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Effects of Different Types of Organic Fertilizers on Growth Performance of *Amaranthus caudatus* (Samaru Local Variety) and *Amaranthus cruentus* (NH84/452)

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Authors' contributions

This work was carried out in collaboration among all authors. Author JCK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CCU and AEA managed the analyses of the study. Author JCK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the effect of different types of organic fertilizers on growth performance of *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452).
Study Design: A randomized complete block design (RCBD) was used for the experiment.
Place and Duration of Study: The field experiment was carried out in the nursery of a homestead garden at No 20, Isaiah Balat Street, Sabo GRA, Kaduna State, Nigeria.
Methodology: The study consists of seven treatments which includes control (no fertilizer), 5 t ha^{-1} and 10 t ha^{-1} poultry manure, 5 t ha^{-1} and 10 t ha^{-1} sewage sludge, 35 kg ha^{-1} and 70 kg ha^{-1} NPK compound fertilizer and also with *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452) in factorial arrangement fitted into a randomized complete block design (RCBD) and replicated three times. Growth performance data were collected on plant height, number of leaves, leaf area and leaf area index from 2 weeks after transplanting (WAT) to 6 weeks after transplanting (WAT).

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Results: The plant height and number of leaves of the two varieties were found in the range of 18.30 - 135.67cm and 13.33 - 78.33cm respectively. Leaf area and leaf area index of the two varieties had values in the range of 41.71 - 258.29cm^2 and 1.76 - 41.72 respectively. At 6 WAT, 10 t ha^{-1} poultry manure recorded the highest value for all the growth parameters for both varieties except for leaf length, leaf width and leaf area of *Amaranthus caudatus* (Samaru local variety), where 10 t ha^{-1} sewage sludge and 70 kg ha^{-1} NPK compound fertilizer were highest.

Conclusion: The experimental results of this study have shown that poultry manure had higher growth performance on the two varieties of Amaranth when compared with sewage sludge and NPK compound fertilizer. The application of poultry manures at 10 t ha^{-1} is therefore recommended for farmers to use to obtain higher yields of Amaranth.

Keywords: Growth; organic and inorganic fertilizers; amaranth; soil and insecticides.

1. INTRODUCTION

Increasing population of the world has doubled the food demands and inundated the available land resources. Alongside other food alternatives, vegetables are considered cheap source of energy [1]. Vegetables are rich sources of essential biochemicals and nutrients such as carbohydrates, carotene, protein, vitamins, calcium, iron, ascorbic acid and palpable concentration of trace minerals [2].

Amaranth has been one of the most important vegetables of Amaranthaceae family. Amaranth has been naturalized in central parts of Asia and possibly Iran [3] and has cultivation history of more than 2000 years [4]. Cultivation of the various *Amaranthus* species is acquiring increasing importance in Nigeria and other parts of African continent where the available species are grown for their leaves [5].

Organic and inorganic fertilizers are essential for plant growth as it supplies plants with the nutrients needed for optimum performance. Organic fertilizer has been used for many centuries whereas chemically synthesized inorganic fertilizers were only widely developed during the industrial revolution. Inorganic fertilizers have significantly supported global population growth, as it has been estimated that almost half the people on the earth are currently fed as a result of artificial nitrogen fertilizer use [6]. Commercial and subsistence farming has been and is still relying on the use of inorganic fertilizers for growing crops [7]. This is because they are easy to use, quickly absorbed and utilized by crops. The continued dependence of developing countries on inorganic fertilizers has made prices of many agricultural commodities to skyrocket [7].

Moreover, most vegetable farmers in tropical Africa are small holders who cannot afford the cost of inorganic fertilizers, although soil fertility limits yield of vegetables especially in urban centres [8]. In Nigeria, fertilizers, being costly and sometimes scarce can make farmers not apply enough for good growth [5]. Fertilizer application rates in intensive agricultural systems have increased drastically during recent years in Nigeria. Farmers depend largely on locally sourced organic fertilizers [8]. In Nigeria, huge amount of organic wastes such as poultry waste, animal excreta, sewage sludge, refuse soil and palm oil mill effluent are generated and heaped on dump sites, posing potential environmental hazard. Incorporating these waste materials into the soil for crop production is expected to be beneficial to the buildup of organic matter layer that is needed for a steady supply of nutrients by tropical soils [9].

Oyedeji et al. [10] reported that NPK and poultry manure improved the growth and yield of three different species of amaranth (*Amaranthus hybridus*, *Amaranthus deflexus* and *Amaranthus cruentus*) but influenced proximate composition differently. Emede et al. [11] reported that poultry manure influenced the plant growth and yield of *Amaranthus cruentus* L. positively. Therefore, the objective of this study was to determine the effect of different types of organic fertilizers on the growth performance of *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452).

2. MATERIALS AND METHODS

2.1 Seeds

The seeds of *Amaranthus caudatus* (Samaru local variety) were obtained from local farmers in Samaru, Zaria, Nigeria while the seeds of

Amaranthus cruentus (NH84/452) were obtained from National Horticultural Research Institute (NIHORT), Ibadan, Nigeria. *Amaranthus caudatus* samples collected were authenticated at the herbarium unit of Biological Sciences Department, Ahmadu Bello University Zaria, Nigeria and a voucher specimen was deposited.

2.2 Study Area

The field experiment was carried out in the nursery of a homestead garden at No 20, Isaiah Balat Street, Sabo GRA, Sabo Tasha, Kaduna State, Nigeria. Kaduna metropolis has a tropical savanna climate with dry winters characterized by maritime air and rainfall is between April and October with annual raining days ranging from 81 to 103 mm. During the reference period, the annual mean rainfall values range from 145.37 mm to 318.67 mm. From the figures above, ample rains are available for the production of many agricultural crops. During harmattan, dry desert wind blows between December and mid February while night temperature is very low. The geographical location of Kaduna metropolis is Latitude $9^0\ 03^1$N and $11^0\ 32^1$N north of the equator and Longitudes $6^0\ 05^1$ E and $8^0\ 38^1$ E East of the Greenwich meridian. Kaduna metropolis has a sub-humid semi arid tropical climate with maximum annual mean temperature ranging from 25.30°C to 36.20°C while the minimum annual mean temperature range of 28.45°C to 34.38°C [12].

2.3 Soil Sampling

Surface soil sample was taken from the experimental site at a depth of 0 – 15 cm at land preparation (after ploughing and harrowing) using the zigzag method. The sample was collected from twenty points and bulked to form a composite sample. The composite sample was air-dried, crushed and sieved through a 2 mm mesh sieve and stored for chemical analysis [13].

2.4 Fertilizers

i. Poultry manure: The poultry manure was collected at Ishaya's poultry farm in Sabo GRA, Sabo Tasha Kaduna State, Nigeria.
ii. Sewage sludge: The dried packed sewage sludge was collected at the sewage site of Ahmadu Bello University Zaria, Nigeria.
iii. NPK compound fertilizer: NPK compound fertilizer (15:15:15) was bought at Kawo market Kaduna State, Nigeria.

2.5 Soil Analysis

The sampled soil was analyzed at the Soil Science Department of the Institute of Agricultural Research, Ahmadu Bello University Zaria, Nigeria. The following parameters were analyzed in the sampled soil; particle size, pH (in water), organic carbon, available phosphorus, total nitrogen, cation exchange capacity (CEC) and exchangeable bases [14].

2.6 Experimental Design and Fertilizer Treatment

The experiment included seven fertilizer treatments for each of the two varieties of Amaranth which are in factorial arrangement fitted into a randomized complete block design (RCBD) and replicated three times. Hence, the experiment had a total of 42 experimental plots. The treatments were: Control (no fertilizer), 5 t ha^{-1} poultry manure, 10 t ha^{-1} poultry manure, 5 t ha^{-1} sewage sludge, 10 t ha^{-1} sewage sludge, 35 kg ha^{-1} NPK compound fertilizer, 70 kg ha^{-1} NPK compound fertilizer [13].

2.7 Planting and Nursery Management

Prior to planting, the amaranth seeds were soaked in water for about 24 hours in order to enhance germination. The soaked seeds were first sown in the nursery of about 1.9 cm deep and were watered twice daily. Appropriate nursery management practices were carried out as at when needed to obtain healthy and uniform seedlings. The experimental site was ploughed, harrowed and prepared into slightly raised beds (plots) of 25 cm width × 80 cm length dimension preparatory to transplanting the crop seedlings. Poultry manure and sewage sludge were incorporated according to treatment level to specific plots during land preparation, thoroughly mixed with the soil and then left for two weeks to allow for mineralization. Half of the NPK Compound fertilizer was applied at day of transplanting while the balance was applied one week later. After two weeks in the nursery, randomly picked seedlings were transplanted to the well prepare beds (plots). The seedlings were watered twice daily using watering can and the surrounding areas were weeded regularly. The experimental area and the surroundings were kept clean to prevent harbouring of pests. Insects were controlled by using "Dime Force Insecticide" with concentration of 1.5 L/ha [15].

2.8 Data Collection for Growth Performance

Data were first collected two weeks after transplanting (WAT) and subsequently at one week interval for up to six weeks after transplanting. Two randomly selected plants were tagged and used in each plot for data collection. Data collected included plant height, number of leaves, leaf length and leaf width, while the leaf area and leaf area index were computed [13].

2.8.1 Determination of plant height

Plant height is the length of the plant from the base of the stem (surface of the soil) to the apex of the leaves. Plant height was measured using a measuring tape for the two tagged plants per plot and the average computed [13].

2.8.2 Determination of number of leaves

The number of leaves was counted from the two tagged plants and the average computed [13].

2.8.3 Determination of leaf area

The Leaf Area (LA) was computed by multiplying the Leaf Length (LL) by the Leaf Width (LW) and the product multiplied by the correction factor [13].

Calculation;

Leaf Area = (Leaf Length × Leaf Width) 0.578.

2.8.4 Determination of leaf area index

The leaf area index (LAI) was computed using this formula [16]:

$$LAI = Y \times N \times LA \times (AP)^{-1}$$

Where: Y = Population of plants per plot (5 plants), N = Average number of leaves, LA = Leaf area, AP = Area of plot (25cm width * 80cm length = 2000cm^2).

2.9 Statistical Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 21.0 computer package. Descriptive statistics was used to determine the measures of central tendency. Means were separated using Duncan Multiple Range test. Values with different superscripts down the column are significantly different at p<0.05.

3. RESULTS AND DISCUSSION

3.1 Soil Analysis Results

Results of analyses of the soil used for this experiment are shown in Table 1. The texture class of the soil is sandy clay loam in which sand was highest with value of 66 ± 2.0%, followed by clay with 24 ± 3.0% and silt was the lowest with value of 10 ± 1.0%. The soil organic carbon, total nitrogen and available phosphorus were 0.46 ± 0.02%, 0.32 ± 0.01% and 7.4 ± 0.30ppm respectively. The exchangeable bases of Sodium, magnesium, calcium, potassium and cation exchange capacity (CEC) contents were 0.34 ± 0.02 Cmol/kg, 0.84 ± 0.02 Cmol/kg, 3.26 ± 0.05 Cmol/kg, 0.65 ± 0.03 Cmol/kg and 5.7 ± 0.20 Cmol/kg respectively. Soil pH value was 7.7 ± 0.2.

3.2 Organic Fertilizer Analysis Results

Results of analyses of the organic fertilizers used for this experiment are shown in Table 2. Poultry manure showed a pH of 7.62 ± 0.04, while the concentrations for total nitrogen, available phosphorus and potassium were found to be 3.53 ± 0.02%, 0.71 ± 0.05% and 1.61 ± 0.03% respectively. Sewage sludge pH was found to be 8.25 ± 0.09; the concentrations of total nitrogen, available nitrogen and potassium were gotten as 2.44 ± 0.03%, 0.97 ± 0.02% and 1.33 ± 0.05% respectively.

3.3 Plant Height

Plant height was significantly (*P*= .05) higher in plants derived from poultry manure treated plots applied at 10 t ha^{-1} treatment and lowest in plants derived from no fertilizer treatment plots for both *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452) as shown in Fig. 1 and Fig. 2. At 2 Weeks After Transplanting (2WAT), the plant height was 26.28±1.07 cm and 45.97±0.88 cm from poultry manure applied at 10 t ha^{-1} treatment for *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452) respectively, which was also consistently highest till maturity (6 WAT) as shown in Fig. 1 and Fig. 2. The highest plant height for the two varieties of amaranth at 6 WAT were both observed in plants treated with 10 t ha^{-1} poultry manure which was significantly (*P* = .05) different from the other treatments. This position was earlier reported by Egharevba and Ogbe [17] and Okokoh and Bisong [18]. The highest plant height exhibited by plants treated with 10 t ha^{-1} poultry manure might have been due to the presence of the primary nutrients plus other minerals found in inorganic manure, and also it may be probably due to favourable nutrient mineralization of poultry manure as a result of the influence of the mineral component on the organic content of the manure [19]. The control plants had the lowest height as they had to depend mainly on the intrinsic soil fertility as exhibited by the soil chemical analysis to be low. A similar effect for control was reported for Amaranthus caudatus by Abayomi and Adebayo [19] and on radish stems amaranth-indian spinach by Islam et al. [20]. The height of the plant is an important growth character directly linked with the productive potential of plants. An optimum plant height is claimed to be positively correlated with productivity of plants [21].

3.4 Number of Leaves

The number leaves were highest for plants treated with 10 t ha^{-1} poultry manure for both varieties of amaranth and were not significantly (*P*= .05) different among the treatments except for the plants in the control group as shown in Fig. 3 and Fig. 4. At 6 WAT, poultry manure applied at 10 t ha^{-1} gave the highest number of leaves with values of 78.67 ± 5.03 and 64.50 ± 3.50 for Amaranthus caudatus (Samaru local variety) and Amaranthus cruentus (NH84/452) respectively. At the start of the experiment, the average number of leaves was highest for poultry manure and NPK compound fertilizers for both varieties of Amaranth. However, between 2 WAT and 4 WAT, the highest development of new leaves was observed in 70 kg ha^{-1} NPK compound fertilizer but not significantly different from 35 kg ha^{-1} NPK and poultry manure. Relatively high content of nitrogen in the NPK compound fertilizer increase the growth and development of new leaves. Normally inorganic fertilizer nutrients are soluble, so the nitrogen was quickly released into the soil leading to fast leaf growth and development. Although, during maturity, leaf development declined because the nutrients were probably exhausted in the soil; however, the reason for the high number of leaves for plants treated with poultry manure compared to the sewage sludge at the early stages was attributed to the high amount of nitrogen in the poultry manure than sewage sludge from chemical analysis, and also due to faster mineralization and release of nutrients from the poultry manure than sewage sludge. At maturity, the 10 t ha^{-1} poultry manure showed the highest average number of leaves for both varieties of Amaranth, which was also reported by Law-Ogbomo and Ajayi [22] for *Amaranthus cruentus*. This also agrees with reports by previous workers such as Sanwal et al. [23] in turmeric (*Curcuma longa*); Premesekhar and Rajashree [24] in Okra (*Abelmuchus esculentus*) who separately attributed higher leaf yield to released nutrients from organic manure application which improved chemical, physical and biological properties of soil. This high leaves development in the poultry manure compared to the sludge is due to the higher amount of nitrogen in poultry manure and continuous release of the nutrients. However, the reason behind the higher number of leaves for plants treated with organic fertilizers than the NPK compound fertilizer may be due to availability of nutrients as affected by the water holding capacity of the soil [25]. Most probably because as the manure quantities increased the water holding capacity of the soil and subsequent nutrient release increases, while the NPK compound fertilizer nutrients have been exhausted as the early stages due to the solubility of the nutrients.

3.5 Leaf Area

At maturity, leaf area which is a measure from the leaf length and leaf width was significantly (*P*= .05) higher in plants derived from plots treated with 10 t ha^{-1} sewage sludge with area of 127.36 ± 3.40cm^2 and 10 t ha^{-1} poultry manure with area of 258.29 ± 23.96cm^2 for *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452) respectively and was lowest in plants derived from plots with no fertilizer (control treatment) as shown in Fig. 5 and Fig. 6. Leaf area were found to be highest in plants from the 70 kg ha^{-1} NPK compound fertilizer for green type and the 10 t ha^{-1} poultry manure recorded the highest for *Amaranthus cruentus* (NH84/452) but there was no significant (*P*= .05) difference among the treatments except for the control treatment. Similar work also reported by Mshelia and Degri [26] on effect of different levels of poultry manure on performance of *Amaranthus caudatus L*. Okokoh and Bisong [18] reported similarly in a research in Calabar that application of poultry manure significantly influenced performance of amaranth. The increase in leaf area had been claimed to be directly influence by nitrogen supply in fertilizer applied [27]. The insignificant difference among the treatments suggests that the nutrients in both organic and inorganic fertilizers increases leaf width but higher amount of nutrients in individual fertilizers may not necessary influence noticeable difference in the width of the plants.

Table 1. Physical and chemical properties of soil used in this experiment

Particulars	Value	Methods
Particle size		
• Clay	24 ± 3.0%	USDA
• Silt	10 ± 1.0%	USDA
• Sand	66 ± 2.0%	USDA
Texture Class	Sandy Clay Loam	USDA
pH (in Water)	7.70 ± 0.20	
Organic Carbon	0.46 ± 0.02%	Walkley-Black method
Available Phosphorus	7.40 ± 0.30 ppm	Bray and Kurts method
Total Nitrogen	0.32 ± 0.01%	Kjeldahl method
Exchangeable bases		
• Calcium (Ca)	3.26 ± 0.05 Cmol/Kg	AAS
• Magnesium (Mg)	0.84 ± 0.02 Cmol/Kg	AAS
• Potassium (K)	0.65 ± 0.03 Cmol/Kg	AAS
• Sodium (Na)	0.34 ± 0.02 Cmol/Kg	AAS
• Cation Exchange Capacity (CEC)	5.70 ±0.20 Cmol/Kg	Ammonium saturation

Values are mean ± standard deviation of triplicate analysis

Table 2. Chemical properties of organic fertilizers used in this experiment

Chemical Properties of the Organic Fertilizers used in the Experiment				
	pH (in H_2O)	Total Nitrogen (%)	Available Phosphorus (%)	Potassium (%)
Poultry manure	7.62± 0.04	3.53 ± 0.02	0.71 ± 0.05	1.61± 0.03
Sewage sludge	8.25± 0.09	2.44 ± 0.03	0.97 ± 0.02	1.33 ± 0.05

Values are mean ± standard deviation of triplicate analysis

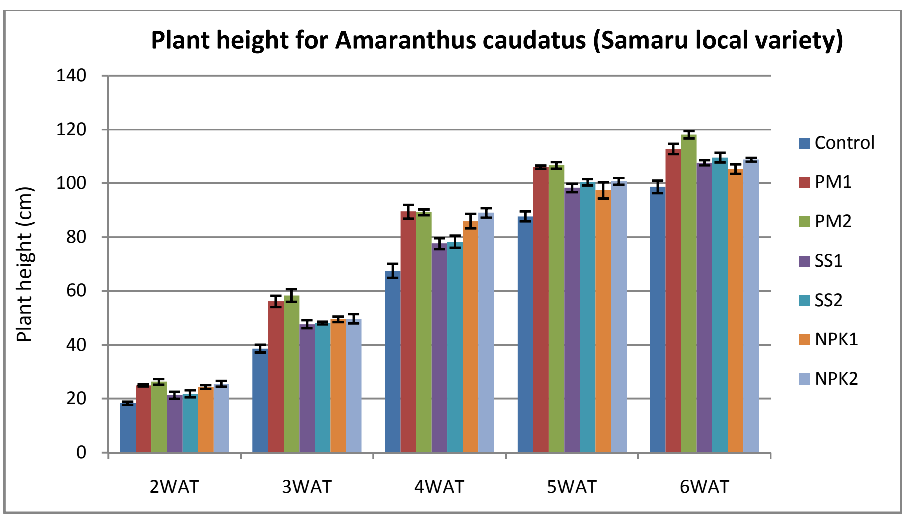

Fig. 1. Effect of organic fertilizers on plant height of *amaranthus caudatus* (samaru local variety)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1};SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

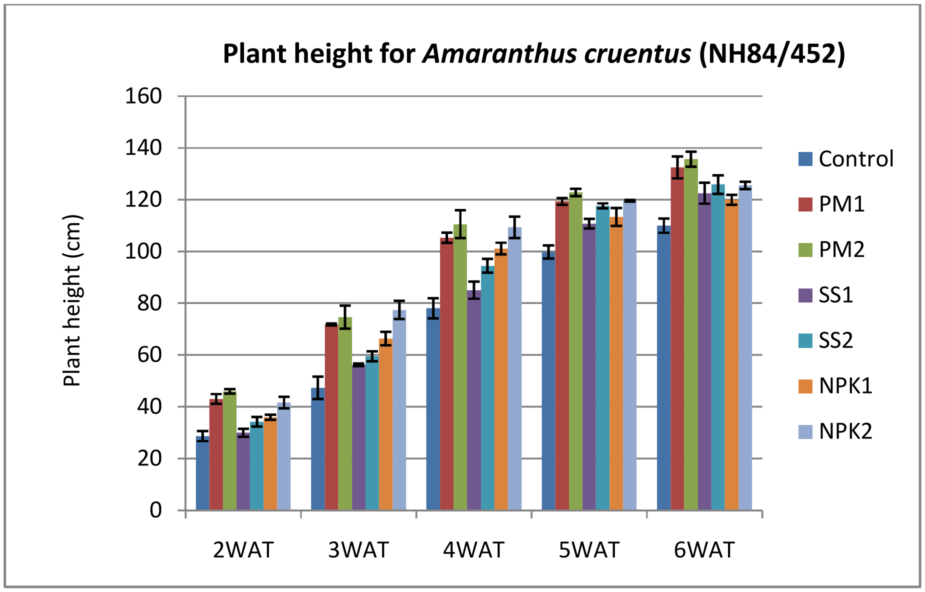

Fig. 2. Effect of organic fertilizers on plant height of *Amaranthus cruentus* (NH84/452)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1};SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

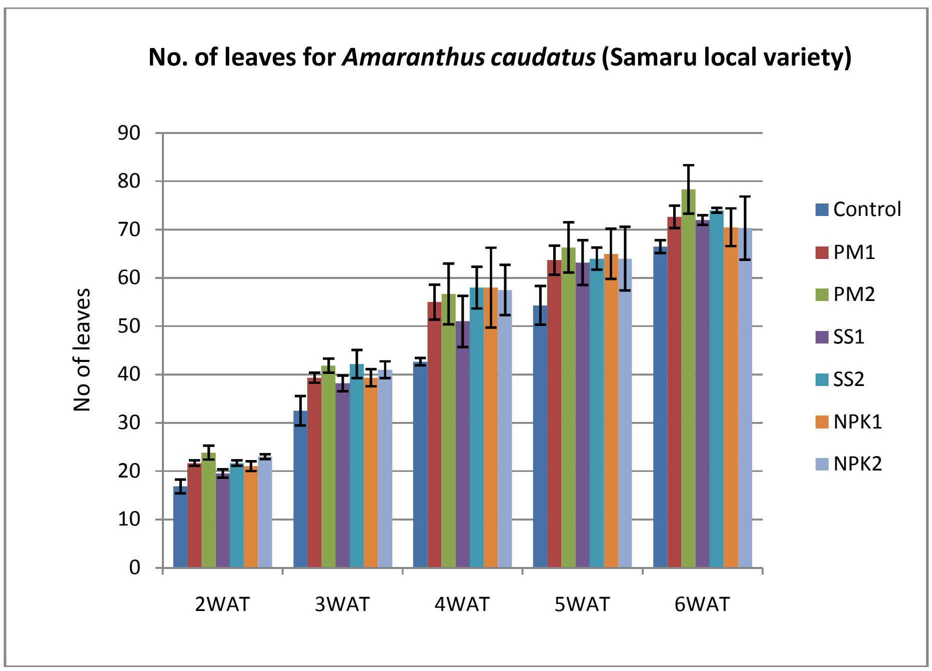

Fig. 3. Effect of organic fertilizers on number of leaves of *Amaranthus caudatus* (Samaru local variety)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1}; SS1= Sewage sludge at 5 t ha^{-1} ; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

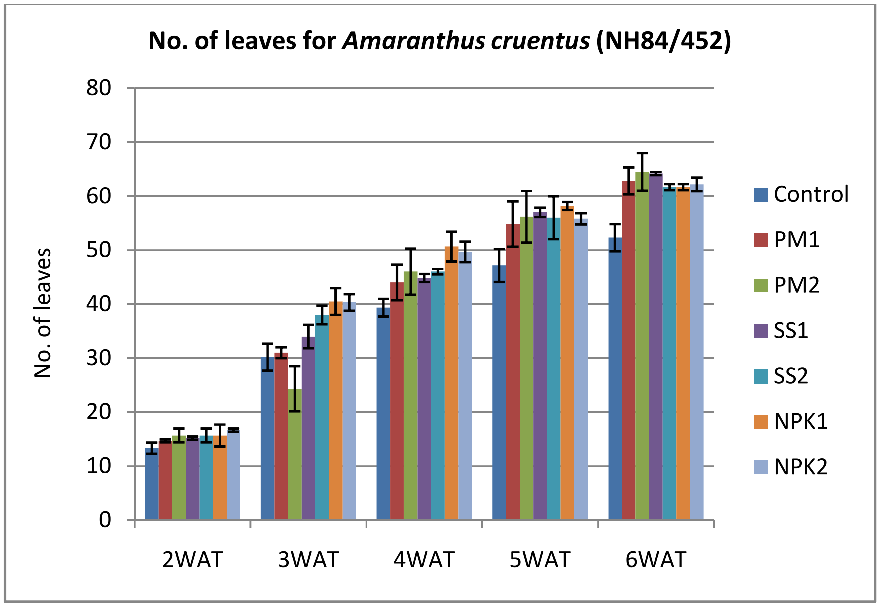

Fig. 4. Effect of organic fertilizers on number of leaves of *Amaranthus cruentus* (NH84/452)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1}; SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

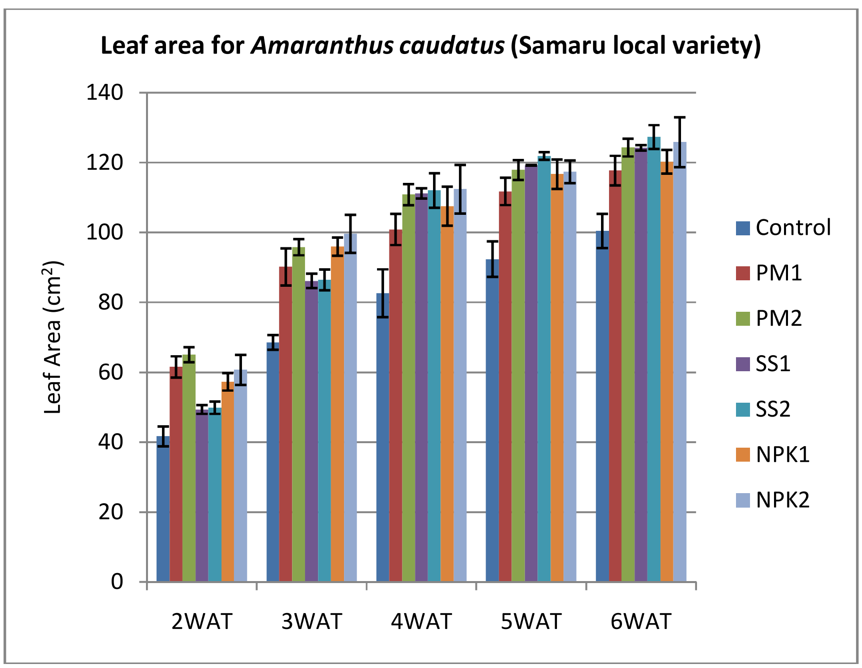

Fig. 5. Effect of organic fertilizers on leaf area of *Amaranthus caudatus* (Samaru local variety)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1};SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

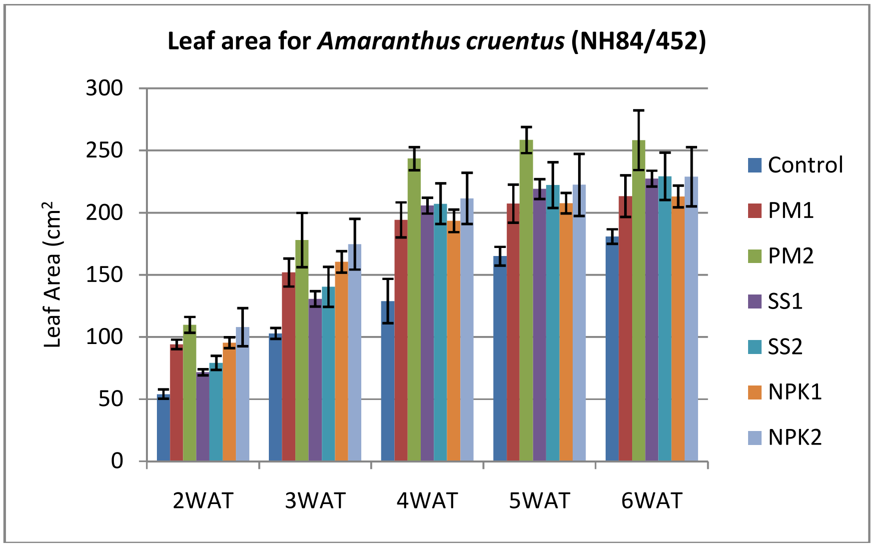

Fig. 6. Effect of organic fertilizers on leaf area of*Amaranthus cruentus* (NH84/452)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1};SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

3.6 Leaf Area Index

Leaf area index which indicates the photosynthetic ability of the plants was significantly (*P*= .05) higher in plants derived from plots treated with 10 t ha^{-1} poultry manure for both *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452) with values of 23.74 ± 1.96 and 41.72 ± 5.48 respectively and was lowest for plants derived from plots with no fertilizer added for both varieties as shown in Fig. 7 and Fig. 8. The 10 t ha^{-1} poultry manure treatment resulted in the highest leaf area index for both varieties of amaranth which is consistent with report on red lettuce [7]. The positive effect of poultry manure

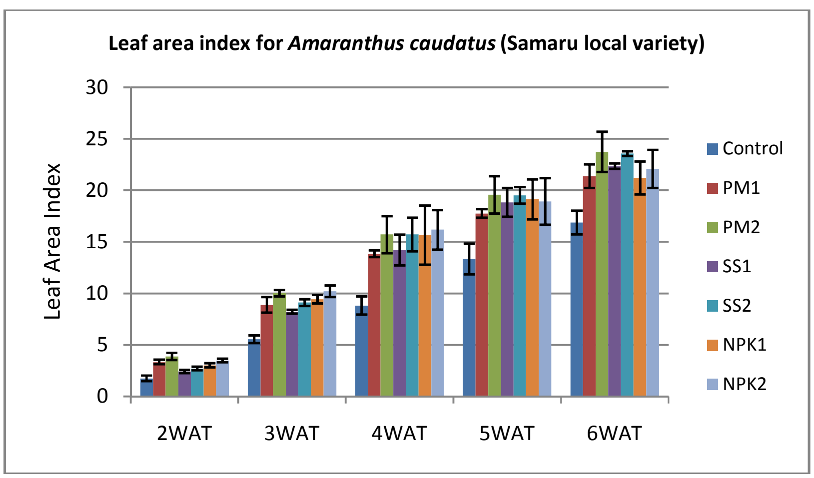

Fig. 7. Effect of organic fertilizers on leaf area index of *Amaranthus caudatus* (Samaru local variety)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1};SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

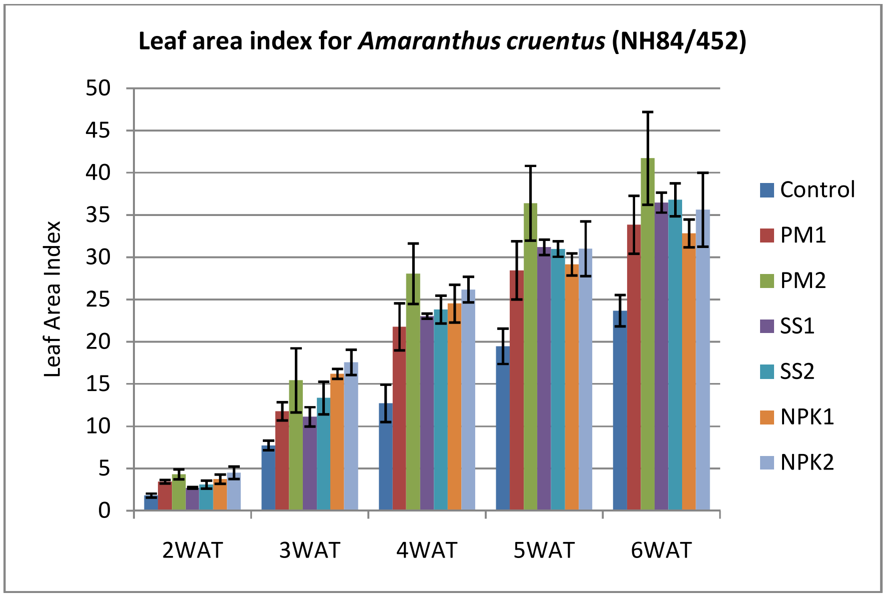

Fig. 8. Effect of organic fertilizers on leaf area index of *amaranthus cruentus* (NH84/452)

Mean values ± standard deviation of triplicate analysis

WAT=Week after transplanting; Control= No fertilizer; PM1=Poultry manure at 5 t ha^{-1}; PM2= Poultry manure at 10 t ha^{-1}; SS1= Sewage sludge at 5 t ha^{-1}; SS2= Sewage sludge at 10 t ha^{-1}; NPK1= NPK compound fertilizer at 35 kg ha^{-1}; NPK2= NPK compound fertilizer at 70 kg ha^{-1}

increasing leaf area index of amaranth was earlier reported by Egharevha and Ogbe, [17]. Law-Ogbomo and Ajayi [22] also reported similar results on *Amaranthus cruentus*. Leaf area index and number of leaves follow the same pattern as both are directly related. The higher leaf area index in poultry manure was caused by the relatively higher nutrient availability which increased the leaf length, number of leaves and leaf width per unit area of the plot. Normally, inorganic chemical fertilizer nutrients are soluble, so the nitrogen was quickly released into the soil thus leading to fast leaf growth and development. However, during maturity, leaf development declined because the nutrients were probably exhausted in the soil. This resulted in the leveling of the leaf growth and development between NPK compound fertilizer, sewage sludge and poultry manure at maturity as sewage sludge and poultry manure was continuously releasing nitrogen. Organic manures like cattle manure and poultry manure have been reported to release both micro and macro nutrients slowly resulting in subsequent promotion of vegetable growth [28,29,30].

4. CONCLUSION

The rapidly rising cost of chemical fertilizers has forced small scale vegetable farmers to look for alternatives such as organic fertilizers; the result of this present study justifies the use of some organic fertilizers over chemical fertilizer due to high vegetative growth and plant development. The present study revealed that application of poultry manure at 10 t ha^{-1} on average effected the highest growth and development of *Amaranthus caudatus* (Samaru local variety) and *Amaranthus cruentus* (NH84/452) with highest values for plant height, number of leaves, leaf length, leaf width, leaf area and leaf area index. This effect can be as a result of the slow decomposition and release of nutrients from the organic fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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