Original Research article

Response of growth and grain yield of Amaranth (*A. hypochondriacus*) to combined manure and inorganic fertilizer pellets and non-pellet application

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ABSTRACT

Grain amaranth (*Amaranthus hypochondriacus* L) has high potential to substitute expensive animal protein because of its high nutritional value and could reduce protein malnutrition in Kenya. However, its production and consumption is low.. Nitrogen fertilization is among the most important factors limiting productivity. Most farmers use manure and little or no fertilizer. Manures alone cannot meet crop nutrient demand over large areas because of the limited quantities, low nutrient content and the high labour requirement. Manure – fertilizer augmented pellets have been suggested as improved alternative.. This study investigated the effects of pellet fertilizer, produced by mixing calcium ammonium nitrate (CAN) and dry cow dung manure on growth and grain yield over a period of two years. The experiment was laid as randomized complete block design (RCBD) with split plot arrangement and replicated three times. The treatments were different combinations of organic and inorganic fertilizer; 0 percent inorganic N and 100 percent organic N, 25 percent inorganic N and 75 percent organic, 50 percent inorganic N and 50 percent organic N, 75 percent inorganic N and 25 percent organic N 100 percent inorganic and 0 percent organic. The controls consisted of non-pelleted combinations and a no fertilizer treatment. All the pellet fertilizer treatments had higher dry matter weight, 1000 seed weight and grain yield compared to control and non-pelleted treatments. Fertilizer combination of 75 percent Organic N and 25 percent inorganic N had the highest grain yield while fertilizer combination of 25 percent organic and 75 percent inorganic recorded the lowest grain yield compared to the other combinations. The use of pellet fertilizer increased grain yield and could be a fertilization alternative, however recommendation for adoption should be done after economic analysis.

Keywords: Acidic acrisols, Grain Yield, Kenya, Inorganic organic combination, Tropics

1. INTRODUCTION

Grain amaranth (*Amaranthus hypochondriacus*) as a vegetable or as grain has been suggested to be a cheap alternative to meat as a protein source.The crop is rich in protein, carbohydrates, lipids, fibre and mineral salts (1). It has 12 to 18 percent crude protein (dry matter basis), which is higher than most grains except soybeans [1; 2]. The lysine content is twice that of wheat protein, three times that of maize, and as much as is found in milk [3]. The amino acid composition of amaranth protein compares with the FAO/WHO protein standard (1).

Grain amaranth has been used in the management of various medical issues among them: diabetes, migraines, hypertension, liver disease, hemorrhage, TB, HIV/AIDS, wounds, kwashiorkor, marasmus, stunting, diarrhea and skin diseases [4]. Besides, it grows fast, is high yielding under a wide range of agro-climatic conditions, is easily digestible, even by convalescents and is tasty in a variety of forms.

Water requirement for growing grain amaranth is 42-47 percent that of wheat, 51-62 percent that of maize and 79 percent that of cotton [4]. In general amaranth is extremely drought tolerant [5]. Some grain will be produced as long as there is enough moisture in the soil for the seeds to germinate, and as long as there is enough rainfall about three weeks after emergence [4]. In regions with marginal rainfall, grain amaranth rather than maize should be grown as a food crop because there is less risk of crop failure.

With its desirable characteristics, grain Amaranth is a crop of choice for food and nutrition security and more importantly as an adaptation/mitigation strategy to climate change. Nevertheless, a survey done in Kenya in 2008 in the Lake Victoria Basin, farmers indicated that lack of awareness on crop husbandry, low soil fertility, and utilization limits the production of grain amaranth [6]. The average grain yield of grain amaranth is 1 t/ha compared to 2.5 t/ha and 3 t/ha achieved with optimal use of fertilizers in Kenya and other countries. Low and declining soil fertility due to continuous cultivation, soil erosion and nutrients losses through runoff and leaching is a serious problem in many parts of Kenya [7]. It is estimated that 30% of increases in harvests by small-scale farmers in the third world in the last three decades is attributable to the use of chemical fertilizers [8]. However, because of escalating chemical fertilizers prices, green manure crops, compost and animal manure are increasingly being used for soil fertility management [9]. In Kenya, only 25% of grain amaranth farmers use either inorganic or organic fertilizer albeit in quantities less than the recommended rates. Most of the farmers are resource poor and cannot afford mineral fertilizers; hence net negative balances of nutrients occur as nutrients are removed from the farm by the harvested product [10]. A key resource that can be used to reverse this trend is manure from livestock which is available at the farm level. However, the use of organic manures alone cannot meet crop nutrient demand over large areas because of the limited quantities available, the low nutrient content of the materials and the high labor demand for processing and application [11]. Moreover, the decomposition of manure and the mineralization of the nutrients contained in it can be fairly slow. Hence to enhance the quality and effectiveness of organic manures, many researchers have recommended a fertilizer- augmented soil enhancing strategy which involves the combined use of manures and mineral fertilizers. This approach combines the short term benefits of mineral fertilizers with the long term values of organic manures [10]. Fertilizer pelleting is one of the slow release technologies. Pelleting is a process of biomass densification which increases bulk density and decreases volume. The process uses some form of mechanical pressure to reduce the volume of grind material and converts the material to a solid form (pellets), which is easier to handle and store than original material. Pelleted fertilizer is a slow-release N fertilizer with long–term effects including reduced leaching losses and enhanced N uptake, as well as positive effects on both health and soil nutrient levels [10, 12, 13]. Fertilizer pelleting has been tried in crops like corn [12] and wheat [13]. There is limited information on use of fertilizer pellets in grain amaranth. The current research was therefore undertaken to investigate the appropriate organic and inorganic fertilizer pellet combination for grain amaranth production in Kenya.

2. MATERIAL AND METHODS

2.1 Site description

Field experiments were conducted during the short rain season of 2011 and the long rain season of 2012 at the Maseno University Research Farm, in Western Kenya. The area lies within latitude N 00 1'-S 00 12' and latitude E 340 24'- E340 47'. The rainfall distribution is bimodal with the long rains from March to July and short rains from September to December [14]. The area receives an annual average rainfall of 1750 mm and the temperature ranges from 15°C-31°C (15). During the experimental period, 1278 mm of rainfall was received in 2011 and 1088.5 mm during the months of January to September, 2011. The mean temperature in 2010 was 25.5°C and 25.3°C in 2012. The major soil type are acrisols [16]. The experimental plots had been under one year fallow before the onset of experiments. The base soil characteristics before the experiment were: Moderate in nitrogen (0.15 percent), low in phosphorus (2.00ppm), very low potassium (0.25 Cmol/kg), moderate organic carbon (1.44 percent) and moderately acidic (pH water; 5.52-5.81 and pH 0.01Cacl$_2$ 4.54-4.85). The nitrogen nutrient content of the pellets ranged from 2.1% to 3.5%. The other physical characteristics are listed in Table 1

Table 1. Properties of soil prior to planting

Property	0-15 cm	15-30cm
pH (H_2O)	5.52	5.81
pH(0.01MCacl$_2$)	4.54	4.85
%Carbon	1.44	1.06
%Nitogen	0.15	0.15
K(cmol kg)	0.25	0.25
Ca (cmol kg)	5.00	3.75
Mg (cmol kg)	1.00	3.00
CEC (cml kg)	11.60	10.80
P (ppm)	2.00	1.00

2.2 Soil Sampling

Soil samples were collected from the experimental plots to establish the initial soil fertility status. Sampling was done the top soil (0-15 cm) and sub-soil (15-30 cm) from each plot using a zig-zag pattern. The soil from the plots was thoroughly mixed to form a composite sample from which a 500 gm portion was picked and subdivided into working samples. Analysis for major nutrients such as Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Cation Exchange Capacity (CEC) and pH was carried out using the acid/alkaline digestion method of analysis as described [7]. The Mehlich- method as described by [(7)] was used to extract P by adding 25 ml of Melchi solution (0.0125 M H2S04 + 0.025 M HCl) to 5 g of soil and shaking suspension for 5 minutes on a reciprocating shaker and P quantified colorimetrically using a spectrophotometer (430 nm wavelength). K was determined using the Flame photometry method.

2.2 Experimental design and agronomic practices

The experiment was laid out as randomized complete block design (RCBD) with split plot arrangement and replicated three times. The main plots measured (17mx6m) with 1m in between. The main plot treatments were pellet fertilizer and non-pellet fertilizer. The subplots measured (3mx6m) with 1m in between. The subplot treatments were of fertilizer combinations: T1- 0 percent inorganic N and 100 percent organic N(9 T ha^{-1}manure), T2 – 25 percent inorganic N and 75 percent organic N (83.3 kg ha^{-1}CAN + 6.8 T ha^{-1}manure), T3 – 50 percent inorganic N and 50 percent organic N (168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure), T4- 75 percent inorganic N and 25 percent organic N (252.8 kg ha-1CAN + 2.3 T ha^{-1}manure), and T5 - 100 percent inorganic and 0 percent organic. Dry cattle manure was used as the organic fertilizer. Calcium ammonium nitrate (CAN) was used as the source of inorganic nitrogen. The pellets were made using a disk type pelleter [22]. Before pelleting, dry cow dung manure and CAN were mixed in the required ratios and ground using a hammer mill. The ground samples were compressed by the pelleter at 270 mp compressive force [22]. Results of laboratory analysis of the manure and pellets are presented in Table 2

Table 2. Nutrient content of the various pellet fertilizer treatments

Nutrient	Treatment				
	T1 manure	T2-83.25 kg ha^{-1}CAN + 6.75 T ha^{-1}manure	T3-168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure	T4-252.75 kg ha^{-1}CAN + 2.25 T ha^{-1}manure	T5-CAN
N- percent	0.83	6.10	13.80	19.5	26
P- percent	0.95	0.55	0.43	0.37	
K- percent	0.32	0.25	0.21	0.20	
Ca- percent	0.28	0.42	0.35	0.22	
Mg- percent	0.1	0.50	0.59	0.40	
C- percent	6.65				
C:N ratio	8.01				
pH (H_2O)	7.60				
pH(0.01MCacl$_2$)	7.20				
CEC (cml kg)	27.20				

Land preparation was done using a tractor powered disc plough and harrow. The seed bed was ploughed and harrowed to fine tilth prior to planting. The fertilizer treatments were mixed with soil before planting. Grain amaranth was planted at a spacing of 30cm x 60cm using hand hoes. Weeding was done three times; 3, 6 and 9 weeks after sowing in both years. All other agronomic practices utilized in experimental plots were that recommended for grain amaranth cultivation in the tropical highlands. These consisted of weed management practices, gapping, and pest control [6].

2.3 Data collection and analysis

Data on days to 50 percent flowering, days to 50 percent maturity, average plant height, stem width, number of leaves, inflorescence length, canopy, plants dry matter weight, grain yield and 1000 seed weight was collected.

Plant height and inflorescent length of grain amaranth were measured on five grain amaranth plants randomly sampled from the inner rows of each plot weekly starting from 5 weeks after planting to harvesting. Days to 50% flowering for each treatment were determined by getting the average of the period it took for half of the plants in each plot to flower. Days to harvest for each treatment were determined by the average period to physiological maturity. Dry matter yields were determined by destructive harvesting of 5 plants from the inner rows of each plot at harvest to avoid changing plant population in the course of plant growth. The plants from each treatment were chopped and dried separately at 65^{o}C for 48 hours in an oven. Grain yield was measured by harvesting the inner rows and the grain threshed and dried to moisture content of 12-13% and then weighed for yield analysis.

All data were subjected to Analysis of variance (ANOVA) using Genstat statistical program [Genstat, 2010]. Significant mean differences among the treatments were separated by Turkey's least significant difference procedure at 5% level of significance.

3. RESULTS AND DISCUSSION

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3.1 Effect of fertilizer application on growth parameters

Application of organic and inorganic fertilizer combinations had significant($p < 0.05$) effect on number of leaves, stem width, plant height, canopy size, and inflorescence length compared to the no fertilizer control (Table 3 and Figure 1). However, there were no significant differences between pelleted and non-pelleted treatments (hence only organic and inorganic combinations are presented). In the non-pelleted treatments, in 2011, the highest number of leaves of was observed in treatment with 83.3 kg ha^{-1} CAN and 6.8 ton ha^{-1} manure (25% inorganic and 75% organic) followed by the treatment with 9T ha^{-1} manure and no fertilizer (0% inorganic and 100% organic) (Table 3). The least number of leaves was observed in the controls with no fertilizer application. In 2012, the manure treatment had the highest number of leaves followed by 168.5 kg ha^{-1}CAN + 4.5 ton ha^{-1} manure then 83.25 kg ha^{-1}CAN + 6.75 ton ha^{-1}manure. In general manure treatment (0% inorganic and 9 ton ha-^{1} (100% organic) had significantly higher number of leaves while treatment 252.75kg ha^{-1} CAN and 2.3T ha^{-1}manure (75% inorganic and 25% organic) had the least number of leaves (Table 3). Length of inflorescence decreased with decreased proportions of manure. Treatment T1 (manure) had an average of 28.4 cm inflorescence length while T5 (CAN) had an average of 18.4 cm flower height (Table 3). On average the non-pellet fertilizer combinations had a higher inflorescence length compared to the pellet fertilizer combinations (Figure 2).

Table 3. Effect of organic and inorganic fertilizer combinations on amaranth growth

Treatment	Parameter							
	Number leaves/plant		Canopy size (cm)		Plant height (cm)		Inflorescence length (cm)	
	2011	2012	2011	2012	2011	2012	2011	2012
T1	29.3	35.5	40.1	42.7	81.3	131.9	28.4	34.8
T2	29.8	30.6	43.0	38.1	83.4	122.6	26.7	32.4
T3	19.4	34.7	35.8	34.4	68.8	98.6	20.1	24.1
T4	15.6	26.8	27.2	27.2	47.8	73.1	17.9	21.5
T5	16.8	16.4	27.4	17.0	55.7	43.4	18.4	22.1
Control	10.6	8.9	16.7	10.8	27.2	30.9	15.2	17.0
$LSD_{0.05}$	2.18	6.11	7.20	10.69	9.10	20.77	3.62	3.96

T = 9 ton manure ha^{-1}; T2 = 83.3 kg ha-1CAN + 6.8 T ha^{-1}manure; T3-168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure ; T4-252.8 kg ha^{-1}CAN + 2.25 T ha^{-1}manure; T5 = 183 kg CAN ha $^{-1}$

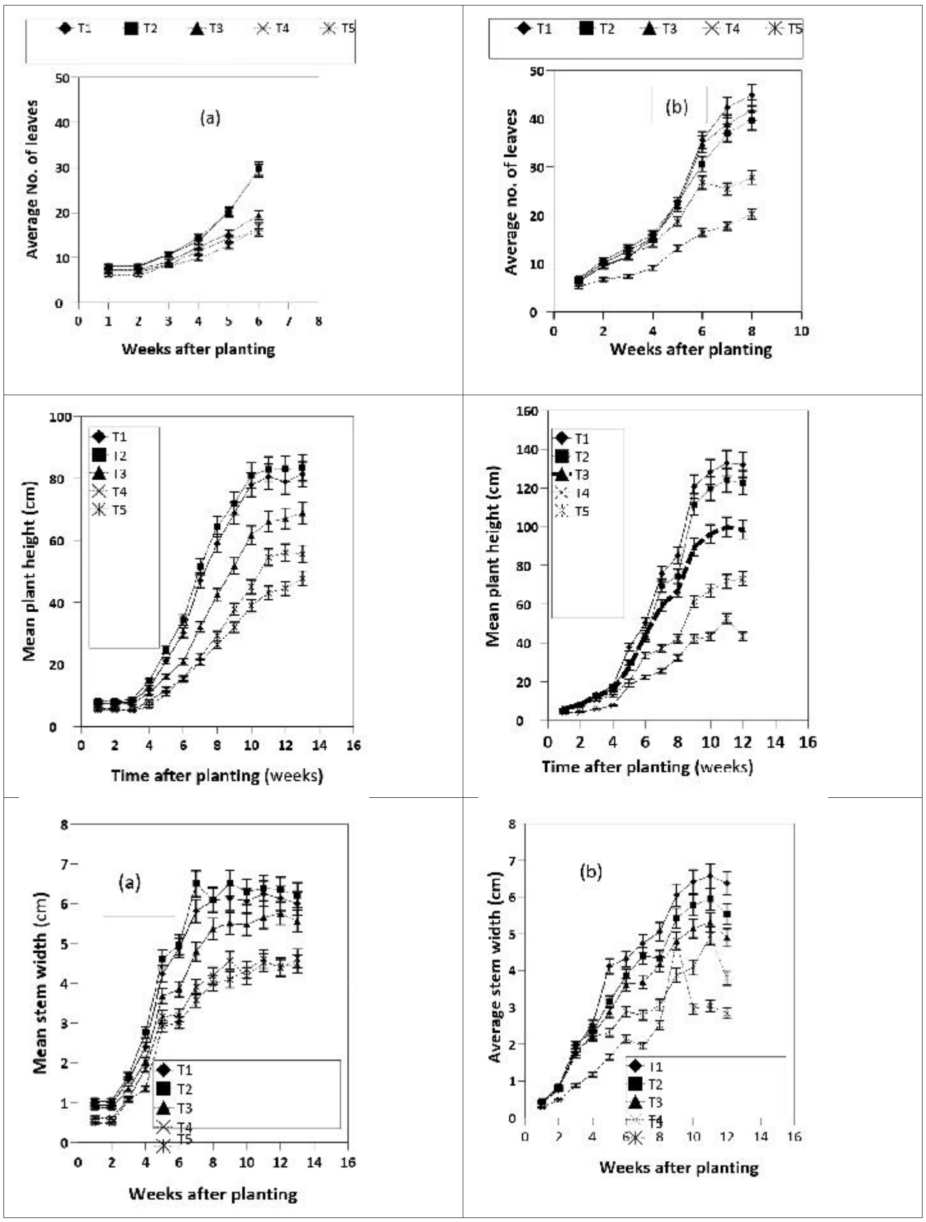

Figure 1. Effect of manure-fertilizer combinations on the growth of grain amaranth in 2011 (a) and 2012 (b) in Kenya. **T = 9 ton manure ha^{-1}; T2 = 83.3 kg ha-1CAN + 6.8 T ha^{-1}manure; T3-168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure ; T4-252.8 kg ha^{-1}CAN + 2.25 T ha^{-1}manure; T5 = 183 kg CAN ha $^{-1}$**

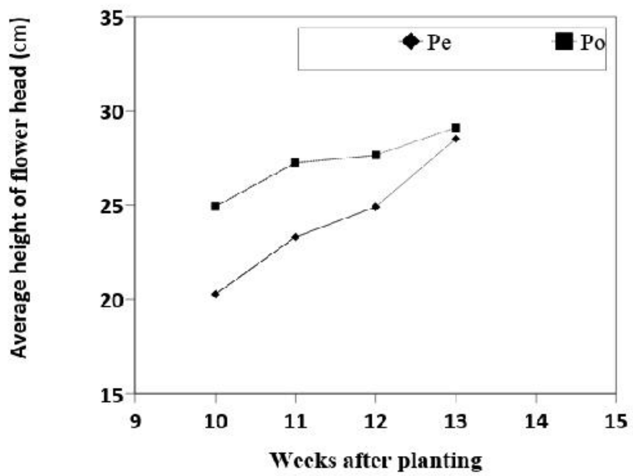

Figure 2. Effect of fertilizer pellets on inflorescence length of grain amaranth in field experiments conducted in Kenya. Po = non-pelleted combination, Pe = pelleted combinations

Overall, the T2 treatment i.e 83.25 kg CAN ha^{-1} + 6.75 T ha^{-1} manure gave the best vegetative growth. This could be attributed to the additive nutrient supply and to a better synchrony of nutrient availability with crop demand, i.e. the immediate availability of nutrients from mineral fertilizers and slow release from manure [12, 13, 17]. [17] reported that application of farmyard manure at the rate of 4 t ha-1 significantly increased the vegetative growth and development of grain amaranth. The low vegetative growth with treatment T5 (100% CAN), may have been due nitrogen leaching from the CAN and only a fraction of the amount applied being available to the plant. In general, non pellet fertilizer combinations had higher values for the number of leaves, plant height, stem width, and canopy than the pelleted fertilizer treatments at the same proportion of inorganic and organic combinations. This is because pellets are leached of their bases and release nitrate nitrogen several weeks later than ordinary compost [12, 13]. Therefore an anaerobic state is maintained inside the pellets, so that nitrification continues. Therefore the effect of pellets is different i.e. pelleting tends to slow down release of nutrients hence slowing growth especially vegetative growth.

3.2. Effect of fertilizer combinations on dry matter production

Fertilizer combinations had a significant effect on the plants dry matter weight (Figure 3). At flowering, the highest dry matter weight was observed in 9 t ha^{-1} manure with no fertilizer and lowest in 252.8 kg ha^{-1} CAN and 2.3 t ha^{-1}manure. At harvesting, the highest dry matter weight was observed in T2 (83.25 kg ha^{-1} CAN and 6.8 t ha^{-1}manure) while the lowest was observed in 252.75 kg ha^{-1} CAN and 2.3 t ha^{-1}manure fertilizer treatments (Figure 3). The dry matter decreased with decreasing proportions of manure. This trend is attributed to the presence of manure and slow release of nutrients to the plant for a prolonged period of time. Similar results were observed by [10[who reported that Stover yield of sorghum was enhanced by an integrated application of farm yard manure and inorganic fertilizers.

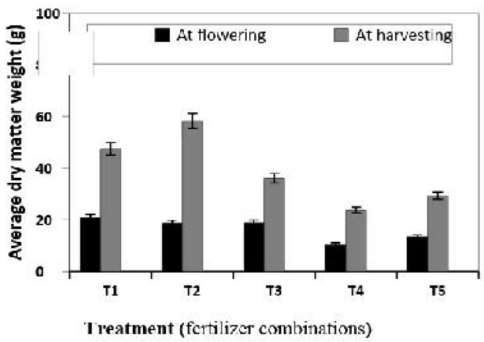

Figure 3. Effect of fertilizer combination on the dry matter production of grain amaranth in field experiment conducted in Kenya T = 9 ton manure ha^{-1}; T2 = 83.3 kg ha-1CAN + 6.8 T ha^{-1}manure; T3-168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure ; T4-252.8 kg ha^{-1}CAN + 2.3 T ha^{-1}manure; T5 = 183 kg CAN ha $^{-1}$

3.3. Effect of fertilizer combinations on yield and yield components

The pellet fertilizer treatments had higher grain yield than non-pellet treatments (Table 4) which decreased with decreased proportions of manure. In the pelleted fertilizer combinations, 100% organic fertilizer with no fertilizer had the highest yield while 50% inorganic and 50% organic fertilizer combination had the lowest yield (Table). In the pelleted fertilizer treatments, 25% and 75% organic fertilizer combination had the highest 1000 seed weight (0.90g) while 50% inorganic and 50% organic fertilizer combination had the lowest value (0.361g). 100% organic fertilizer alone had the highest yield of 1412kg ha^{-1}. Among the non pelleted fertilizer treatments, 100% organic, 25% inorganic and 75%, 50% inorganic and 50% organic fertilizer treatments had the highest 1000 seed weight (0.91g) while 75% inorganic and 25% organic treatment had the lowest 1000 seed weight (0.89g) (Figure 4).

Table 4. Effect of fertilizer pelleting on grain yield of amaranth in Kenya in 2011 and 2012

		Grain yield (kg/ha)				
		Fertilizer treatments (combination)				
		T1	T2	T3	T4	T5
Pellets 2011		1176.7	619.2	545.0	344.2	500.8
2012		1412.2	743.7	654.8	413.1	601.3
Non-pellets	2011	367.5	444.2	523.3	192.5	376.7
2012		441	533	628	231	452
$LSD_{Pellets}$				141.3		
$LSD_{Fertilizer\ combination}$				209.8		
$LSD_{pellets\ x\ fertilizer\ combination}$				265.7		

T = 9 ton manure ha^{-1}; T2 = 83.3 kg ha^{-1}CAN + 6.8 T ha^{-1}manure; T3-168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure ; T4-252.8 kg ha^{-1}CAN + 2.3 T ha^{-1}manure; T5 = 183 kg CAN ha $^{-1}$

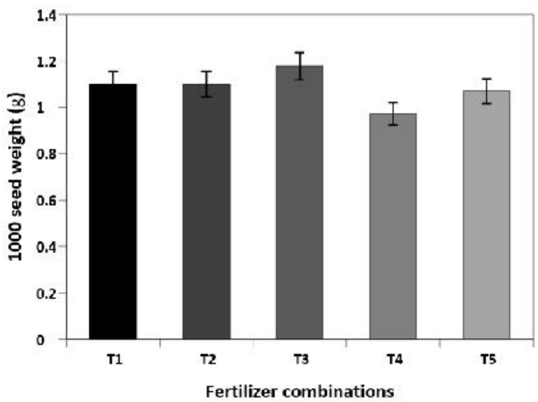

Figure 4. Effect of manure-fertilizer combinations on the 1000 seed weight of grain amaranth in field experiments conducted in Kenya T = 9 ton manure ha^{-1}; T2 = 83.3 kg ha-1CAN + 6.8 T ha^{-1}manure; T3-168.5 kg ha^{-1}CAN + 4.5 ha^{-1}manure ; T4-252.8 kg ha^{-1}CAN + 2.3 T ha^{-1}manure; T5 = 183 kg CAN ha^{-1}

The increase in grain yield could be due to increase in growth and yield attributes (number of leaves, plant height, stem width, inflorescence length and dry matter weight). Fertilizer pellets had significant effect on the plant's dry matter weight, 1000 seed weight and hence grain yield. These results could be attributed to the beneficial effect of combining CAN with manure which thus regulated nutrient release to the plant. This is in addition to the reduction of N losses through leaching and hence a constant supply of nutrients to the roots. Besides, the manure component of the pellet fertilizer released N and P slowly as well as contributing to the soil organic matter (12; [13; 19]. [12] reported higher grain weight in corn with application of pellet fertilizer comprising of 92 kg N ha-1 and 600 kg ha^{-}1cow manure. [13] also found out that application of fertilizer pellets comprising of 50 kg ha^{-1} urea and 100 kg ha-1 manure had higher 1000 seed weight and grain yield of wheat than other treatments.

The results also show a trend of reducing yield as the amount of organic fertilizer reduces. These results are similar to those of [17] who reported that, the application of inorganic nitrogen at the rate of 50 kg N ha^{-1}combined with $4tha^{-1}$of farm yard manure significantly increased the growth and development of amaranth through increased plant height, plant dry matter weight and leave area index and that the results were significantly the same as using 100kg Nha^{-1}(inorganic) alone or 4 t ha^{-1} farmyard manure alone. [6] reported that grain amaranth grown using manure alone had better yields that grain amaranth grown using inorganic fertilizer alone. These results also agrees with those of [20] and [21], who reported that a combination of maize stover compost and urea fertilizer at rate of 3.0 t ha^{-1} + 30 kg N ha^{-1} significantly enhanced amaranth growth and yield attributes. Similarly, [21] reported that high and sustained crop yield can be obtained with judicious and balanced nitrogen combined with organic matter amendment. [10] working on sorghum reported that grain yield was significantly enhanced due to application of farm yard manure, mineral fertilizer and their interactions.

3.4. Relationship between yield and other growth parameters

The regression of yield and growth parameters; plant height, stem width, canopy, shoots and inflorescence length was significant. Yield was positively correlated to plant height, stem width, number of shoots and inflorescence length. The regression model of other factors and yield:

Yield = 581.6 + 13.3height + 0.003inflorescence length + 0.82 canopy +0.459 stem width + 0.002 shoots (R^2 = 0.515).

These results shows that plant height had the highest effect on yield followed by stem width, then number of shoots and canopy size. Plant height determines exposure of leaves to sunlight. Tall plants have more leaves exposed to sunlight for photosynthesis. With photosyntates partitioning this means more photosyntates are translocated to developing seeds making them heavier.

4. CONCLUSION

The use of organic and inorganic fertilizer combination is useful in grain amaranth production, as it ensures continued supply of nutrients to the plant resulting in sustainable crop production. Application of CAN at the rate of 83.25 kg ha^{-1}in combination with cow dung manure at the rate of 6.8 t ha^{-1}significantly increased the growth, development and yield of grain amaranth through increased number of leaves per plant, individual plants' canopy size, plant height, stem width, plant dry matter weight and 1000 seed weight. The use of fertilizer pellets is a good alternative in grain amaranth production. However there is need for a cost benefit analysis of use of pellets before recommendation for adoption.

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