Response of Growth and Grain Yield of Amaranth (*A. hypochondriacus*) to Combined Manure and Inorganic Fertilisfertiliser Pellets and Non-pellets

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Original Research Article

ABSTRACT

Grain amaranth (*Amaranthus hypochondriacus* L) has high potential to substitute expensive animal protein because of its high nutritional value and is potential to reduce protein malnutrition in Kenya. However, its production and consumption are low. Nitrogen fertilisation is among the most important factors limiting productivity. Most farmers use manure and little or no fertiliser. Manures alone cannot meet crop nutrient demand over large areas because of the limited quantities, low nutrient content and the high labour requirement. Manure – fertiliser augmented pellets have been suggested as an improved alternative. This study investigates the effects of pellet fertiliser, produced by mixing calcium ammonium nitrate (CAN) and dry cow dung manure on growth and

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grain yield of *Amaranthus hypochondriacus* L over a period of two years. The experiment was laid as randomised complete block design (RCBD) with split plot arrangement and replicated three times. The treatments were different combinations of organic and inorganic ffertiliser; 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 non fertiliser treatment. All the pellet fertiliser treatments had higher dry matter weight, 1000 seed weight and grain yield compared to control and non-pelleted treatments. Fertiliser combination of 75 percent Organic N and 25 percent inorganic N had the highest grain yield while fertiliser combination of 25 percent organic and 75 percent inorganic recorded the lowest grain yield compared to the other combinations. The use of pellet fertiliser increased grain yield and could be used as an alternative, however, recommendation for adoption should be done after economic analysis.

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Keywords: Acidic acrisols; grain yield; Kenya; Inorganic- organic combination; tropics.

1. INTRODUCTION

Grain amaranth (*Amaranthus hypochondriacus*) as a vegetable or grain has been suggested to be a cheap alternative to protein source. The crop is rich in protein, carbohydrates, lipids, fibre and mineral salts [1, 2]. 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 [1,2]. The amino acid composition of amaranth protein has been compared with the FAO/WHO protein standard [2].

Grain amaranth has been used in the management of various medical issues.: Diabetes, migraines, hypertension, liver disease, haemorrhage, TB, HIV/AIDS, wounds, kwashiorkor, marasmus, stunting, diarrhoea and skin diseases are among some of them [3, 4]. Besides, it grows fast, is high yielding under a wide range of agro-climatic conditions, 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 was done in Kenya in 2008 in the Lake Victoria Basin, where farmers indicated that lack of awareness on crop husbandry, low soil fertility, and utilisation limits the production of grain amaranth [6]. The average yield of grain amaranth is 1 t/ha compared to 2.5 t/ha and 3 t/ha achieved with the optimal use of fertilisers 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% increase in harvests by small-scale farmers of the third world in the last three decades is attributable to the use of chemical fertilisers [8]. However, because of escalating price of chemical fertilisers , 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 fertiliser albeit in quantities less than the recommended rates. Most of the farmers are resource poor and cannot afford mineral fertilisers; hence net negative balances of nutrients occur as nutrients are removed from the field by the harvested product [10]. A key resource that can be used to reverse this trend is livestock manuring available at the farm level. However, the use of organic manures alone cannot meet crop nutrient demand over large areas because of the limited available quantities, the low nutrient content of the materials and the high labour demand for processing and application [12]. Moreover, the decomposition of manure and the mineralisation 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 fertiliser- augmented soil enhancing strategy which involves the combined use of manures and

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mineral fertilisers. This approach combines the short- term benefits of mineral fertilisers with the long- term values of organic manures [10, 11]. Fertiliser 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 [11]. Pelleted fertiliser is a slow-release N fertiliser 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, 13, 14]. Fertiliser pelleting has been tried in crops like corn [13] and wheat [14]. There is limited information on the use of fertiliser pellets in grain amaranth. The current research was therefore undertaken to investigate the appropriate organic and inorganic fertiliser pellet combination for grain amaranth production in Kenya.

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2. MATERIALS 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 [15]. 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 is Acrisols [17]. The experimental plots had been under one year fallow before the onset of the experiment. The base soil characteristics before the experiment were: Moderate in nitrogen (0.15 percent), low in phosphorus (2.00 ppm), 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

2.2 Soil Sampling

Soil samples were collected from the experimental plots to establish the initial soil fertility status. Sampling was done from the topsoil (0-15 cm) and sub-soil (15-30 cm) from each plot in 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 along with Cation Exchange Capacity (CEC) and pH was carried out using the acid/alkaline digestion method of analysis [7]. The Mehlich-method [7] was used to extract P by adding 25 ml of Melchi solution (0.0125 M H2S04 + 0.025 M HCI) to 5 g of soil and shaking the suspension for 5 minutes on a reciprocating shaker and P quantified colourimetrically using a spectrophotometer (430 nm wavelength). K was determined using the Flame photometry method.

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Table 1. Properties of soil prio to planting

Property	**0-15 cm**	**15-30 cm**
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

2.3 Experimental Design and Agronomic Practices

The experiment was laid out as randomised complete block design (RCBD) with split plot arrangement and replicated three times. The main plots measured (17m × 6m) with 1m in between. The main plot treatments were pellet fertiliser and non-pellet fertiliser. The subplots measured (3 m × 6 m) with 1m in between. The subplot treatments were of fertiliser 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 fertiliser. Calcium ammonium nitrate (CAN) was used as the source of inorganic nitrogen. The pellets were made using a disk type

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Table 2. Nutrient content of the various pellet fertiliser 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				

pelleter [23]. 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 [23]. Results of the laboratory analysis of the manure and pellets are presented in Table 2.

Land preparation was done using a tractor powered disc plough and harrow. The seedbed was ploughed and harrowed to fine tilth prior to planting. The fertiliser treatments were mixed with soil before plantation. 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 utilised in experimental plots were recommended for grain amaranth cultivation in the tropical highlands. These consisted of weed management practices, gapping, and pest control [6].

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2.4 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. The harvesting day for each treatment was 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°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

3.1 Effect of Fertiliser Application on Growth Parameters

Application of organic and inorganic fertiliser combinations had significant($p < 0.05$) effect on the number of leaves, stem width, plant height, canopy size, and inflorescence length compared to the non- fertiliser control (Table 3 and Fig. 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 was observed treated 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 fertiliser (0% inorganic and 100% organic) (Table 3). The least number of leaves was observed in the controls with no fertiliser 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 a 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 an average, the non-pellet fertiliser combinations had a higher inflorescence length compared to the pellet fertiliser combinations (Fig. 2).

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 better synchrony of nutrient availability with crop demand, i.e. the immediate availability of nutrients from mineral fertilisers and slow release from manure [13, 14, 18]. The application of farmyard manure at the rate of 4 t ha-1 can significantly increase the vegetative growth and development of grain amaranth [18]. The low vegetative growth with T5 treatment (100% CAN), may have been due to nitrogen leaching from the CAN and only a fraction of the amount applied was available to the plant. In general, non- pellet fertiliser combinations had higher values for the number of leaves, plant height, stem width, and canopy than the pelleted fertiliser 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 [13,14]. 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 the release of nutrients hence slowing growth especially vegetative growth.

3.2 Effect of Fertiliser Combinations on dry Matter Production

Fertiliser combinations had a significant effect on the plants' dry matter weight (Fig. 3). At flowering, the highest dry matter weight was observed in 9 t ha^{-1} manure with no fertiliser 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 fertiliser treatments (Fig. 3). The dry matter decreased with decreasing proportions of manure. This trend is attributed to the presence of manure and a slow release of nutrients to the plant for a prolonged period of time. Similar results were observed by Alemu and Bayu [10] who reported that stover yield of sorghum was enhanced by an integrated application of farmyard manure and inorganic fertilisers.

3.3 Effect of Fertiliser Combinations on Yield and Yield Components

The pellet fertiliser treatments had higher grain yield than non-pellet treatments (Table 4) which decreased with decreased proportions of manure. In the pelleted fertiliser combinations, 100% organic fertiliser with non fertiliser had the highest yield while 50% inorganic and 50% organic fertiliser combination had the lowest yield (Table). In the pelleted fertiliser treatments, 25% and 75% organic fertiliser combination had the highest 1000 seed weight (0.90g) while 50% inorganic and 50% organic fertiliser combination had the lowest value (0.361g). 100% organic fertiliser alone had the highest yield of

Table 3. Effect of organic and inorganic fertiliser 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

T1 = 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}

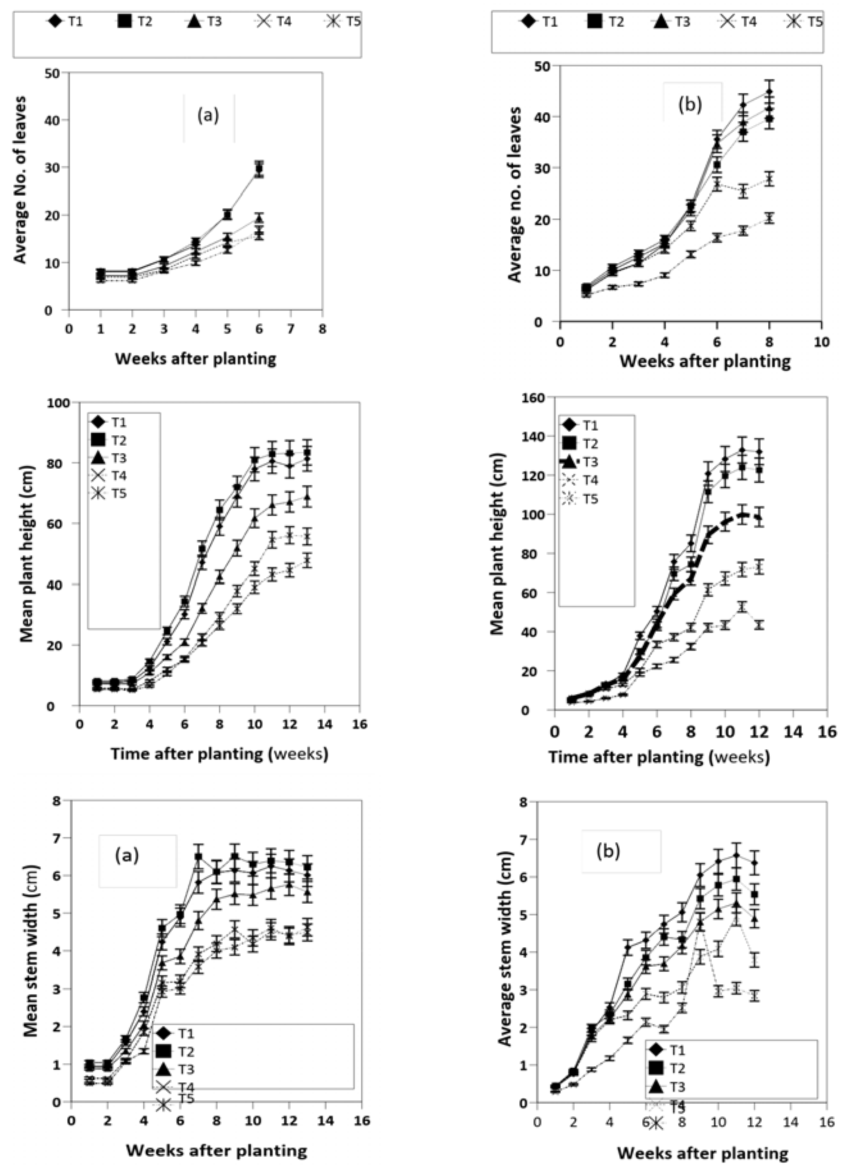

Fig. 1. Effect of manure-fertiliser combinations on the growth of grain amaranth in 2011 (a) and 2012 (b) in Kenya

T1 = 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 $^{-1}$

1412kg ha^{-1}. Among the non-pelleted fertiliser treatments, 100% organic, 25% inorganic and 75%, 50% inorganic and 50% organic fertiliser treatments had the highest 1000 seed weight (0.91g) while 75% inorganic and 25% organic treatment had the lowest 1000 seed weight (0.89g) (Fig. 4).

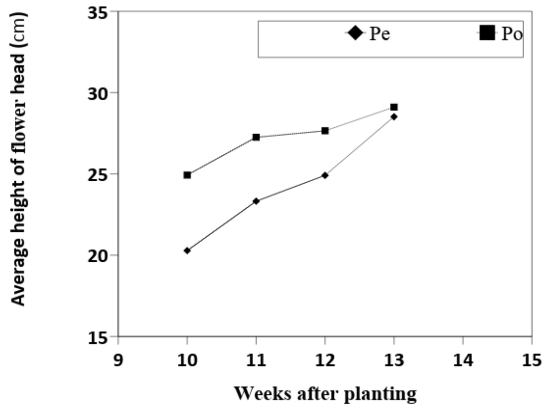

Fig. 2. Effect of fertiliser pellets on inflorescence length of grain amaranth in field experiments conducted in Kenya

Po = non-pelleted combination, Pe = pelleted combinations

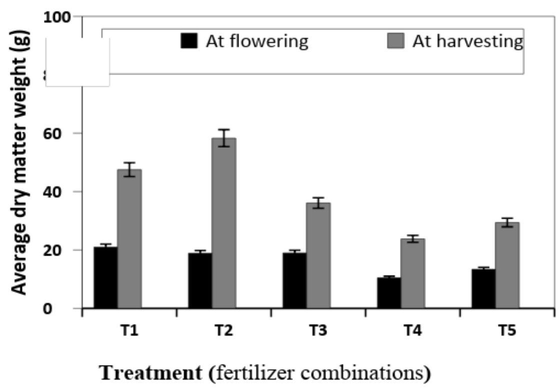

Figure 3. Effect of fertiliser combination on the dry matter production of grain amaranth in field experiment conducted in Kenya

T1 = 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 $^{-1}$

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

		Grain yield (kg/ha)				
		Fertiliser 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 $_{Fertiliser\ combination}$			209.8			
LSD $_{pellets\ x\ fertiliser\ combination}$			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 $^{-1}$

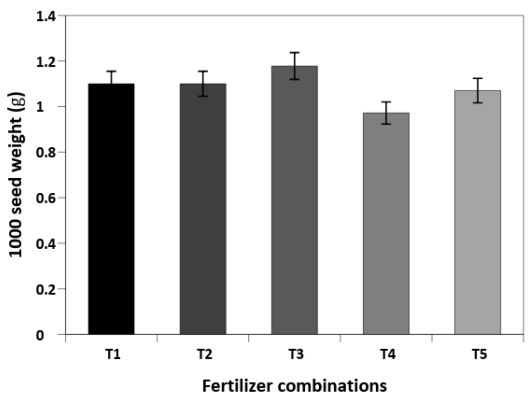

Fig. 4. Effect of manure-fertiliser combinations on the 1000 seed weight of grain amaranth in field experiments conducted in Kenya

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). Fertiliser pellets had a 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 provides a constant supply of nutrients to the roots. Besides, the manure component of the pellet fertiliser released N and P slowly as well as contributing to the soil organic matter [13; 14; 20]. Bagheri et al., [13] reported higher grain weight in corn with the application of pellet fertiliser comprising of 92 kg N ha-1 and 600 kg ha^{-1}cow manure. Jeiran et al., [14] also found out that the application of fertiliser 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 fertiliser reduces. These results are similar to those of Ainika et al., [18] who reported that, the application of inorganic nitrogen at the rate of 50 kg N ha^{-1}combined with 4tha^{-1}of farmyard 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. Similarly Olowoake [25] reported that organic fertilisers fortified with mineral fertiliser showed great potential in the production of grain amaranth and could also be used effectively in increasing soil fertility for amaranth production. Nyankanga et al.,[6] reported that grain amaranth grown using manure alone had better yields than grain amaranth grown using inorganic fertiliser alone. These results also agree with those of Akanbi and Togun [21] and Makinde [22], who reported that a combination of maize stover compost and urea fertiliser at a rate of 3.0 t ha^{-1} + 30 kg N ha^{-1} significantly enhanced amaranth growth and yield attributes. Similarly, Makinde [22] reported that high and sustained crop yield can be obtained with judicious and balanced nitrogen combined with organic matter amendment. Alemu and Bayu [10], working on sorghum reported that grain yield was significantly enhanced due to the application of farmyard manure, mineral fertiliser and their interactions. Tafti [24], working on medicinal pumpkin reported that treatment of 1.5 ton animal manure + 150 (Kg) Urea as pellet with 2000 ppm of microelements gave higher yield and quality compared to non-pelleted treatments.

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

4. CONCLUSION

The use of organic and inorganic fertiliser combination is useful in grain amaranth production, as it ensures continuous 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 fertiliser pellets is a good alternative in grain amaranth production. However, there is a need for a cost-benefit analysis of the use of pellets before recommendation for adoption.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bressani R. Composition and nutritional properties of amaranth. InParedes-Lopez (Ed) Amaranth biology, chemistry, and technology 2018 pp. 185-205. Boca Raton: CRC Press.
2. Teutonico RA, Knorr D. Amaranth: Composition, properties, and applications of a rediscovered food crop. Food Technol. 1985; 39:49-60.
3. Caselato-Sousa VM, Amaya-Farfán J. State of knowledge on amaranth grain: a comprehensive review. J. Food Sci. 2012; 77(4):93-104.
4. 4.Mwangi D. Amaranth as a promising Crop for Food, Nutrition, Healing and Poverty Eradication in Africa. Presentation at the Amaranth Institute Meeting on amaranth Farming and Technology Transfer, August 14 and 15, 2003,Ames, Iowa 2003.
5. Johnson BL, Henderson TL. Water use patterns of grain amaranth in the northern Great Plains. Agronomy J. 2002; 94(6):1437-43.
6. Nyankanga RO, Onwonga RN, Wekesa FS, Nakimbungwe D, Masinde D, Mugisha J. Effect of Inorganic and Organic Fertilisers on the Performance and Profitability of Grain Amaranth (*Amaranthus caudatus* L.) in Western Kenya. Journal of Agric Sci 2012; 4(1): 223- 232
7. Okalebo, JR., Gathua KW, Woomer PL. Laboratory methods of soil and plant analysis: A working manual. 2nd ed. TSBF-CIAT and SACRED Africa, Nairobi, Kenya, 2002.
8. Stewart WM, Dibb DW, Johnston AE, Smyth TJ. The contribution of commercial fertiliser nutrients to food production. Agronomy Journal. 2005 ; 97(1):1-6.
9. Place F, Barrett CB, Ade Freeman H, Ramisch JJ, Vanlauwe B. Prospects for integrated soil fertility management using organic and inorganic inputs: Evidence from smallholder African Agricultural Systems. Food Policy, 2003; 28: 365-378.
10. Alemu G, Bayu W. Effects of Farm yard Manure and Combined N and P Fertiliser on Sorghum and Soil Characteristics in Northern Ethiopia. J. sustain agric, 2005; 26(2).
11. Alemi, H, Kianmehr, MH, Borghaee, AM. Effect of pellet proccessing of fertiliser on slow-release nitrogen in soil. Asian J. Plant Sci., 2010; 9 (2): 74-80.
12. Zafari A, Kianmehr MH. Livestock manure management and pelleting. Agric Eng Int: CIGR J. 2012 ;14(3):78-84.
13. Bagheri R, Akbari GHA, Kianmehr MH, Sarvastani ZA, Hamzekhanlu MH. The effect of pellet fertiliser application on corn yield and its components. Afric J. Agric Res 2011; 6(10): 2364-2371.
14. Jeiran EH, Mohammad HK, Mohammad E, Qolam AA, Onwonga RN. The effect of Pellet fertiliser application on wheat yield

and its components. Int Res J. Plant Sci 2010; 1(6):163-171.
15. Jama B, Rob AS, Buresh RJ. Agronomic and economic evaluation of organic and inorganic sources of phosphorus in Western Kenya. Agron J, 1997; 89: 597-604.
16. Abednego K, Qureish N, Bashir J. Annotated Inventory of Agroforestry Related Work in western Kenya (1987 – 2003). World Agroforestry Centre, Nairobi, 2003.
17. FAO. Map of World Soil Resources. 1:25 000 000. FAO Rome, 2003.
18. Ainika JN, Auwalu BM, Yusuf AU. Response of grain Amaranth (*Amaranthus cruentus* L.) to Nitrogen and Farmyard Manure Rates in Northern Guinea and Sudan Savanna Ecological Zones of Nigeria. World J Eng Pure Appl Sci. 2011; 1 (2): 46 – 9
19. Eyvazi J, Iran NH, Kianmehr MH. Effect of slow-release from mixed pellet fertiliser of urea and dry cow manure in wheat yield and its components M.Sc. Thesis, Department of Agronomy, College of Aboureihan, University of Tehran, Iran 2008.
20. Ayuso MA, Pascal JA, Garcia C, Hernades T. Evaluation of urban wastes for agricultural use. Soil Sci and Plant Nutr; 1996; 142:105-11.
21. Akanbi WB, Togun AO The influence of maize Stover compost and nitrogen fertiliser on growth, yield and nutrient uptake of amaranth. Sci Hortic 2002; 93:1-8.
22. Makinde EA Effects of an organo - mineral fertiliser application on the growth and yield of maize. J Applied Sci Res 2007; 3(10):1152-1155
23. Hara M. Fertiliser pellets made from composted livestock manure. Extension Bulletin-Food and Fertiliser Technology, Central Asian Pacific Region 2001; 506, 1-12.
24. Tafti ARD, Alahdadi I, Nadjafi F, Kianmehr MH, Bagheri M, Akbari GA, Sharifi-Rad J. Evaluation of different amounts of pelleted manure with urea and micro elements on yield and seed quality of medicinal plant, pumpkin (*Cucurbita Pepo* Var.Styriaca). Int. J. Adv. Biol. Biom. Res, 2014; 2 (10), 2663-2677
25. Olowoake AA. Influence of organic, mineral and organomineral fertilisers on growth, yield, and soil properties in grain amaranth (Amaranthus cruentus. L). J. Organics (JO). 2014;1(1):39-47.