of food, either as vegetable or grain. The leaves contain 17.5–38.3% dry matter protein of which 5% is lysine (Oliveira and de Carvallo 1975). Vitamin A and C are also found in significant level. Muloskozi et al. (2004) reported that a total of 100 g of vegetable material cooked without oil can contribute 45% of daily vitamin A requirement. Despite its nutrients advantages to consumers, many factors still limit its growth, particularly climatic conditions and soil characteristics. Growth of *Amaranthus cruentus* L. is often affected by low or unreliable rainfall (Cunningham

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✉ Francis Imade
imadefrancis@gmail.com;
imadefrancis@aauekpoma.edu.ng

Oyeyemi A. Dada
oa.dada@mail.ui.edu.ng; oadada247@yahoo.com

[1] Department of Botany, Faculty of Life Sciences, Ambrose Alli University, Ekpoma, Edo State, Nigeria

[2] Department of Botany, University of Ibadan, Ibadan, Oyo State, Nigeria

et al. 1992), low level of soil nutrient, among other abiotic constraints.

Nutrients availability in soil is greatly affected by low pH, coarse texture, soils and by leaching thereby limiting base cations such as Ca^+, $Mg^+$and K^+. Improving and maintaining soil structure is known to aid nutrient retention and soil biological health. Although, nitrogen is the most common limiting nutrient in most soil (Craine and Jackson 2010). Manure or organic fertilizers are valuable fertilizer for any farming operation due to their ability to supply needed nutrients for crop growth. The use of manure has, however, declined generally on many farms over the past fifty years (Kato and Place, 2011). This is due to several factors, chiefly among them are farm specialization with increasing separation of crop and livestock production and cost of transporting bulky manure. Despite these limitations, manure is beneficial to soil and crop grown on it (Carl and Bierman 2005). Organic fertilizer including compost do not only supply many nutrients for crop production including micronutrients but they are also valuable sources of organic matter. Application of organic fertilizers helps increasing water holding capacity of coarse-texture sandy soils, ensures slow release of nutrients and also enhances growth of earthworms and other beneficial soil organisms. Most leafy vegetables return small amount of crop residue to soil, thus application of compost and other organic amendments help to maintain soil organic levels (Carl and Bierman 2005; Oworu and Dada 2009; Ojo et al. 2014).

Arbuscular mycorrhizal Fungi (AMF) play important role in acquisition of mineral nutrients, especially the slowly mobile ions such as phosphorus (Gazey et al. 2004). It has also been shown that plants grown on AMF augmented soil are more resistant to biotic and abiotic stresses in nature (Karaki and Al Radded 1997; Silva-Sánchez et al. 2008). AMF constitutes an important group of symbionts associated with agricultural crops. This symbiosis may enhance the root systems ability to absorb and carry phosphorus and other soil elements of low mobility by means of a network of mycelia, thus promoting optimum plant growth (Raiman et al. 2007).

Utilization of AMF in augmenting poor soil is gaining wide research attention (Ibijbijen et al. 2006). Many researchers have observed different effects of inoculation of free living diazotrophs and AMF on different species of cultivated plants (Pérez-Montãno et al. 2014). Results have indicated that the interaction between these two groups of microorganisms, in many instances, result in improved plant growth and fungal infectivity or stimulate the effectiveness of the free-living diazotroph (Barea et al. 2002). There is, however, sparse information on effect combination of AMF and compost in improving fertility status of nutrient deficient soil. This study, therefore, conducted to investigate growth, dry matter and yield of *Amaranthus cruentus* L. grown on poor soil augmented with *Arbuscular mycorrhiza* Fungus (*Glomus intraradices*) and cattle dung—maize residue based compost (Maize Stover + Cattle Dung) used singly or in combination.

Materials and methods

Study site

The study was a pot experiment carried out in the greenhouse of the Department of Botany, Faculty of Science, University of Ibadan, Nigeria. The geographical area of the site is located at 7°26′N and 3°54′E at the elevation 215 m of the sea level. Polythene pots with a diameter of 14 and 18.5 cm in depth was used for the study. The pots were each filled with 5 kg sterilized soil.

Composting materials and inoculum source

The materials used for composting were fresh cattle dung collected from Faculty of Veterinary Medicine while maize stover were obtained from the University Teaching and Research Farm both in University of Ibadan, Nigeria. Composts were prepared from cattle dung, a well cured-poultry manure and maize Stover. The proportion of the maize stover to the animal wastes (cattle dung) was 3:1 on dry weight basis. Each of the organic waste was laid out in layers, a layer made up of 30 kg maize stover and 10 kg of either cattle dung. Ten of such layers made up a heap of about $3.1 \times 1.0 \times 1.0\ m^3$ for the respective compost. These were prepared using concrete described by Dada and Aminu (2013). *Glomus intraradices* an Arbuscular Mycorizal Fungus (AMF) used for the study was obtained from the Department of Botany, University of Ibadan, Ibadan.

Soil and compost analysis

The soil was collected (0–15 cm depth) using a soil auger from Practical Year Training Programe (PYTP) field of the Faculty of Agriculture and Forestry, University of Ibadan, Nigeria. The PYTP field is continuously cultivated with maize and leafy vegetables used for training agricultural students in their penultimate year. The soil and matured compost samples were air-dried under shade for 2 weeks before taken for analysis at Department of Agronomy, University of Ibadan. Both samples were analysed for pH as described by Mckeague (1978) total nitrogen using Kjeldahl procedure followed by distillation described by Bremner and Mulvaney (1982); Organic carbon using the method described by Walkley (1947); Available phosphorus and extractable cations such as Ca^{2+}, Mg^{2+} and Fe^{2+} by atomic absorption spectrophotometer. Also physical properties such as sand, silt, and clay and bulk density of soil sample were determined using procedures described by International Institute of Tropical Agriculture (IITA 2002).

Plant material and sowing

Seeds of *Amaranthus cruentus* L. were obtained from Department of Agronomy. The seeds were sown using broadcast method. A week after sowing, it was thinned to ten plants per pot. Weeds were rouged regularly and the pots were watered as needed.

Treatments and experimental design

There were four treatments comprising of a control, application of compost, AMF singly or in combination with compost. The four treatments were: control (No amendment), 2.5 g AMF + 2.5 g compost ($\equiv$4 t ha^{-1}), 5 g of AMF and 5 g compost ($\equiv$8 t ha^{-1}). The collected soil was sterilized at 1.05 kg/cm^2 (121 °C) for 15 min using an autoclave. The treatments were applied a week before sowing to allow for proper mineralization. The four treatments were arranged in a Completely Randomized Design (CRD) with six replicates.

Data collection

Data collection commenced 2 weeks after sowing (WAS) and continued until final harvest (6WAS). Data were collected from two tagged plants at the middle of each pots on number of leaves and plant height (cm), fresh shoot yield (g) and dry matter (g) components. At 4, 5 and 6 WAS one plant was uprooted per treatment to determine the relative growth rate. At final harvest, the tagged plants were uprooted to determine the weight of fresh shoot. The plant parts were kept in an envelope and oven dried to a constant weight at 80 °C after which they were weighed on a sensitive balance to evaluate the dry matter yield.

Chlorophyll content determination

Chlorophyll contents were determined using the method of Poora (2002). Leaf samples from each treatment were randomly harvested and weighed. Leaf sample was cut into smaller chips and placed in a mortar. 1 g of fresh plant sample was crushed in acetone with pestle and mortar. The mixture was made up to 100 ml volume in a volumetric flask. Absorbance of each sample was read using Atomic Absorption Spectrophotometer (AAS Model SP9) at the desired wavelength of chlorophyll *a*, chlorophyll *b* and total chlorophyll was determined using the formulae below.

$$\text{Chlorophyll } a\,(\mu\text{g/ml}) = 12.25(\text{A663.6}) - 2.55(\text{A646.6})$$

$$\text{Chlorophyll } b\,(\mu\text{g/ml}) = 20.31(\text{A646.6}) - 20.31(\text{A663.6})$$

$$\text{Total chlorophyll } (\mu\text{g/ml}) = 17.76(\text{A646.6}) + 7.34(\text{A663.6}).$$

Determination of abscorbic acid

10 g of the slurry sample was weighed into a 100 ml volumetric flask and diluted to 100 ml with 3% meta phosphoric acid solution (0.0033 M EDTA). The diluted samples were filtered using a Whatman filter paper No. 3. The filtrate (10 ml) was pipette into a small flask and titrated immediately with a standardized solution of 2.6 dichlorophenol-in-dephenol to a faint pink end point. The ascorbic acid content of the fruit was calculated from the relationship below.

$$\frac{V \times T}{W \times 100}(\text{mg ascorbic acid per 100g sample}),$$

where: $V =$ ml dye used for titration of aliquot of diluted sample. $T =$ ascorbic acid equivalent of dye solution expressed as mg per ml of dye. $W =$ gram of sample in aliquot titrated.

Proximate composition

The proximate constituents of the crop were determined according to AOAC (1998). All analyses were carried out in triplicate.

Data analysis

Data were analysed with analysis of variance (ANOVA) using a General linear model (GLM) of statistical analysis system (SAS 2002). Differences in means were compared using Least Significant Difference (LSD) at $P \leq 0.05$.

Results

The results of the pre-trial physico-chemical properties of the soil and compost revealed that the compost was rich in both macro and micro elements. The total N (4.6 g/kg), available P (15.3 mg/kg), OC (46.1 g/kg) and K (0.6 cmol/kg) in the compost were higher than those in the soil. The mineral constituents N (1.9 g/kg), K (0.4 Cmol/kg) in the soil were relatively below the critical limit for growing *Amaranthus cruentus* Table 1.

Influence of various treatments on number of leaves produced by *A. cruentus* on soil deficient in nutrients

Table 1 Chemical characteristics of compost and soil (0–15 cm) used for the study Source: Dada and Aminu (2013)

	pH (H_2O)	OC	N	P	Na	Ca	Mg	K	Fe	Silt	Clay	Sand	Bulk density
Soil	6.5	18.4	1.9	13.0	0.4	1.2	0.7	0.4	58	6.1	10.8	83.1	1.7
Compost[a]	6.5	46.1	4.6	15.3	0.4	1.4	0.8	0.6	167	nd	nd	nd	nd

nd not determined

[a] Dry weight basi

augmented with various soil amendments either singly or in combination is shown in Fig. 1a. The results showed that there was no significant ($P > 0.05$) difference in number of leaves of *Amaranthus* grown on nutrient deficient soil treated with different soil amendments. However, pots treated with AMF+ Compost had highest number of leaves (9.67).

Height of *Amaranthus* was influenced by various types of soil amendments (Fig. 1b). Pots treated with compost produced the tallest (16.42 cm) plants while shortest plants (14.07 cm) were observed in pots treated with AMF although there was no significant difference in the response of the crop to different types of amendments with respect to height.

There was significant ($P \leq 0.05$) difference in the fresh weight of *A. cruentus* on poor soil treated with different amendments (Fig. 2a). Pots augmented with 8 t ha^{-1} of compost (CDMS) produced highest (5.59 g) fresh weight whereas, least fresh weight (3.19 g) was produced in pot augmented with AMF. Application of 8 t ha^{-1} compost promoted better dry matter production compared to other amendment treatments (Fig. 2b).

The results obtained for the relative growth rate was not significantly ($P > 0.05$) different among the different amendments. Application of different amendments to poor soil had no significant effect on relative growth rate of *A. cruentus* grown on such soil. However, the crop had better relative growth rate (0.26 g day^{-1}) in pots augmented with compost than pot amended with AMF which had the least (0.17 g day^{-1}) rate (Fig. 3a). Application of different organic amendment on poor soil had significant influence on chlorophyll content of *A. cruentus*. Highest chlorophyll content (0.89 µ/100 g) was recorded in pots treated with 8 t ha^{-1} of CDMS while pots treated with the combination of AMF and CDMS had least (0.76 µ/100 g) chlorophyll content (Fig. 3b).

Generally, the proximate composition of *A. cruentus* grown on poor was significantly influenced by soil amendments. The results obtained for the determination of crude protein content showed significant ($P < 0.05$) difference among the different amendments. *Amaranthus* treated with 8 t ha^{-1} compost had highest crude protein (16.33%) while least crude protein content was recorded in AMF treated pots (Table 2).

Crude fibre content of *A. cruentus* on poor soil was significantly influenced by the amendments (Table 2). Application of different organic amendments to poor soil had significant influence on fibre content of *A. cruentus* whereas application of combination of AMF+ compost treated pots had the highest (16.85%) crude fibre content while least fibre (15.31%) was observed in AMF treated pots.

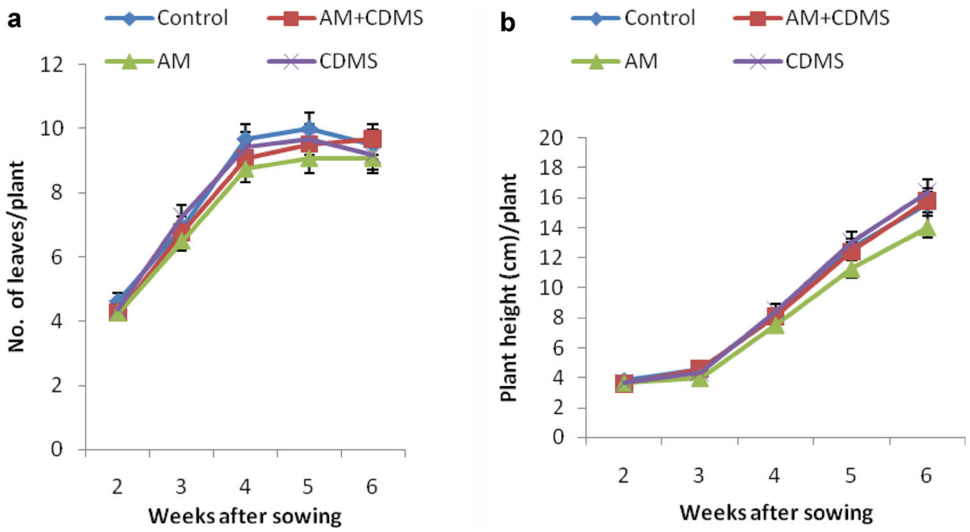

Fig. 1 **a** Influence of various soil amendments on number of leaves of *A. cruentus*. **b** Influence of various soil amendements on height (cm) of *A. cruentus*

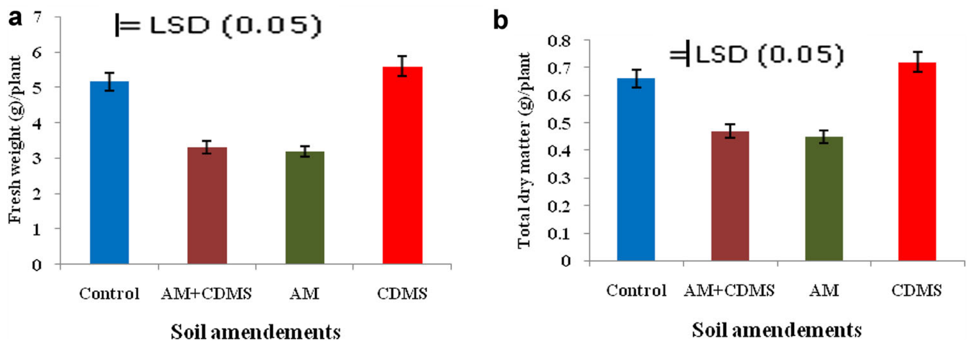

Fig. 2 **a** Influence of various soil amendements on weight of fresh shoot (g) of *Amaranthus cruentus*. **b** Influence of various soil amendements on biomass yield (g) of *A. cruentus*

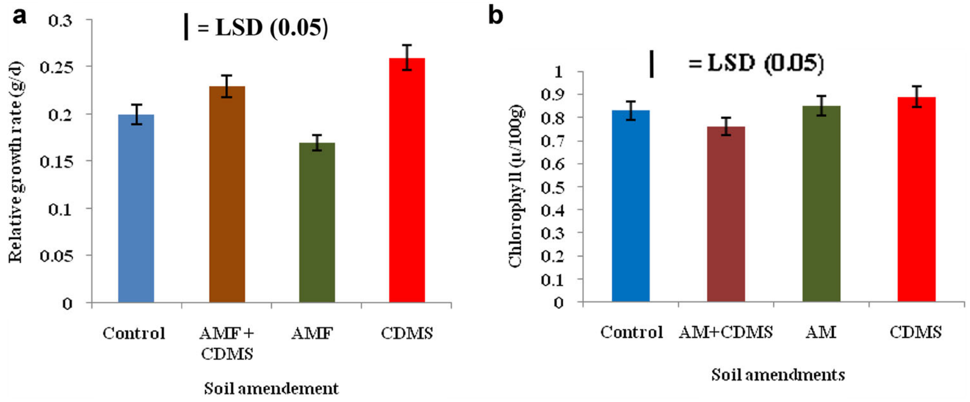

Fig. 3 **a** Influence of different amendments on relative growth rate of *A. cruentus*. **b** Influence of different amendments on chlorophyll contents of *A. cruentus*

Table 2 Effect of application of different organic amendments on proximate compositions of *Amaranthus cruentus* L. grown on nutrient deficient soil

Organic amendments (t ha^{-1})	Percent (%)					Ascorbic acid (mg/g)
	Crude protein	Crude fibre	Fat	Ash	Moisture content	
CDMS	16.33	16.70	5.80	12.36	13.41	14.61
AM + CDMS	15.93	16.85	4.97	11.69	12.9	12.41
AM	14.88	15.31	4.78	11.25	11.94	13.93
Control	15.74	16.77	5.08	12.19	12.94	14.49
Mean	15.72	16.41	5.16	11.87	12.80	13.86
CV	0.17	2.22	0.23	0.29	0.25	0.14
LSD ($P \leq 0.05$)	0.09	1.16	0.04	0.11	0.10	0.06

CDMS compost, *AM* arbuscular mycorrhiza

There was significant difference in fat content of poor soil treated with different organic amendments. Application of 8 t ha^{-1} of compost significantly enhanced fat content of *A. cruentus* on poor soil. Least fat (4.78%) content was observed in pots treated with the combination of AM + CDMS. There was significant difference in the ash content of *A. cruentus* on poor soil treated with different organic amendments (Table 2). Pots augmented with 8 t ha^{-1} of CDMS produced highest (12.36%) ash content. The results of moisture content was significantly ($P < 0.05$) different among the different amendments. Highest (13.41%) moisture content was recorded in pots treated with 8 t ha^{-1} of CDMS. AMF treated pot had least (11.94%) moisture content. The ascorbic acid contents was highest (14.61 mg/100 g) in CDMS treated pots whereas least (12.41 mg/100 g) was observed in pots treated with combination of AMF + CDMS (Table 2).

Discussion

Application of compost singly or in combination with AMF enhanced leaf formation in *Amaranthus cruentus* on poor soil. Compost and AMF had been reported to enhance plant growth, plant water stress tolerance (Cruz et al. 2000), nutrient cycling and soil quality (Ishii et al. 2004). This possibly explains why organic amendments promoted better growth of *A. cruentus* than in the control pots. The superior improvement in plant height on compost treated pot suggests that compost is likely to possess growth promoting substances which enhanced stem elongation and ultimately the plant height. Miezah et al. (2008) reported that growth substances such as IAA, GA3 and cytokinins were isolated from compost and co-compost. Carl and Bierman (2005) had reported that application of compost supply 70% organic nitrogen, phosphorus and potassium uptake require for improving plant growth. This simply explains reasons why compost augmented pots had better growth performance than other amendments.

Augmentation of poor soil with compost, promoted higher fresh leaf yield better than other amendments. This means that compost could serve as an alternative to expensive and scarce inorganic fertilizers (AdeOluwa and Akinyemi 2014) that could be used by poor resource leavy vegetable growers. The poor fresh shoot yield response of *Amaranthus cruentus* to AMF augmentation either singly or in combination with compost presumes a likelihood of antagonistic effects between AMF and compost.

Compost application to poor soil significantly promoted better production of fresh shoot weight which is the main economic yield of *A. cruentus*. Manios and Kepetanois (1992) had reported that nutrient supplied by farmyard manure affects and increases crop biomass yield. Our observation in this study implies, that the applied compost probably supplied sufficient nutrient which was taken up to synthesis vegetative and morphological development better than when AMF was applied singly or in combination with compost.

The impressive performance of *A. cruentus* with respect to total biomass accumulation in pots augmented with compost over other treatments showed that the applied compost supplied the needed nutrient as required by the crop for its metabolic functions. Several authors have reported that pattern of nutrient release by organic amendments is a vital factor which determines the plant growth and dry matter accumulation. (Akanbi and Togun 2002; Odeleye et al. 2007; Eifediyi et al. 2010).

Amaranthus cruentus had better relative growth rate in compost-augmented pots than in other treatments which perhaps might be due to steady release of nutrients as required by the crop. This invariably tends to enhance photosynthetic activities and hence performance of the crop better than other amendments. Similar observation had been reported on horticultural plants (Abad et al. (1997), on pineapple (Liu et al. 2013) and on tomato (Mashavira et al. 2015). The minimal relative growth rate observed in other treatments apart from compost treated pots might be due to utilization of available P and C for structural development by AMF at the expense of the plant, this agrees with the observation of Graham and Abbott (2000).

Amaranthus cruentus treated with compost had better proximate compositions possibly due to the availability of sufficient nutrients in the applied compost which were translocated into appropriate sources where they were partitioned into respective sinks. Akhtar et al. (2010) had reported linear relationship between quality of constituents of compost and vegetative development and nutrient uptake in lettuce and amaranthus. Similarly, superior chlorophyll content recorded in compost augmented pots suggests abundance of chlorophyll synthesis by the leaves and other tissues resulting from adequate nutrient supply and other precursors of chlorophyll. Bittenbender et al. (1998) and Naikwade (2014) in separates reports concluded that compost application to nutrient limiting soil improved quality and quantity of both biomass and proximate constituents of maize.

The poor performance of combination of AMF + compost suggests that the compost probably provided a good substrate for the AMF to thrive being an obligate saprophyte/symbionts. Consequently, the nutrients that could have been released for plant growth might have been used up by the organism. Since *A. cruentus* is a short duration crop, the time required for the AMF to release the nutrient for uptake might be behind the crop growth range. Hence, the crop might have been harvested before the nutrients were released thus not benefiting the crop. Similar observations had been made on cherry fruit by Stefano et al. (2004), on *Linum usitatissimum* by Cavagnaro et al. (2005) and on onions by Khang et al. (2011). Besides, it is not unlikely that the organism (*Glomus intraradices*) was a poor symbiont with *Amaranthus cruentus* whereby the organism used large amount of carbon from its host. Report of Burleigh et al. (2002) explained similar observations where they found that *Gi. rosea* was a very poor symbiont with *Lycopersicon esculentum* and *Medicago truncatula* compared with the other AMF tested.

Conclusion

Application of compost to nutrient deficient soil promoted growth, fresh shoot and dry matter yield of *A. cruentus*. Similarly, proximate composition of the crop was appreciably influenced by compost application. Applying combination of compost and AMF to augment poor soil may not be a good option in amaranthus production as the outcome in this study showed that amarathus performed poorly under such treatments. Therefore, this study recommends utilization of 8 t ha^{-1} cattle dung based compost in augmenting poor soil to enhance growth and quality of *Amaranthus cruentus* L.

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