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Response of pig weed *Amaranthus cruentus* to organic and inorganic fertilizers

Reason Charachimwe[1], Lovejoy Tembo[*1,2], Sommerset Mhungu[1]

[1]*Faculty of Agriculture, Women's University in Africa, Harare, Zimbabwe*

[2]*Faculty of Agriculture, Zimbabwe Open University, Harare, Zimbabwe*

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Abstract

Amaranthus is a relatively new and underutilized crop that has developed from being a weed to a vegetable in many developing countries. However, its commercialization has been hampered by limited agronomic guidelines that will facilitate large scale production of the vegetable. A field experiment was conducted at Horticultural Research Centre in Marondera, Zimbabwe to investigate the response of *Amarunthus cruentus* to organic and inorganic fertilizer. The trial was laid out in a randomized complete block design with eight treatments replicated three times. The treatments used were 0 (control), 10, 15, 20t/ha cattle manure and four levels of inorganic fertilizers 100, 200, 300, 400kg/ha NPK (7:14:7). Significant differences ($P<0.05$) were observed with respect to germination percentage, fresh yield, number of shoots, stem girth and plant height. All the inorganic fertilizer treatments outperformed the organic fertilizer in all parameters assessed. Further research is recommended to determine the appropriate rates of organic fertilizers for optimum performance.

* **Corresponding Author:** Lovejoy Tembo ✉ ltembo13@gmail.com

Introduction

Amaranthus cruentus of the family Amaranthaceae is a dicotyledonous plant that is grown for its edible leaves and seeds. It originated from Central America and was an important crop during the Aztec, Mayan and Incan civilizations before it was outlawed by the Spanish because of its religious significance and use in ancient rituals (Venskutonis and Kraujalis, 2013; Eastman, 2014). More recently production of Amaranthus has risen owing to its high nutritive value and it has widely spread in all countries of tropical Africa. It is the main leafy vegetable in Benin, Sierra Leone, Togo and is very important in Southern Nigeria, Kenya, and Democratic Republic of Congo (Spetters and Thompson, 2007; Das, 2016). The crop is adapted to a variety of soil types including marginal soils, but grows best on deep well-drained fertile soils. Loose and friable soils with high organic matter content are ideal for an early crop and high yield (Palanda and Chang , 2003).

Amaranthus cruentus is finding popularity among African countries and has evolved from being a weed to a fully-fledged leafy vegetable (O'Brien and Price, 2008). In Zimbabwe it still is an underutilized crop but with potential for commercialization due to its nutritional and medicinal values (Schippers, 2000). Amaranthus is a nutritious vegetable and contains relatively high amounts of minerals and vitamins, which are needed for healthy body growth, sustenance and alleviation of hunger and malnutrition mostly experienced in developing countries like Zimbabwe (Aphane *et al.,* 2003). However, heavy feeder crop production in Africa is often limited by soil fertility in line with the law of the minimum (Johnson *et al.,* 2015). In Zimbabwe where two thirds of the soils are sandy and more often derived from granitic rock, there is inherent poor soil fertility therefore natural recapitalization from fallowing is often not adequate (Nyamangara *et al.,* 2000). Thus, attaining high yields without addition of fertilizers is often impossible for crops like *A. cruentus* which are heavy feeders (Olefintoye *et al*., 2015). Most smallholder farmers in Zimbabwe are resource-poor and may not afford the inorganic fertilizers due to exorbitant prices. Moreover, inorganic fertilizers are often in short supply and when they are available; their cost is prohibitive for the average farmer (Rukuni, 2006).

Besides being expensive, recent studies have shown that the presence of excessive amounts of nitrates and chemical salt of nitrogen from mineral fertilizers in food-stuffs is detrimental to health of mankind and animals (Panda, 2006; Forman and Silverstein, 2012). Moreover a continuous dependence on inorganic fertilizers leads to a decrease in organic matter content, degraded soil physical properties, increased rate of erosion and soil acidity due to instability of soil aggregates (Olowoake, 2014).

Organic manures are thus a viable option as they are economically and ecologically viable hence are a partial substitute to costly inorganic fertilizers. The use of organic fertilizers can improve the overall soil condition and reduce the pollution of the environment by inorganic fertilizers (Law-Ogbomo *et al.,* 2011). According to Panda (2006), the quality of crops is improved when they are produced organically than when grown using inorganic fertilizers. Moreover, studies have shown higher Vitamin C content in leafy vegetables produced organically than in conventionally produced vegetables (Williams, 2002).

The use of organic manures should thus be emphasised especially with the HIV/AIDS pandemic where organically produced vegetables are preferred because they boost immune system (Wright, 2008). However, there is limited information on vegetable amaranths production in Zimbabwe as the crop is relatively new and underutilised.

Therefore commercialisation of the crop means that proper agronomic guidelines that will facilitate the large scale production of the vegetable in viable manner need to be established. Thus, the objective of this research was to investigate the effects of organic and inorganic fertilizers on growth and yield of *Amaranthus cruentus*.

Materials and methods

Experimental site

The research was carried out at the Horticultural Research Centre which is located 67km east of Harare in Agro-ecological Region II in Mashonal and East Province of Zimbabwe. It is situated on longitude of 31° 28' E and, latitude of 18° 11' S and an altitude of 1630m above sea level. The area receives annual rainfall between 750 and 1000mm and experiences mean annual temperature range of 19.5 °C to 24.6°C. Day length ranges from 13.2 hours in summer to 11.1 hours in winter. The soils have a pH range of 4.0-4.3 on the Calcium Chloride Scale (Parwada *et al.,* 2016).

Experimental design and treatments

The experiment was laid out as a Randomised Complete Block Design with eight treatments replicated three times. The treatments consisted of four levels of NPK (7:14:7) compound fertilizer, 100, 200, 300 and 400kg/ha as inorganic fertilizer, three levels of cattle manure; 10, 20, 30t/ha as organic fertilizer and 0 as a control.

Soil and manure analysis

Pre-cropping soil physico-chemical analysis of the experimental site and manure was carried out prior to land preparation. The samples were analyzed for pH, total nitrogen, exchangeable bases, calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and phosphorus (P). Total nitrogen was analysed using the Micro-Kjedahl method described by Bremner (1960). Exchangeable calcium, magnesium, potassium and sodium were determined using the atomic absorption spectrophotometry and available phosphorous was determined using the Mehlich 3 method described by Mehlich (1984). The results of the analyses are presented in Table 1.

Trial management

Land preparation was carried out by digging and harrowing to give a well pulverised flat surface. Twenty-four gross plots measuring 1.8× 1.5m comprised of 6 rows per plot with access path ways of 0.6m. The inner 4 rows were considered as the net plot for assessment.

Decomposed cattle manure from three year old Tuli beef herd and inorganic fertilizer were applied as per treatment and were thoroughly incorporated into the soil in the dry state (Grubben, 2004).Amaranths seeds were drilled in situ in shallow furrows drawn 0.3m apart and covered with soil to a depth of 0.02m. A seed rate of 10kg/ha was used on each plot and irrigation was applied soon after planting to promote germination(Palanda and Chang, 2003). Gradually thinning was done at 0.05m height to a final spacing of 0.3 x 0.15m at two to three weeks after sowing (WAS). Weeds were managed occasionally by hand pulling to avoid crop damage throughout the period of the experiment. Cut worms and locustwere the common pest which were controlled twice using Carbarly and Malathion at application rates of 200 and 250g/ha respectively.

Data collection

Germination percentage was recorded at 50 % emergency. Plant growth parameters were recorded on 10 randomly selected plants on weekly basis. Plant height was recorded using a flexible tape measure. Numbers of shoots were physically counted and stem girth was measured using a veneer calliper at the plant crown. Gradual topping was done weekly to discourage early flowering and encourage prolonged harvesting. Fresh yield was measured using a digital scale.

Data analysis

Data was subjected to analysis of variance (ANOVA) using Genstat version 14 and mean separation was carried out using the least significant difference (LSD) test at 5% probability level.

Results and discussion

Percentage germination

Mean germination percentages showed significant differences within treatments ($P<0.001$). 400kg/ha NPK had the highest (85%) mean germination percentages while 20t/ha cattle manure had the lowest (20%) mean germination percentage. After mean separation all manure treatments did not show any significant difference ($p>0.05$) among themselves (Fig. 1).

Higher percentage germination on NPK amended soil can be ascribed to the availability of essential nutrients such as N, P and K. This was in agreement with Blackshaw and Rode (1991), who proposed that amaranthus is highly responsive to nutrients, especially the nitrate form of nitrogen which can stimulate seed germination. Levels of potassium and nitrogenous compounds have all been previously associated in relieving weed seeds from dormancy (Alboresi *et al.*, 2005).

Table1. Chemical composition of cattle manure and soil.

Parameter	Cattle manure	Soil
Total nitrogen	1.60%	0.05%
Available P	425mg/kg	3mg/kg
Exchangeable Mg	4775mg/kg	2375mg/kg
Exchangeable Ca	2525mg/kg	1500mg/kg
Exchangeable K	230mg/kg	25mg/kg
Exchangeable Na	70mg/kg	115mg/kg
Soil pH	-	5.2

This concurs with Baskin and Baskin (1998) who reported that nitrogenous compounds can stimulate germination of many weed species including amaranths. However, higher rates of cattle manure 15 and 20t/ha produced the least germination percentage (25% and 20% respectively (Fig. 1).

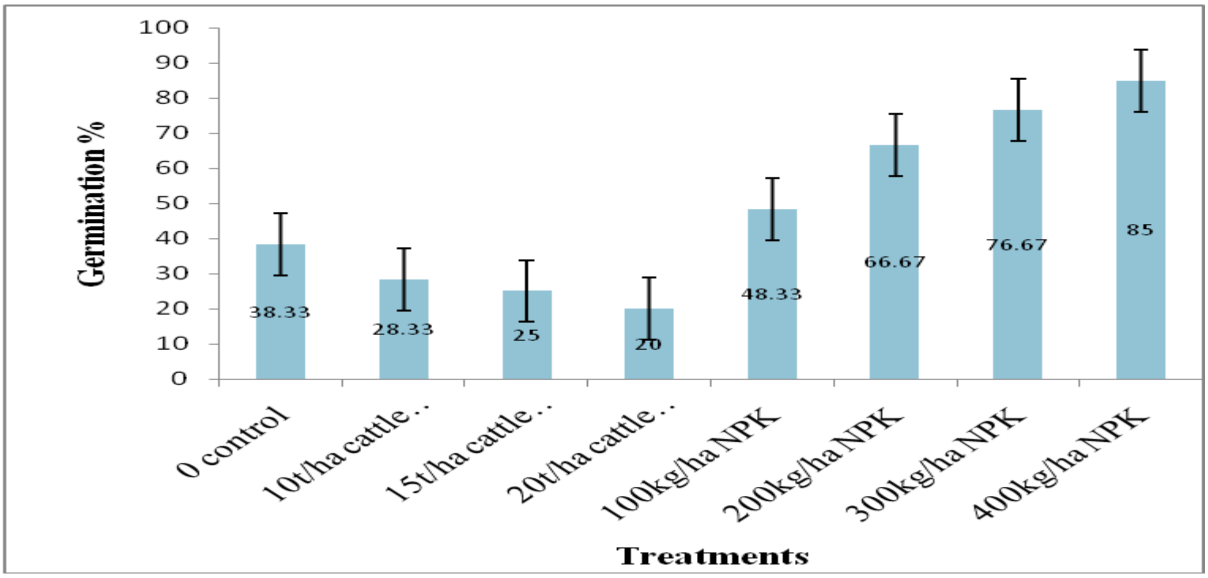

Fig.1. Effect of fertilisers on seed germination of *Amarathus cruentus.*

This could be attributed to the fact that as manure decomposes, more heat is produced which may have affected seed viability (Hartmann *et al.,* 2011). *Amaranthus cruentus* requires an optimum temperature of 18-25° C for germination because extreme temperature may lead to a series of morphological, physiological, biochemical and genetic changes that can adversely affect seed germination (Chayan *et al.,* 2003; Steckel *et al.,* 2004; ISTA, 2010;).However, from the weather data collected during the cropping season temperature ranged between 26 and 27 ˚C . This disparity could have affected seed germination because increased temperature by manure decomposition could have reached a lethal limit were the seed is injured or induced to secondary dormancy since the plant requires temperatures below 26°C (Steckel *et al.,* 2004: Bewley and Black, 1994).

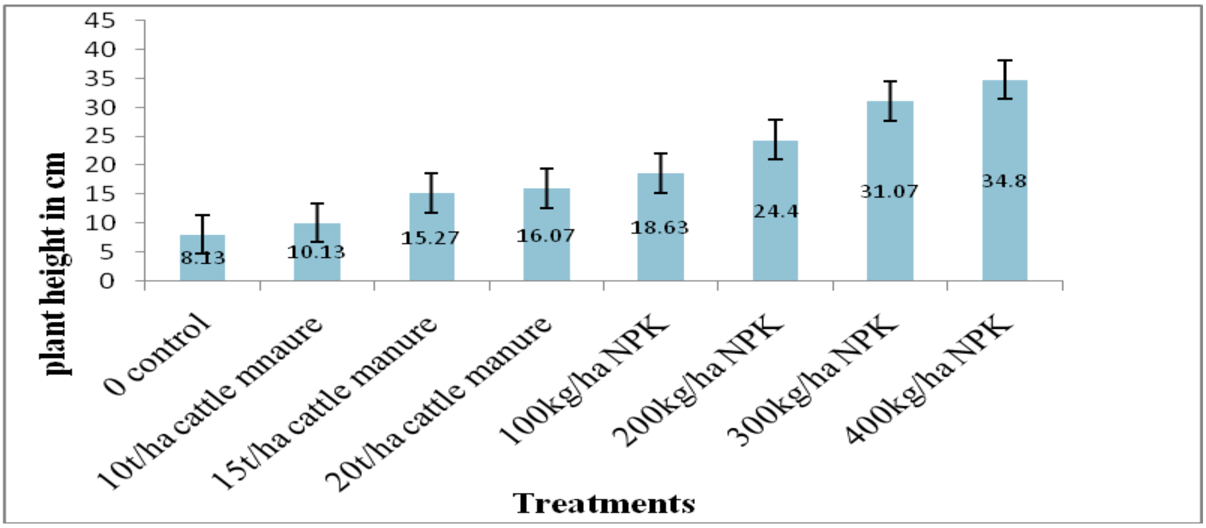

Fig.2. Effect of different fertilizers on plant height of *Amaranthus cruentus*.

This concurred with the findings of Sekar (2010), who reported that application of manure in higher doses can affect seed germination of *A. cruentus* due to increased temperatures. *Amaruthus cruentus* originated from Northern America where relatively low temperatures are experienced and is not well adapted to high temperatures (Nuugulu, 2001). According to Aufhammer *et al.*, (1998) germination of *A. cruentus* is photoblastic which enables it to germinate on soil surface or where it can take advantage of light to synthesise food, before food reserves of the small seed run out. Other researchers propounded that high germination response of amaranth cultivars depends on direct sunlight which helps in breaking seed dormancy (Dupriez and Leener, 1989: Aufhamme, 1998). Therefore, the application of cattle manure could have acted as a physical barrier to direct sunlight thereby inhibiting germination.

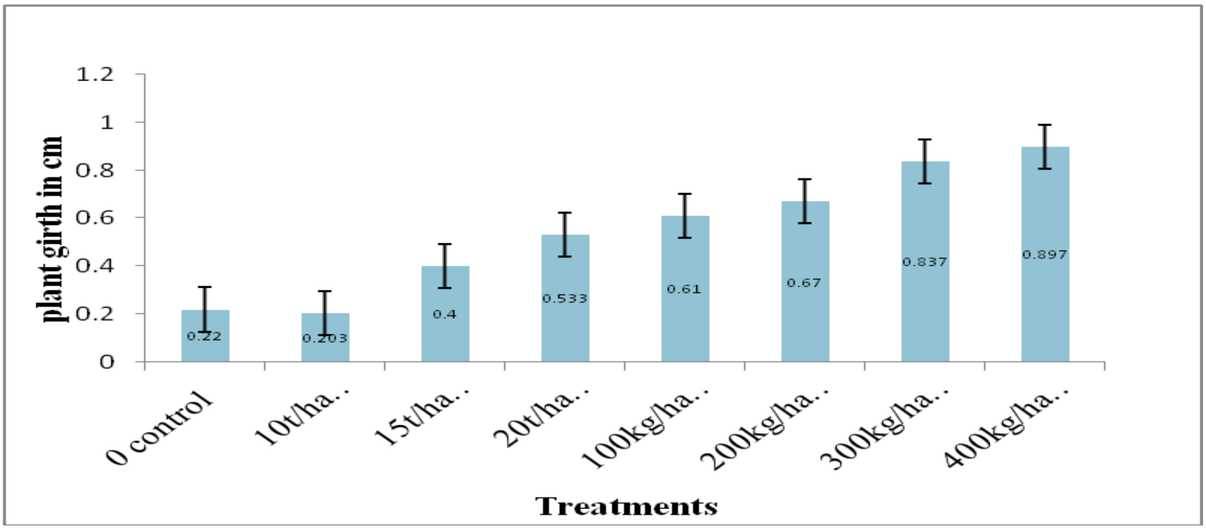

Fig.3. Effect of different fertilizers on plant girth of *Amaranthus cruentus*.

Plant height

Significant differences ($p<0.001$) were noted amongst treatments with respect to plant height. The highest mean height of 34.8cm was obtained from 400kg/ha NPK and the least plant height of 8.13cm wasobtained from control (0) treatment. The control treatment was not significantly different ($p>0.05$) from 10t/ha cattle manure (Fig. 2). The higher performance of amaranths in NPK fertilizer over cattle manure is indicative of the ease of dissolution of nutrients in the inorganic fertilizer being in a more soluble form readily available for plant uptake. According to Schippers (2000), *A. cruentus* requires soil with adequate mineral nutrients for rapid growth, hence NPK fertilizer could have met the nutrient requirements by quick mineralization of inorganic component supplying nutrients such as nitrogen. These results concur with the findings ofother researchers who confirmed an increase in growth of *A. cruentus* with application of NPK fertilizer (Law-Ogbomo *et al.,* 2011: Olofintoye *et al.*, 2015).

Plant girth

There was a significant difference (p<0.001) among treatments with respect to plant girth. The highest mean girth (0.897 cm) was obtained from 400kg/ha NPK and 10t/ha produced the least mean girth (0.203 cm) but was not significantly different from control (0) (Fig. 3).

The lowest growth responses obtained from 10t/ha cattle manure and control can be attributed to the low nutrient availability coupled with slow nutrient release nature of cattle manure. Compared to inorganic fertilizers, cattle manure contains relatively small amounts of nutrients which are not readily available for plant uptake (Lampkin, 2000). Hence it is possible that after emergence, the supply of essential nutrients was insufficient to promote continued rapid growth. Cattle manure also contains useful soil nutrients that are needed for growth of plants but their composition is in the crude form that is released slowly to the soil (Ayeni, 2010).

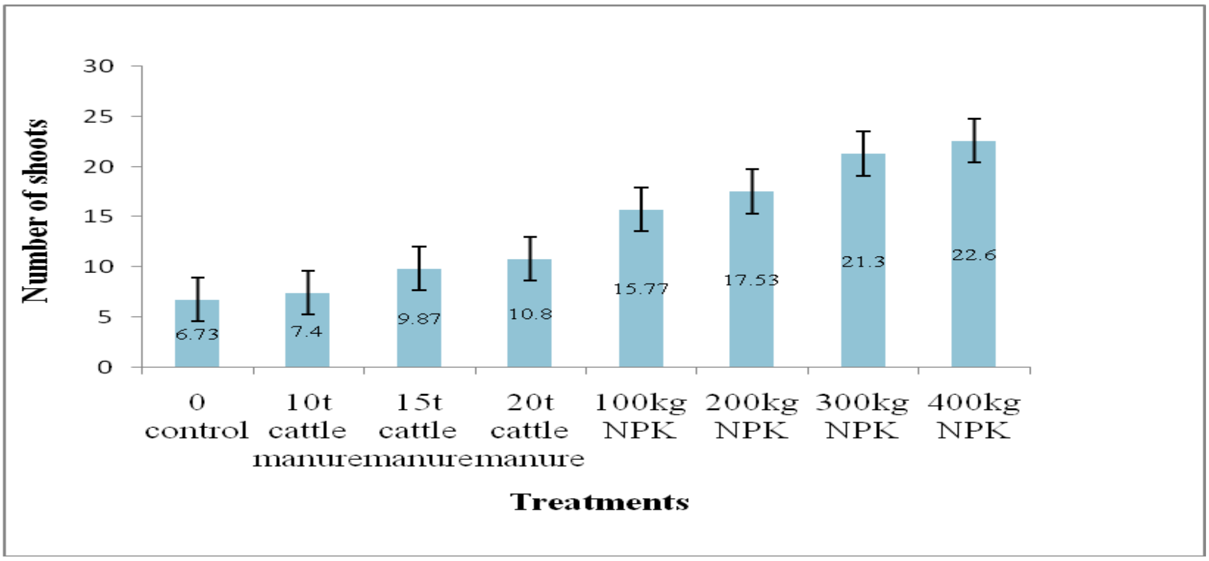

Fig. 4. Effect of different fertilizers on number of shoots of *Amaranthus cruentus.*

The rate of cattle manure decomposition could have been insufficient to release nitrogen rapidly enough to meet the needs of a fast growing plant such as amaranth.

Therefore, immobilisation of N and P by microbial activities could have exceeded mineralisation which decreases the nutrient availability for plant uptake. The findings of this research concur with Chiweta *et al.,*(2011),who observed that cattle manure need more time to decompose for the nutrients to be available for plant uptake and rapid growth.

Number of shoots

A significant difference in number of shoots was recorded (P<0.001) amongst treatments. 400kg/ha NPK produced the highest number of shoots 22.6 while the control (0) produced the least number of shoots (6.73) (Fig.4) but no significant difference was observed (p>0.05) among cattle manure and control treatments (Fig. 4).Pre-cropping soil analysis showed that the soil was low in nitrogen, phosphorus and slightly acidic (Table 1) which is less suitable for amaranths growth which requires a soil pH range of 5.5 (Chiweta, 2011).

Hence the poor growth rates and less number of shoots can be attributed to the inherent soil infertility and soil acidity which may have limited nutrient availability for plant uptake to promote cell division (Onyango *et al.,* 2011).

The acidic soil conditions inhibit availability of essential elements such as N and P and in acidic soils P forms compounds with iron and aluminium and these reactions reduce availability of P due to fixation (Mshelia, 2014; Jones, 2012).Control plants were stunted as they had to depend mainly on the low intrinsic soil fertility (Table 1).

Total fresh yield

A significant difference ($p<0.001$) was noted amongst treatments with respect to total fresh yield of amaranths. The highest mean fresh yield value of 11.83t/ha was obtained from 400kg/ha NPK which was not significantly different ($p>0.05$) from other NPK treatments. This could be attributed to the availability of nitrogen in NPK amended soil which stimulates plant vegetative growth and increase biomass. As a result, increments in leaf area increase the rate of plant photosynthesis and thus higher dry matter production.

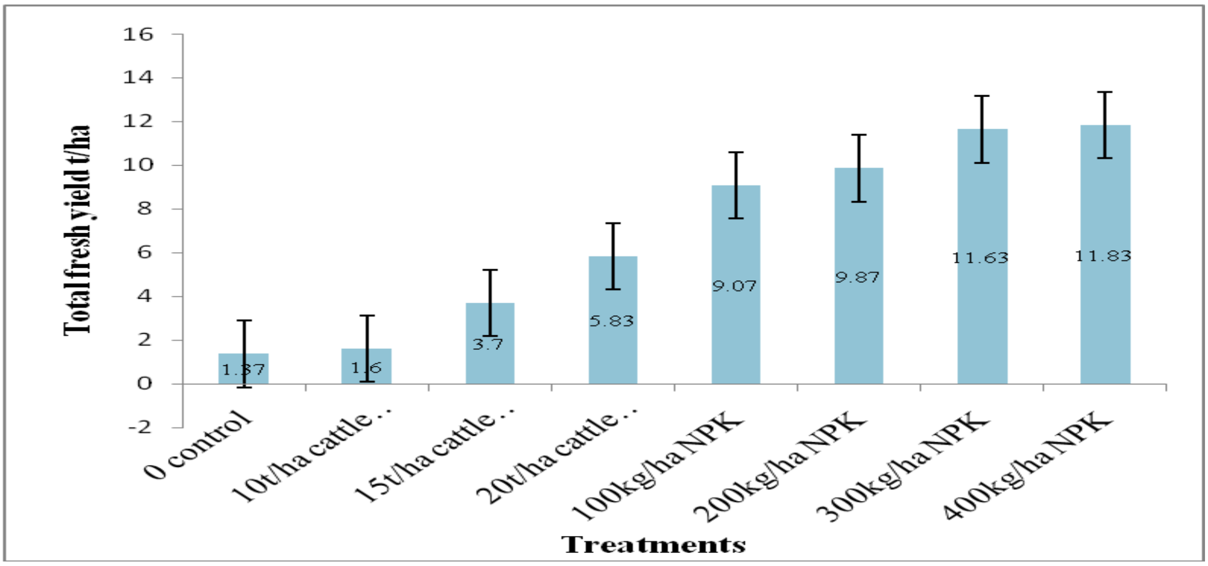

Fig. 5. Effect of different fertilizers on total fresh yield of *Amaranthus cruentus*.

This is in agreement with Olaniyi *et al.,(*2008), who reported that fresh and dry shoot yield was significantly influenced by applied nitrogen rates. The control (0) treatment produced the least fresh yield of 1.37t/ha which was not significantly different ($p>0.05$) from 10t/ha cattle manure (Fig. 5).

The lower yields could have been caused by poor growth due to poor soil fertility and slow release of nutrients from cattle manure (Naramabuye, *et al.,*2007). Lower yields in cattle manure amended soils concur with results of Adediran *et al.*,(2004), working with maize (*Zea mays*) and cow pea (*Vigniaung uiculata*) who reported that the use of manure did not result in significant yields. Plants that received cattle manure or no fertilizer were stunted in growth and pale in colour compared to healthy plants from NPK amended soils. This could be attributed to nitrogen deficiency which limits production of protein and other materials for new cells thus lowering yield. In general the maximum yield from this research (11.83t/ha) was low as compared to the results of Olaniyi *et al,* (2008) for different varieties of *Amaranthus*. The lower yields could have been caused by dry spells experienced during this study as the latter crop was grown under irrigation, while in the present study it was grown under rain fed conditions.

Conclusion

From the results of this experiment, it can be concluded that the application of inorganic fertilizer NPK (7:14:7) is effective in promoting germination, growth and yield of *A. cruentus*.

However, these results failed to justify the use of cattle manure over NPK (7:14:7) fertilizer due to low germination, growth and yields. Based on the results of this study, application of 400kg NPK (7:14:7) is recommended for optimum germination, growth and yield of *A. cruentus*. However, due to residual effects of inorganic fertilisers, further research is recommended to determine the appropriate rates of organic fertilizers for optimum performance.

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