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The Effects of Organic Fertilizers on the Growth and Yield of Amaranthus (*Amaranthus hybridus* L.) Grown in a Lath House

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Authors' contributions

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

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ABSTRACT

Amaranthus is also known as African spinach is a good source of carotene, folic acid, vitamin C, calcium, iron and micronutrients. It is believed to have been used widely among hunter-gatherers. The objective of the experiment was to find the effects of organic fertilizers on amaranthus growth, development and yield. The experimental design was a Randomized Complete Block Design (RCBD) with four treatments and each replicated five times. Plant growth and yield increased ($P<0.05$) on amaranths fertilized with stillage. Kraal manure followed the stillage in terms of performance with the control (no fertilizer) recording the least significant effect on growth and yield of amaranthus. Because of stillage's impact on the growth and yield of amaranthus, it is recommended for a grower aiming for high yields of amaranthus using organic fertilizer.

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1. INTRODUCTION

Plants and animals are important in supplying gardens with natural fertilizers through their excrements. Animal excrements including liquids and solids can be used for fertilizing gardens. Animal manures include cow dung (popular among most Swazi rural farmers), excrements from horses, goats, sheep, rabbits, poultry and slurry; this is a combination of urine and some solid dung forming an unpleasant smelling liquid. Urine and slurry contain nitrogen and mineral salts which are valuable for soil fertility.). Fodder which is eaten by animals is the source for the fertilizing elements contained in animal dung [1].

Commercial fertilizers are composed of mineral salts which are soluble in water. Fertilizers must be supplied in the right quantities and at the right time. Insufficient quantities are relatively less valuable. Excessive quantities, on the other hand, are not completely utilized by the plants which result in some fertilizer being leached away by infiltrating water and run-off, which becomes a waste of resources. Overdose will simply poison plants [2].

Amaranthus is also known as amaranth, African spinach, bush greens, spinach greens etc. Amaranths belong to the family Amaranthaceae. There is a large number of species and varieties of Amaranthus. Many hybrids occur between amaranths and have been designated as separate species. There are two kinds of amaranths i.e. vegetable and grain amaranths [3]. Amaranths are excellent vegetables because; they grow relatively fast with a relatively high yield potential (40 t/ha of fresh leaves or 4.5 t /ha of dry matter after four weeks from sowing). They are less susceptible to soil-borne diseases when compared with other vegetables, they are relatively easy to cultivate, they are suitable for crop rotation with any other vegetable crop and compensate for the high mineral uptake which is inherent, to a high yield and a good nutritional composition; amaranths react well to fertilizers especially to organic manure [4].

Because of the low cost of production and high yield, amaranth is one of the cheapest dark green leafy vegetables in tropical markets hence its description as a poor man's spinach. Even though amaranths are not virtually listed in agricultural statistics it does not make it any less important [5]. Amaranths can cause a weed problem due to their vigorous production. Seeds of weedy amaranths have remarkably long viability of up to 40 years [6], Norman [1] reported that the plant is an annual herb with erect thick succulent stems reaching a height of 0.6-2.0 m. Leaves are simple with long petioles and are alternate.

Most people living in rural areas of Swaziland cannot access vegetables such as spinach due to their scarcity and price of seeds; as a result, they tend to rely on naturally growing amaranthus, which may not be enough to sustain them. Organic fertilizers are more available and relatively cheap when compared to the scarce and expensive inorganic (synthetic) fertilizers. So knowing the effect of using stillage and other organic fertilizers on the growth and yield of amaranthus is very important. The study was aimed at helping people living in rural areas to grow enough amaranthus to sustain themselves, by picking the best type of organic fertilizer to use in producing amaranthus.

2. MATERIALS AND METHODS

2.1 Experimental Site

The project was carried out at the University of Swaziland, Luyengo Campus, in the Horticulture Department lath house. The site is located at Luyengo, Manzini region, in the Middleveld agro-ecological zone. Luyengo is located at 26º34'S and 31º2' E. The average altitude of the area is 750 m above sea level. The mean annual precipitation is 980 mm with most of the rain falling between October and April. Drought hazard is approximately 40%. The average summer temperature is 27ºC and the winter temperature is about 15ºC. The soils of Luyengo are classified under the Malkerns series. The experimental lath house was made of black polythene net and light transmission into the lath house was 452 lumens. The experiment was carried out from late August 2012 up until late January 2013. The soils are Ferrasolic or merely Ferralitic soil intergrades to fersialitic soils or typic ultisoils. The soil used in the experiment area was sandy loam [7].

2.2 Experimental Layout and Design

Kraal manure was collected from the Animal Science Department and used as organic fertilizer. It is the most abundant and easy to access fertilizer in rural areas of Swaziland. Bare soil with zero or no fertilizer applied was sourced from the Horticulture Department, Farm and was used as the control treatment. Compost was obtained from Caters Garden Center, Mbabane, Swaziland. The compost contained NPK (0.8% N-10.5% P- 0% K). Stillage was obtained from Simunye Enviro Applied Products, Simunye, Swaziland. The stillage contained 1% N, 0.2% P and 5.5% K and was used as the fourth treatment. Watering was done twice a day in the morning and late afternoon, especially on hot sunny days. Lastly, amaranths seeds were germinated into seedlings for growing in the green house, sand was used as the germination medium [2].

The experimental design was a Randomized Complete Block Design (RCBD). The experiment consisted of five blocks which had 32 plants each (four treatments, each treatment having eight plants) randomly assigned [8]. Each plant was in a 61.3 cm^2 black polythene bag and the amaranthus seedlings were planted at the centre of the planting bag and the planting bags were spaced at 45 cm between two bags [2]. Amaranthus seeds sourced from the Malkerns Research Station were sown in two 100 cell trays filled with sand and subjected to germination requirements for six weeks (early August to late September) inside the greenhouse. Plastic bags with an inside bottom diameter and inside top diameter of 19.5 cm and a height of 35.5 cm was used to plant each amaranthus seedling. A 5 L knapsack sprayer was filled with 0.009 L (measured with a measuring cylinder) of stillage and topped up with room temperature tap water (room temperature) and mixed well by thorough shaking. This mixture was sprayed on the leaves of amaranth until they were saturated and the stillage mixture started to drip off, from the leaves. The remaining stillage in the sprayer was poured from the top of the sprayer into the soil to be absorbed through the roots. The kraal manure and compost were measured using a balance scale, the fertilizers were bagged, measured and applied in brown paper bags. The application rate was 3.25 kg/plant for both kraal manure and compost respectively (Table 1). A trowel was used to spread and mix the fertilizers with the soil until they were hardly visible. The soil was obtained from the Horticulture department farm, panel 17 and pasteurized at 80ºC for 30 minutes. After pasteurization the soil was poured into the planting bags using a trowel, the bags were filled to ½ full, ¾ full and 4/5 full for kraal manure and compost, stillage and control respectively.

Table 1. Application rates of the treatments

Treatment code	Treatment description	Rate of application/plant
(1)	Control	no fertilizer applied
(2)	Compost	3.25 kg
(3)	Kraal manure	3.25 kg
(4)	Stillage	9 ml

2.3 Soil Analysis

Samples of soil used in the experiment were sent to Malkerns Research Station laboratory for analysis. The experimental area soil was found to have a pH of 5.4, exchangeable acidity of 0.31 meq/100 g, phosphorus of 40 mg/kg and potassium of 112 mg/kg (Table 2). The Research Station recommended the application of Dolomitic lime at a rate of 1 ton/ha to raise the pH, but since amaranthus can grow in pH ranging from 4.5 to 8, so the dolomitic lime was not necessary. The nutrient composition of compost, kraal manure and stillage are shown in Table 2.

After transplanting, watering was done using a watering can. Irrigation was done according to what the plant needed for example phonologically, upon detecting that the soil and plant needed water. After watering at field capacity it would normally be done once in every three days. The compost and kraal manure were applied 6 weeks before transplanting at a rate of 3.25 kg per bag/ plant respectively and stillage was applied during transplanting and at 3 weeks after transplanting using a rate of 0.009 L per plant.

2.4 Data Collection

Data collection began on the second week after transplanting (WAT) when the amaranths were fully established and data collection continued at two-week intervals up until 8 WAT after transplanting. In each block, 20 plants (5 from each treatment) were randomly selected and tagged and used for data collection. The data collected included the following growth parameters: plant height, leaf area (length x width x correction factor 0.65), number of leaves, stem girth, leaf fresh mass, leaf dry mass and leaf colour score. The leaf area was determined by measuring the length (cm) and width (cm) of amaranth leaves that were fully developed, per plant using a ruler. The leaf length was

Table 2. The nutrient composition of garden soil, compost, kraal manure and stillage

Parameter	Type of medium component			
	Garden soil	Compost	Kraal manure	Stillage
pH (H_2O)	5.4	6.2	8.2	5.47
Exchangeable Acidity (meq/100 g)	0.31	0.25	0.2	0.2
P (mg/kg)	40	55	1975	150000
K (mg/kg)	112	135	11004	1800
N (mg/kg)	6.5	10.5	150	700

measured at the broadest part of the blade. The leaf area was calculated using the formula length (cm) x width (cm) x correction factor (0.65) of amaranth [2]. After measuring the fresh leaf mass, using the brown paper bags, the samples were placed in the oven for 24 hours (recommended time for amaranth leaves) at 100ºC even though 70ºC is the recommended drying temperature (the only oven the researcher had an access to, had stern written warning pinned on it, warning users not to change the 100ºC temperature when drying). After removing the samples from the oven they were allowed to cool down for about 20 minutes. Once they were cool the mass was measured using an electronic weighing scale (1000/0.1 g) made in Shanghai, China. Leaf colour rating was started at two weeks after transplanting and continued at two-week interval until the 8 WAT. Leaf colour density was virtually estimated using a leaf colour scores scale from 1 to 5 (1 = yellow leaves; 2 = yellow-green; 3 = light-green; 4 = green; 5 = very-green) [2].

2.5 Data Analysis

Collected data were analyzed using MSTAT-C statistical package [9]. Data were subjected to analysis of variance (ANOVA). Where statistical differences were detected, the mean separation was done by Duncan's New Multiple Range Test (DNMRT) at 5% probability level [8].

3. RESULTS

3.1 Plant Height

There were ($P<0.05$) differences in plant height at 2, 4, 6 and 8 weeks after transplanting between amaranths plants with no fertilizer applied (control), compost, kraal manure and stillage (Fig. 1). Amaranthus plants fertilized with stillage were found to have the highest mean plant height (cm), followed by plants fertilized with kraal manure, then compost. The lowest plant height (cm) was obtained from control plants (Fig. 1). At 2 weeks after transplanting the means of plant height were 6.4 cm, 6.7 cm, 7.1 cm and 7.9 cm for control, compost, kraal manure and stillage respectively. At 4 weeks after transplanting the means of plant height were 15.9 cm, 23.3 cm, 29.3 cm and 35.9 cm for control, compost, kraal manure and stillage respectively. At 6 weeks after transplanting means of plant height were 31.4 cm, 37.5 cm, 43.9 cm and 50.0 cm for control, compost, kraal manure and stillage, respectively. At 8 weeks after transplanting means of plant height were 39.4 cm, 48.4 cm, 60.6 cm and 69.8 cm for control, compost, kraal manure and stillage respectively (Fig. 1).

3.2 Leaf Area

There were ($P<0.05$) difference in leaf area at 2, 4, 6 and 8 weeks after transplanting between amaranths planted with no fertilizer (control), compost, kraal manure and stillage (Fig. 2). Amaranth plants fertilized with stillage were found to have the highest leaf area (cm^2), followed by plants fertilized with kraal manure, then compost and lastly the plants in the control (no fertilizer). At 2 weeks after transplanting the means of leaf area were 1.2 cm^2, 2.2 cm^2, 2.4 cm^2 and 3.0 cm^2 for control, compost, kraal manure and stillage, respectively. At 4 weeks after transplanting the means of leaf area were 3.1 cm^2, 3.6 cm^2, 4.1 cm^2 and 4.8 cm for control, compost, kraal manure and stillage, respectively. At 6 weeks after transplanting the means of leaf area were 7.9 cm^2, 9.0 cm^2, 9.4 cm and 9.9 cm^2 for control, compost, kraal manure and stillage, respectively. At 8 weeks after transplanting the means of leaf area were 12.0 cm^2, 14.3 cm^2, 16.7 cm^2 and 19.3 cm^2 for control, compost, kraal manure and stillage, respectively (Fig. 2).

3.3 Stem Girth

There were ($P<0.05$) difference in stem girth at 2, 4, 6 and 8 weeks after transplanting between amaranths plants planted with no fertilizer (control), compost, kraal manure and stillage (Fig. 3). Amaranthus plants fertilized with stillage were found to have the thickest stem girth (cm), followed by plants fertilized with kraal manure, then compost and lastly the plants in the control (no fertilizer). At 2 weeks after transplanting the means of stem girth were 0.29 cm, 0.33 cm, 0.35 cm and 0.38 cm for control, compost, kraal manure and stillage, respectively. At 4 weeks after transplanting the means of stem girth were 0.49 cm, 0.52 cm, 0.56 cm and 0.61 cm for control, compost, kraal manure and stillage, respectively. At 6 weeks after transplanting the means of stem girth were 0.61 cm, 0.68 cm, 0.754 cm and 0.86 cm for control, compost, kraal manure and stillage respectively. At 8 weeks after transplanting the means of stem girth were 0.81 cm, 0.93 cm, 1.02 cm and 1.17 cm for control, compost, kraal manure and stillage, respectively (Fig. 3).

3.4 Number of Leaves

There were ($P<0.05$) difference in the number of leaves at 2, 4, 6 and 8 weeks after transplanting between amaranths plants planted with no fertilizer (control), compost, kraal manure and stillage (Fig. 4). Amaranths plants fertilized with stillage were found to have the highest number of leaves, followed by plants fertilized with kraal manure, then compost and lastly the plants in the control (no fertilizer). At 2 weeks after transplanting the means of the number of leaves were 26.6, 31.9, 38.1 and 43.2 for control, compost, kraal manure and stillage, respectively. At 4 weeks after transplanting the means of the number of leaves were 41.8, 56.4, 66.3 and 73.5 for control, compost, kraal manure and stillage, respectively. At 6 weeks after transplanting the means of the number of leaves were 41.8, 56.4, 66.3 and 73.5 for control, compost, kraal manure and stillage, respectively. At 8 weeks after transplanting the means of the number of leaves were 58.6, 75.4, 88.40 and 95.60 for control, compost, kraal manure and stillage, respectively (Fig. 4).

3.5 Leaf Colour Scores

There was no ($P>0.05$) difference in leaf colour scores between amaranth plants planted with no fertilizer (control) and with compost at 2 weeks and 6 WAT (Fig. 5). There was ($P<0.05$) difference between kraal manure and stillage at 2 WAT and in leaf colour scores at 4, 6 and 8 WAT among the treatments applied i.e. control, compost kraal manure and stillage. At 2 WAT the means of leaf colour scores were 4.1, 4.0, 4.4 and 5.1 for control, compost, kraal manure and stillage, respectively. At 4 WAT the means of leaf colour scores were 2.2, 2.6, 3.6 and 4.4 for control, compost, kraal manure and stillage, respectively. At 6 WAT the means of leaf colour scores were was 5.0, 5.6, 6.0 and 6.6 for control, compost, kraal manure and stillage, respectively. At 8 WAT the means of leaf colour scores were 1.2, 1.8, 3.0 and 3.6 for control, compost, kraal manure and stillage, respectively (Fig. 5). The colour scores started In statistical analysis there is a bit high and almost the same level across all treatments at 2 WAT, then they dropped at 4 weeks and 8 WAT with the highest scores observed at 6 WAT. The amaranths at 2 WAT had a similar amount of nutrients available to them and were still at their early stage of development. At 4 WAT the amaranth had used up some of the initially available nutrients and was now at a bit higher stage of development than at 2 WAT hence the drop in leaf colour.

3.6 Fresh and Dry Leaf Masses

There were significant ($P<0.05$) difference in fresh leaf mass between amaranths plants planted with no fertilizer (control), compost, kraal manure and stillage (Fig. 6). Amaranths plants fertilized with stillage were found to have the highest fresh leaf mass (g), followed by plants fertilized with kraal manure, then compost and lastly the plants in the control (no fertilizer) (g). The means of fresh leaf mass were 16.2 g, 23.1 g, 28.7 g and 32.0 g for control, compost, kraal manure and stillage, respectively (Fig. 6).

There were significant ($P<0.05$) difference in dry leaf mass between amaranths plants planted with no fertilizer (control), compost, kraal manure and stillage (Fig. 6). Amaranths plants fertilized with stillage were found to have the highest dry leaf mass, followed by plants fertilized with kraal manure, then compost and lastly the plants in the control (no fertilizer). The means of fresh leaf mass were 4.1 g, 6.6 g, 8.2 g and 9.1 g for control, compost, kraal manure and stillage, respectively (Fig. 6).

4. DISCUSSION

There were ($P<0.05$) differences in plant height at 2, 4, 6 and 8 WAT. Amaranthus plants fertilized with stillage were found to have a higher mean plant height followed by plants fertilized with kraal manure, compost and control, respectively. The findings of this study were in line with findings by Ogunlela, et al. [10] who reported that amaranth height increased with fertilizer application. During transplanting there were some difficulties with maintaining the planting bag shapes as they were still new, this resulted in some of the amaranths to be not aligned in the centre of the bag as per requirement.

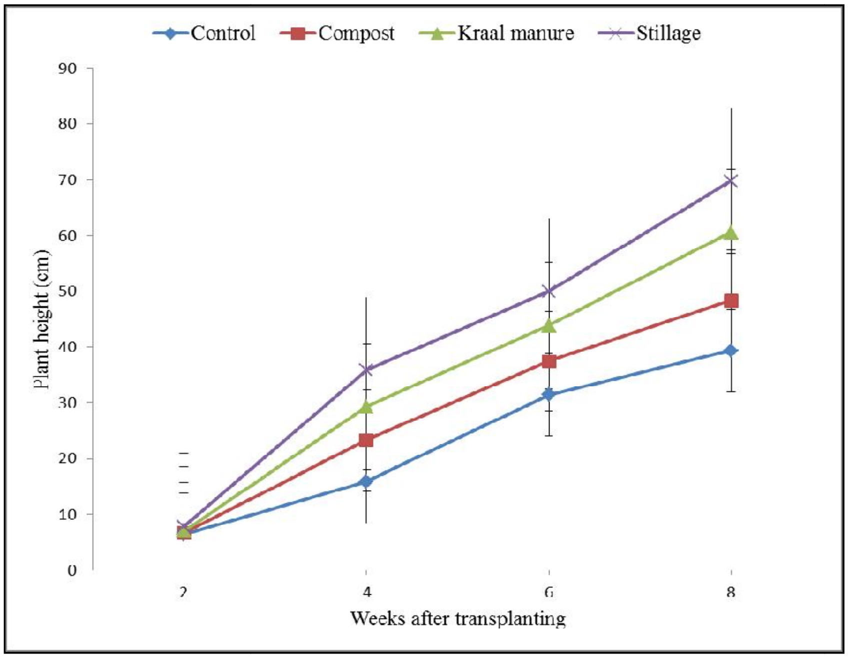

Fig. 1. Effect of different types of organic fertilizers on plant height of *Amaranthus hybridus L.* throughout 8 WAT

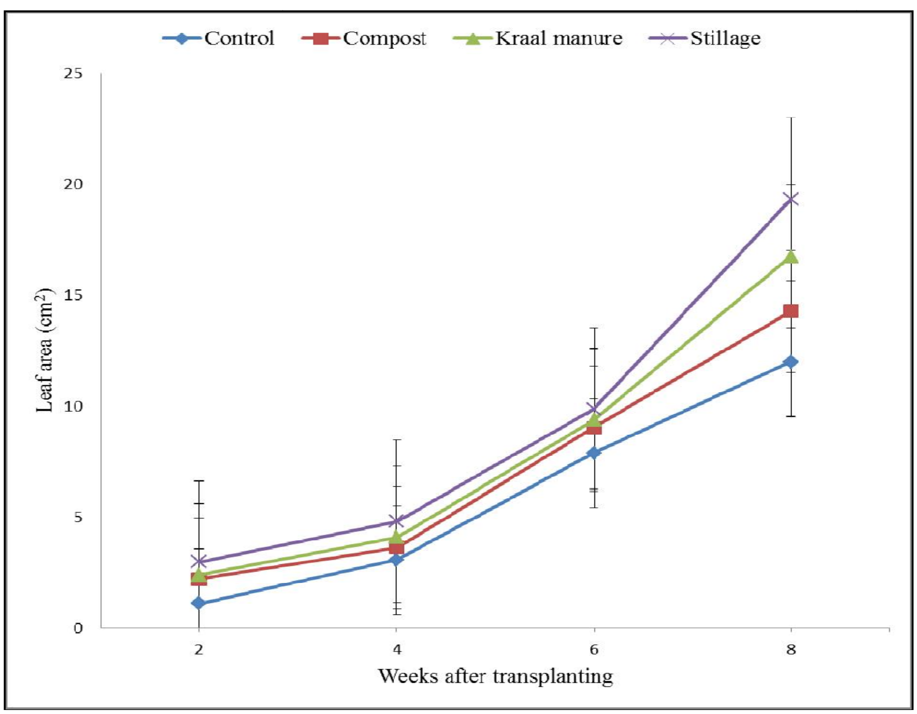

Fig. 2. Effects of different types of organic fertilizers on the leaf area of *Amaranthus hybridus L.* over a period 8 WAT

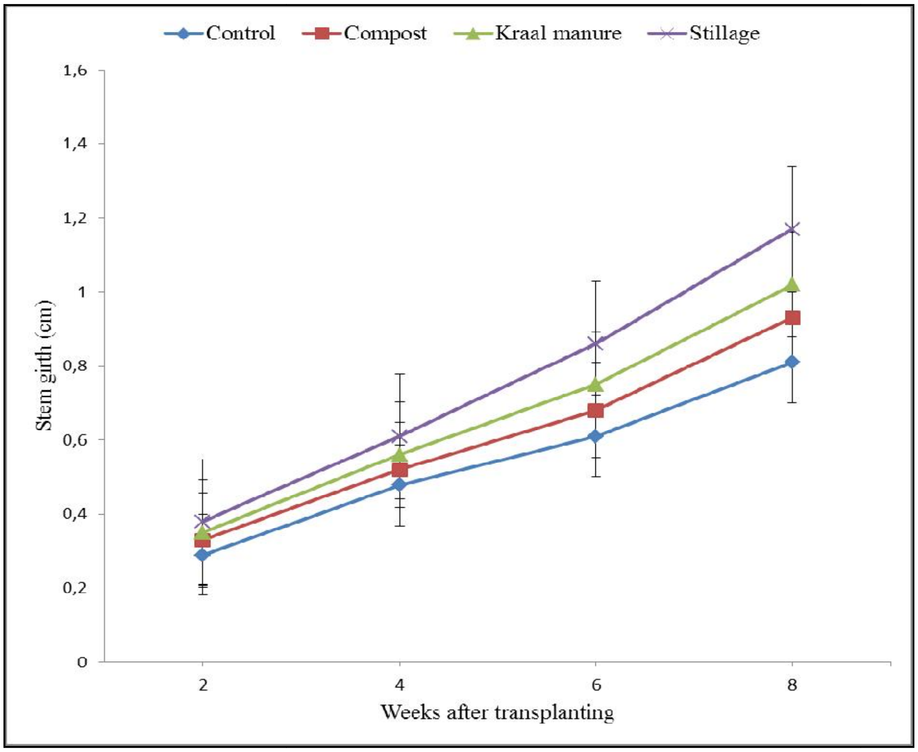

Fig. 3. Effects of different types of organic fertilizers on stem girth (cm) of *Amaranthus hybridus L.* throughout 8 WAT

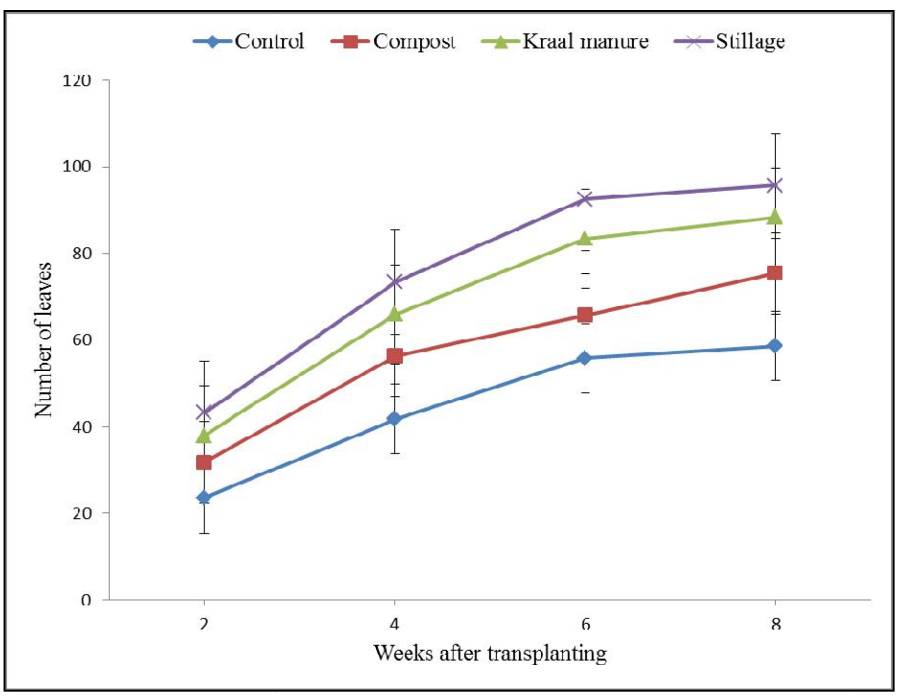

Fig. 4. Effects of different types of organic fertilizers on the number of leaves of *Amaranthus hybridus L.* throughout 8 WAT

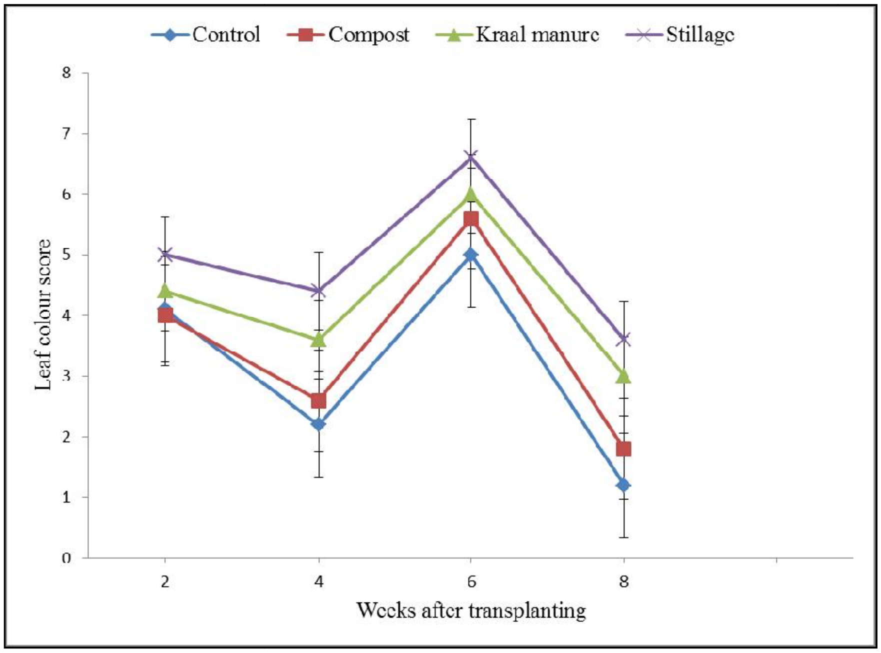

Fig. 5. Effects of different types of organic fertilizers on leaf colour score of *Amaranthus hybridus L.* throughout 8 WAT

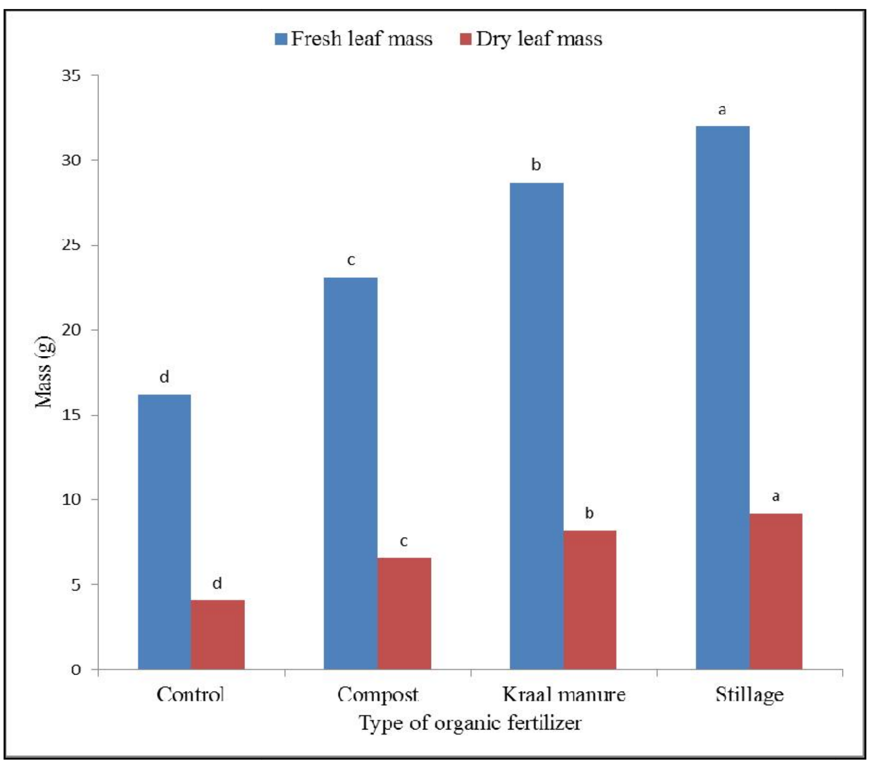

Fig. 6. Effects of different types of organic fertilizers on fresh and dry leaf mass of *Amaranthus hybridus L.* throughout 8 WAT. Bars with the same letter are not significantly different from one another at P=0.05. Mean separation by Duncan's New Multiple Range Test (DNMRT)

There were (P<0.05) differences in leaf area at 2, 4, 6 and 8 WAT. Stillage had the highest mean leaf area followed by kraal manure and compost, respectively, with the control having the lowest mean leaf area. The findings were in related with those of King, et al. [11] even though they were not for the same crop, who reported that stillage increased leaf area in sugarcane. This could be attributed to the large quantities of available potassium contained in stillage [12].

There were (P<0.05) differences in stem girth between the four treatments, at 2, 4, 6, and 8 WAT. The mean stem girth was found to be relatively higher for plants from both stillage and kraal manure while compost and control recorded the lowest in that order, respectively. The findings of this study were consistent with findings by Edje and Ossom [2] who reported that growth including stem girth increased with increased application of organic fertilizers.

There were (P<0.05) differences in the number of leaves at 2, 4, 6 and 8 WAT. Stillage had the highest mean number of leaves followed by kraal manure and compost, respectively; with the control having the lowest mean number of leaves. The number of leaves although not in severity may have been affected by natural abscission (dropping off of leaves) due to disease attack in some Amaranth plants or underdeveloped leaves in other amaranth plants [3].

There were significant differences in leaf colour score between plants in compost and control at 2 and 6 WAT. There were differences in leaf colour score at 4 and 6 weeks after transplanting. Although statically leaf colour score of plants fertilized with stillage was not (P>0.05) different from leaf colour score of plants fertilized with kraal manure; it had a higher mean leaf colour score than kraal manure mathematically. The colour mean scores started as a similar score line then peaked and dropped towards the end of the experiment. The findings were consistent with those of Chang and Palanda [4] who reported that amaranths leave start out green or dark green and change to bright yellow with time. A possibility of human error exists under this parameter as the naked eye of the researcher was used to assign leaf colour scores to plants.

There were (P<0.05) differences in fresh leaf mass at 2, 4, 6 and 8 WAT. There was also (P<0.05) difference in dry leaf mass at 2, 4, 6 and 8 WAT. Amaranthus fertilized with stillage and kraal manure was found to have the highest mean dry and fresh mass (yield) followed by compost and lastly Amaranthus in the control. The findings of this study are similar with those of Masarirambi, et al. [6] who reported that although amaranths were a low management crop and grew in poor soils, the yield is increased with fertilizer application and that organic fertilizers do not only improve yield but it also maintains soil fertility. Increased vegetable yield with the use of kraal manure has been previously reported for okra [5]. Soil could be enriched with the application of organic material which tends to decompose and release relatively large amounts of nitrogen into the soil before planting each fresh crop to boost yield and nutrient uptake [10]. Such information must be conveyed to all stakeholders through extension [13,14,15].

5. CONCLUSION AND RECOMMENDATION

The results obtained from the investigation showed that all the organic fertilizers i.e. stillage, kraal manure and compost had (P<0.05) differences in six of the seven parameters of *Amaranthus hybridus L.* measured i.e. plant height, number of leaves, leaf area, stem girth, leaf wet mass and leaf dry mass. Leaf colour score was the only parameter where all the organic fertilizers showed no (P>0.05) difference. Stillage followed by kraal manure and compost in that respective order had the highest impact on growth and yield of *Amaranthus hybridus L.*

Further research on different stillage application rates may be done. This is because the Amaranthus responded exceptionally well to stillage in terms of growth and yield. The quality of Amaranthus in terms of taste should be added as a parameter in future researches. This is because most Swazi people usually go for tasty food over healthy food and having both qualities in the Amaranthus will be a leap forward towards promoting healthy eating habits in the Kingdom.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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