Original Research Article

Sorghum Growth and Yield as Influenced by Farmyard Manure and Inorganic Fertilizer in Post Mined Soils

Abstract

Mining plays an important role in Kenyan Economic development through provision of employment, raw materials as well as foreign income. Despite the important role played by this sector, it is associated with land degradation, impacting food security. Closure of mines calls for rehabilitation process through establishment of native trees, grass or crops. In order to promote crop production as a reclamation measure, performance of sorghum in post mined soils was evaluated in the south dune site of base titanium limited Kwale Company. The experiments were laid down in Randomized Complete Block Design (RCBD) with split plot arrangement and replicated thrice. Fertilizer, Manure, Manure + Fertilizer, Control (unfertilized) and Gadam and Silla sorghum varieties were tested. Data collected included: Initial soil properties, plant height, number of leaves, leaf length, leaf width, stem circumference, panicle length, panicle circumference and grain yield per hectare. Data collected was subjected to analysis of variance using Genstat software and means separated using the Fisher's protected least significant difference at ($P \leq 0.05$).The soils were slightly acidic with low levels of exchangeable P, K, S, Cu and Bn. Manure + fertilizer significantly ($P \leq 0.05$) increased plant height by 14% (gadam), and 28% (silla), number of leaves per plant by 28% (gadam) and 29% (silla), panicle length by 18% (gadam), 8% (silla), dry matter by 30% (gadam) 40% (silla) and grain yield by 50% for both gadam and silla varieties compared to control plots in both varieties. Average yields in both seasons for manure + fertilizer treated plants were significantly high (5.3 tones/ha) for Silla variety and (5.7 tones/ha) for Gadam variety. Where gadam produced slightly high grain yield than silla variety by 7%. Combined application of farmyard manure and inorganic fertilizer were most effective in enhancing sorghum growth, dry matter and yield. Growth and yield data collected showed that combined farmyard manure + fertilizer can supportoptimal sorghum production in the post mined soils. Owing to the fact that the soils have compromised profile, soil structure and fertility, long term trials and simulation models are required to ascertain optimal sorghum production while ensuring sustainable soil health in such soils.

***Keywords**: farmyard manure, mining, inorganic-fertilizer, sorghum, post mined soils, reclamation.*

1.0 Introduction

Sorghum (Sorghum bicolor (L) Moench), is a cereal crop quantitatively ranked the world's fifth most important cereal grain after wheat, maize, rice and barley [1; 2]. The crop is native to tropical Africa, but widely produced throughout the tropical, subtropical and arid regions of the world. Its tolerance to drought, water logging conditions, saline-alkaline infertile soils and high temperatures makes it to be considered globally as a crop for resource poor small-scale farmers in arid and semi-arid lands (ASALs) [3; 4]. These attributes also make it a promising alternative for enhanced food and income security in the face of global warming and climate change [5; 6].

In Kenya sorghum is ranked third after maize and wheat in terms of cereal production and has been noted to do well on a wide range of soils including those with very low fertility [7; 8]. The potential of sorghum to catalyse regional development and improve food security is considerably high. It is a crop with vast untapped potential which can be harnessed in poverty alleviation, employment creation, and reducing malnutrition in the country.

Mining is an imperative activity that upholds income generation, employment creation, source of industrial raw materials and economic development globally. Despite the significant role played by the industry, mining is classified as a form of land degradation that disturb ecological unit balance through loss of above and below ground biota and overall soil health [9]. Closure of mining process marks the beginning of post mining reclamation process which involves returning soil into the excavated areas and initiating soil attributes rebuilding by allowing colonization by either indigenous plant species or new species more so trees and grasses. Although mined soils can be reclaimed through crop farming to contribute towards food security, this approach has not been exploited and documented widely across the globe. The current research therefore aimed at establishing the performance of sorghum in post mined soils when subjected to manure and inorganic fertilizers.

2.0 Materials and Methods

2.1 Site Description

The study was carried out from September 2020 to September 2021 at the south dune site of Base Titanium Limited (BTL) Company – Kwale which is a recently post mined field trial plotlocated in Kwale County, 50km south of Mombasa town. The site lies between latitudes 1^0 and 4^0 south, and Longitudes $38^0$and 41^0 east and coastal lowlands agro-ecological zone three (CL3). It is generally warm throughout the year with high relative air humidity varying from 95% along the coastal strip to 60% in the hinterland. The temperatures within the area range from 24^0C to 32^0C with low temperatures being experienced during the coldest month of June and July and high temperatures of 32^0C being experienced during the hottest months of January and February [10]. It receives annual rainfall of between 400mm to 1680mm which is distributed between March to August long rains and October to December short rains.Long rain season is, however, the most important cropping season receiving 75% of annual rainfall. Although the original soils within the area are well drained, red to dusky red, very friable, sandy clay loam, or loamy sandy Rhodicferralsoils[10], the current post mined soils have been reconstituted through replacing and compacting the stock piled sand after mining and spreading a considerable layer of originaltop soil.

Comment [DAL1]: Shall be interesting with mapping

2.2 Experimental Layout, Design and Crop Husbandry

The experiment was laid down in Randomized Complete Block Design (RCBD) with split plots arrangement and replicated three times. The treatments were sorghum varieties and fertilizer and /or manure application. Main plots consisted Gadam and Silla sorghum varieties while sub plots consisted control (no input), sole manure, manure + fertilizer and sole fertilizer. Sorghum was planted at a spacing of 75cm by 20cm. Subplot had five rows and each row had 11 plants making 3.75m by 2.2m plots. The plots were separated by 1m path making a block of 6.75M by 5.4M main plot. Main plots were separated by 1m gap making a block of 6.75m by 6m. Each block was separated by a 1.5m gap making an experimental plot of 6.75.m by 19.2.m and a plant population of 1320 plants. Gadam and Silla varieties were used because they are commonly grown within Kwale region, high yielding, early maturing and drought tolerant. Manure was applied before planting at a rate of 8tons/ha while fertilizers used were: diammonium phosphate (DAP), NPK (17:17:17), calcium ammonium nitrate (CAN) and muriate of potash (MOP). Split application was carried to ensure provision of 90kgN/ha, 45kg P/ha, 45kg Kg/ha. Normal agronomic practices such as weeding, pest and disease control, were carried out as recommended.

Comment [DAL2]: Where did you inspire? In the literature? Please indicate the sources

2.3 Data Collection

Data collected include: initial soil properties, plant growth and yieldparameters. Initial soil sampling was carried out using stratified random sampling technique as described by Carter and Gregorich [11]. Eight soil samples were randomly takenfrom each strata using soil auger at 0-30cm depth. The samples were thoroughly mixed and a 1.0 kg composite sample for each depth was packed and taken to the laboratory for analysis. The composite samples were then packed and taken to the laboratory for characterization. Parameters analyzed in the laboratory were reaction (pH), total nitrogen (N), exchangeable phosphorus (P), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg), exchangeable zinc (Zn) exchangeable copper (Cu) and exchangeable manganese (Mn), cation exchange capacity (CEC) and organic carbon (OC). All chemical analysis was carried out following the procedures described by [12].

Evaluation of crop growth and yield was carried out by randomly selecting by five plants from the inner three rows per plot and tagging them seven days after germination. The five plants were used for collecting data on plant height, number of leaves per plant, stem circumference, leaf length, leaf width, panicle height, panicle circumference, biomass and grain yield.

2.3.1 PlantHeight

Plant height was determined by measuring the height of each tagged plant per plot from the base to the tip of leaf of the main shoot of a plant using a ruler and recorded in centimeters (cm). The measurements were done on weakly bases from two weeks after emergence till physiological maturity

2.3.2 Number of Leaves Per Plant

Number of leaves were established by counting the total number of leaves in each tagged plant per plot on weekly bases from two weeks after crop emergence till physiological maturity.

2.3.3 Panicle Height, Circumference and Number

Panicle height and circumference was determined by measuring the height from the base of the panicle to its top using a measuring tape measure. Panicle circumference on the other hand was evaluated by measuring its circumferenceusing a string and ruler from florescence stage to physiological maturity. All measurements were recorded in centimeters (cm). Number of panicles per plot was determined by counting all the panicles per plot during florescence stage. The number was then equated with total number of plants per plot to get percent florescence.

2.3.4 Biomass

During harvesting, both above ground and below ground biomass was weighed when fresh and then taken to the laboratory for drying. The root and above ground plant samples were dried in an oven at 65^0C temperature for about 48 hours until a constant weight and then weighed to determine dry biomass.

2.3.5 Grain Yield

Ten plants were randomly selected from the three inner rows and harvested. The grains per plant was counted and recorded, then grain weight per plant and total grain weight of the ten plants weighed using digital weighing balance and recorded in grams (gm). All the grains were sun dried to obtain <4% moisture content then final dry grain weight was measured and recorded. Obtained yield was calculated and recorded in tones/Ha.

2.4 DataAnalysis

Data collected was subjected to Analysis of Variance (ANOVA) using the Genstat statistical software [13]. The means obtained were separated using Duncan New Multiple Range Test at 5% level of significance.

3.0 Results

3.1 Initial Soil Properties

Initial soils were observed to have optimal levels of exchangeable calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), Zinc (Zn) and pH (Table 1). Exchangeable phosphorus (P), potassium (K), Sulphur (S), boron (B), copper (Cu), cation exchange capacity (CEC), total nitrogen (TN) and organic matter (OM) were however observed to be at low.

Table 1:Initial soil properties

Variable	pH	P	K	Ca	Mg	S	Fe	Mn	. B	Cu	Zn	CEC	TN	OM	PSD
Value	6.44	10.6	109	509	100	15.4	159	196	0.43	0.87	2.39	4.29	0.078	1.65	SL

SL-Sandy loam, P-phosphorus, K-Potassium,Ca-Calcium, Mg-Magnesium, S-Sulphur, Fe-Iron, Mn-Manganese, B-Boron, Cu-Copper, Zn-Zinc, CEC-Cation exchange capacity, TN-Total nitrogen, OM-Organic matter.

3.2 ComparativeEffects of Fertilizer and Farmyard Manure on Sorghum Plant Height (Cm).

Application of manure and fertilizer was observed to significantly improve sorghum height (figure 1). Although sole manure +fertilizer recorded the highest average plant height throughout the cropping season, for both varieties, average height of crops treated with sole fertilizer and manure +fertilizer was not significantly different. Similarly, the height of sole manure treated plants and control were not significantly different for both gadama and silla varieties.

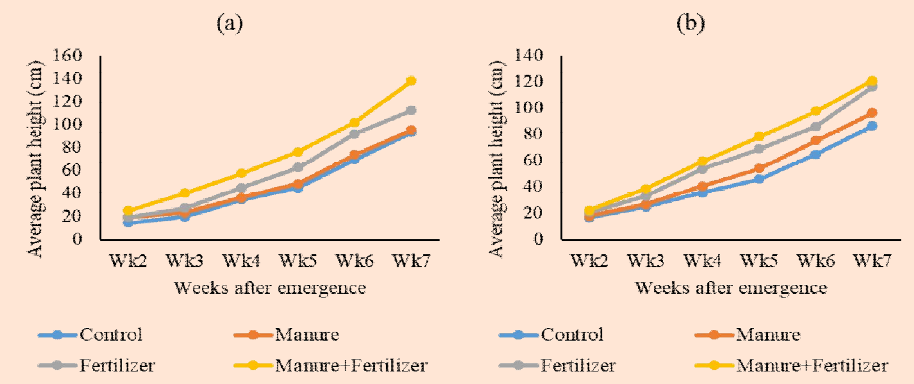

Figure 1: Average plant height (cm) of (a) Gadam and (b) Silla sorghum varieties subjected to manure and inorganic fertilizer for two cropping seasons in post mined soils

3.3 ComparativeEffects of Fertilizer and Farmyard Manure on Sorghum Leaf Development

Farmyard manure and fertilizer application significantly ($P \leq 0.05$) improved sorghum leaf development (Table 2). Inorganic fertilizer + farm yard manure was observed to support the highest average number of leaves compared to other amendments. Gadama and silla variety treated with manure+ fertilizer having an average of 22% and 27%

respectively more leaves compared to control plots. Number of leaves in crops applied with sole fertilizer and fertilizer+ manure was, however, not significantly different in several weeks during the cropping period. Similar scenario was observed in control and manure applied soils. There was no observed significant (P≤0.05) difference on varietal response to manure and fertilizer application.

Table 2: Comparative effects of farmyard manure and fertilizer on sorghum leaf development in post mined mined soils.

	Average number of leaves											
	Gadama Variety						Silla Variety					
	Season One			Season two			Season one			Season two		
Amendments	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**
Control	7a	9a	10a	7a	10a	10a	8a	9a	10a	8a	9a	10a
Manure	8a	9a	10a	7a	11b	11b	8a	10a	11b	9b	11b	12b
Fertilizer	9ab	12b	12b	8b	11b	12c	10b	12ab	12c	10c	12c	12b
M+F	9bc	12bc	14c	8b	12c	13d	10b	13c	14d	10c	13d	14c
P≤0.05(amend)	0.01	<0.001	<0.001	0.02	<0.001	<0.001	0.01	<0.001	<0.001	0.02	<0.001	<0.001
P≤0.05(variety)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	9.6	7.6	3.2	9.6	6.9	3.2	9.6	7.6	3.2	9.6	6.9	3.2

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

3.4 ComparativeEffects of Fertilizer and Farmyard Manure on Sorghum Leaf Length

Farmyard manure and fertilizer application significantly (P≤0.05) improved sorghum leaf length (Table 3). Inorganic fertilizer + farm yard manure was observed to support the highest average leaf length compared to other amendments. Gadama and silla variety treated with manure+ fertilizer had an average of 13% and 9% respectively longer leaves compared to control plots. Leaf length of crops applied with sole fertilizer and fertilizer+ manure was, however, not significantly different in several weeks during the cropping period, a scenario that was observed in control and manure applied soils. There was no observed significant (P≤0.05) difference on varietal response to manure and fertilizer application in the first season.

Table 3: Comparative effects of farmyard manure and fertilizer on average sorghum leaf length (cm).

	Average leaf length (cm)											
	Gadama variety						Silla variety					
	Season One			Season two			Season one			Season two		
Amendments	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**
Control	45.4a	70.6a	72.9a	49.6a	70.7a	73.7a	55.7a	71.4a	77.7a	67.3a	74.8a	76.7a
Manure	48.8a	71.4a	77b	56.4b	72.6b	75.3b	57.3a	75.9a	79.5a	71.6a	78.0b	79.3b
Fertilizer	54.3b	74.8ab	79.8b	68.3c	73.7b	76.7b	58.9a	78.6ab	82.3b	72.1ab	78.9b	80.3b
M+F	54.7b	77.3b	83.5c	68.7c	76.3c	78.7c	61.2b	79.5b	89.5c	74.1bc	80.3c	82.2c
P≤0.05(amend)	0.049	0.053	<0.001	<0.001	<0.001	<0.001	0.049	0.053	<0.001	<0.001	<0.001	<0.001
P≤0.05(variety)	ns	ns	ns	0.041	0.045	0.002	ns	ns	ns	0.041	0.045	0.002
CV%	7.5	6.2	3.2	5.1	1.8	1.5	7.5	6.2	3.2	5.1	1.8	1.5

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

3.5 Comparative Effects of inorganic Fertilizer and Farmyard Manure On Sorghum Panicle Length and Circumference

Farmyard manure and fertilizer application significantly (P≤0.05) influenced sorghumpanicle length and circumference development (Table 4). Inorganic fertilizer + farm yard manure was observed to support the highest average Panicle length and circumference compared to other amendments. Gadama and silla variety treated with manure+ fertilizer had an average of 23% and 18% respectively longer panicles compared to control plots. Panicle circumference for gadama and silla was also observed to be 19% and 16% respectively wider in manure + fertilizer applied soils compared to unfertilized soils. Panicle length and circumference of crops applied with sole fertilizer and fertilizer+ manure was, however, not significantly different in several weeks during the cropping period, a scenario that was also observed in control and manure applied soils. There was no observed significant (P≤0.05) difference on varietal response to manure and fertilizer application in the two cropping seasons.

Table 4: Comparative effects of farmyard manure and fertilizer on average sorghum panicle length (cm) and circumference (cm).

	Panicle length				**Panicle circumference**			
	Gadama variety							
	Season 1		Season 2		Season 1		Season 2	
Amendments	**W10**	**W13**	**W10**	**W13**	**W10**	**W13**	**W10**	**W13**
Control	16.6a	16.8a	19.5a	19.7a	14a	15.4a	20.4a	21.1a
Manure	16.6a	17.6a	20.7a	20.7a	16.5b	17.3b	20.9a	22.6b
Fertilizer	21.1bc	22bc	22.9b	22.7ab	17.8b	20.1c	22.3b	23.7c
M+F	22.4cd	24cd	24.8c	22.8bc	19.11c	19.8b	23.2b	25.0d
	Silla variety							
Control	19.5a	21.5a	26.9a	27.4a	13.7a	16.4a	19.8a	20.2a
Manure	21.7a	23.4a	27.8a	28.1b	13.9a	17.3a	20.2a	21.1a
Fertilizer	27b	23.6a	28.2ab	29.0c	18.1b	19.6b	21.0b	22.5b
M+F	28.4c	27.6bc	29.6c	30.0d	19.1b	20.2c	21.5b	22.8b
P≤0.05(amend)	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001
P≤0.05(variety)	ns	ns	ns	ns	ns	ns	ns	ns
CV%	12	8.7	2.8	2.1	9.3	5.3	3.7	3.5

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

3.6 Comparative Effects of Fertilizer and Farmyard Manure on Sorghum Stem Circumference

Farmyard manure and fertilizer application significantly (P≤0.05) influenced sorghum stem circumference development (Table 5). Inorganic fertilizer + farm yard manure was observed to support the highest average stem circumference compared to other amendments. Gadama and silla variety treated with manure+ fertilizer had an average of 21% and 24% respectively wider stems compared to control plots. Stem circumference of crops applied with sole fertilizer and fertilizer+ manure was, however, not significantly different in several weeks during the cropping period, a scenario that was also observed in control and manure applied soils. There was no observed significant (P≤0.05) difference on stem circumference varietal difference on manure and fertilizer application in the two cropping seasons.

Table 5: Comparative effects of farmyard manure and fertilizer on average sorghum stem circumference (cm)

	Average stem circumference (cm)											
	Gadama variety						**Silla variety**					
	Season One			**Season two**			**Season one**			**Season two**		
Amendments	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**	**W3**	**W5**	**W7**
Control	7.1a	7.9a	8.9a	4.7a	7a	7a	6.7a	7.1a	7.4a	6a	7.3a	7.3a
Manure	7.8a	9.1b	8.0a	5a	8b	8a	6.8a	7.5a	8.7a	7a	8b	8a
Fertilizer	7.9a	9.1b	9.6b	5a	9c	9ab	8.4b	8.9ab	9.8b	8ab	9c	9ab
M+F	8.8ab	9.8bc	10.5bc	6.3ab	9.3d	9.3bc	8.5bc	9.0bc	9.9bc	8.3bc	9.7d	9.6c
P≤0.05(amend)	0.033	0.043	0.021	0.002	<0.001	<0001	0.033	0.043	0.021	0.002	<0.001	<0001
P≤0.05(variety)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	12	14.2	12.6	14.7	4.6	4.6	12	14.2	12.6	14.7	4.6	4.6

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

3.7 ComparativeEffects of Fertilizer and Farmyard Manure on Sorghum Dry Matter.

Farmyard manure and fertilizer application significantly (P≤0.05) influenced sorghum dry matter accumulation in the two cropping seasons (Table 6). Inorganic fertilizer + farm yard manure was observed to support the highest average stover and root dry matter yield compared to other amendments. Overal dry matter yield of gadama and silla variety treated with manure+ fertilizer was 50% and 45% respectively higher than control plots. Roots and stover yield of crops applied with sole fertilizer and fertilizer+ manure was significantly different except for silla variety season two. Stover and roots dry matter yield was also significantly different except season one for both gadama and sillastover and season one and two for gadama root dry matter. There was no observed varietal significant (P≤0.05) difference on stover and root dry matter accumulation on manure and fertilizer application in the two cropping seasons.

Table 6: Average dry matter yield (tons/ha) of sorghum as influenced by manure and fertilizer in post mined soils

	Average dry matter yield (tons/ha)							
	Stover				Roots			
	Gadam		Silla		Gadam		Silla	
Amendments/Variety	S1	S2	S1	S2	S1	S2	S1	S2
Control	0.6a	6.9a	0.9a	7.1a	0.2a	2a	0.2a	2.2a
Manure	0.8a	9.4b	0.9a	10.5b	0.24a	2.3a	0.3b	2.7b
Fertilizer	1.0b	11.4c	1.2ab	12.2c	0.3b	2.7b	0.4c	3.1c
M+F	1.6c	14.1d	2.0c	12.7c	0.5c	3.1c	0.5d	3.7d
P≤0.05(amend)	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P≤0.05(variety)	ns	ns	ns	ns	ns	ns	ns	ns
CV%	23.8	13.8	23.8	13.8	17.2	11.3	17.2	11.3

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

3.8 ComparativeEffects of Fertilizer and Farmyard Manure on Sorghum Grain Yield

Farmyard manure and fertilizer application significantly (P≤0.05) influenced average sorghum grain yieldin the trial period(Table 7). Inorganic fertilizer + farm yard manure was observed to support the highest average grain yield compared to the other amendments. Overallgrain yield forgadama and silla variety treated with manure+ fertilizer was 53% and 44% respectively higher than control plots.The was no observed significant (P≤0.05) difference on the effect of manure and/ or fertilizer on sorghum varieties.

Table 7: Average sorghum grain yield (tons/ha) as influenced by manure and fertilizer titanium mined in soils

	Average Grain yield (tons/ha)			
	Gadam variety		Silla variety	
Amendments	Season one	Season two	Season one	Season two
Control	2.26a	3.2a	2.1a	3.8a
Manure	3.2b	4.1b	2.8b	5.1b
Fertilizer	4.4c	5.3c	3.9c	5.5c
M+F	5.0d	6.5d	4.4d	6.2d
P≤0.05(amend)	<0.001	<0.001	<0.001	<0.001
P≤0.05(variety)	ns	ns	ns	ns
CV%	14.3	7.1	14.3	7.1

Values followed by the same letter(s) on the same column are not significantly different at P ≤ 0.05

Comment [DAL3]: Interesting result

4.0 Discussion

4.1 InitialSoil Properties

The levels of exchangeable Calcium (Ca>425ppm), Magnesium (Mg>80ppm), Iron (Fe>30pm), magnesium (Mn>30ppm) and zinc (Zn>2ppm) observed in the post mined soils are described by[14; 15] to be optimal for crop growth. Conversely, the levels of exchangeable phosphorus (P<20ppm), potassium (K<120ppm), sulphur (S<20ppm), Boron (Bo<0.8ppm), copper (Cu<1.5ppm), total nitrogen (<0.2%) and CEC< 15Cmolkg^{-1} found in the soils in the trial site are classified by [14] to be low and unable to support optimal crop growth and yield. Presence of such low nutrient levels is a common phenomenon in post mined soils [16; 17] attributable to soil degradation in the mining process. According to Mensah [9], mining process disrupts soil profile, structure, biota and essential nutrient cycles leading to poor soil fertility status.

4.2 Response of sorghum growth and yield to farmyard manure and inorganic fertilizer in post mined soils

4.2.2 Effects of Inorganic fertilizer on crop development and yield

Soils treated with manure + fertilizer were observed to support significantly more leaves, higher plant height, panicle length, stem circumference, leaf length, Leaf area index (LAI), dry matter and grain yield compared to sole manure, sole fertilizer and control. This phenomenon can be attributed to synergistic effect of manure and fertilizer on on soils. While inorganic fertilizer supplies applied nutrients in readily available forms and quantities within the exchange complex for plant uptake, manure on the other hand support sustainable nutrient availability through promotion of aggregate stability, temperature regulation, water and nutrient holding capacity and biological activities such as decomposition and mineralization[18; 19; 20; 21]. The synergy improves root penetration, nutrient uptake and favorable environment within the rhizosphere leading to improved plant growth that entails leave numbers, LAI, leaf length, plant height and stem circumference (20; 21; 22]. As the key food manufacturing organ through photosynthesis, increased leaf numbers, length and LAI indicate greater production and translocation of assimilates to other parts of the plant leading to improved root development, biochemical processes, plant height, dry matter accumulation and grain yield[23; 24]. The synergistic effects of farmyard manure and inorganic fertilizer on crop growth have been reported in research findings by [17; 25; 26; 27; 28; 29; 30].

Combined farmyard manure and inorganic fertilizer was observed to promote higher significantly dry matter and grain yield compared to other treatments in both varieties. The increase dry matter and grain yield can be attributed to the improved plant growth, LAI and number of spikes per panicle leading to increase below and above ground biomass accumulation hence high grain yield. This is generally attributed to improved soil physical, chemical and biological properties leading to improved nutrients availability and uptake. This finding corresponds to reports by [31; 32; 33] who reported that use of organic manure and fertilizer led to improved soil fertility leading to increased grain weight, grain yield, leaf area index (LAI) and chlorophyll content. They also collaborate with findings by [34] who reported that combination of manure and inorganic fertilizer increase nitrogen transformation, macro and micronutrients uptake and nutritional composition resulting to increased dry matter. Similarly, [17; 32; 33; 35] reported improved dry matter accumulation and crop yield on soils applied with combination of manure and fertilizer compared to sole manure, sole fertilizer and unfertilized post mined soils.

Comment [DAL4]: Must be documented

5.0. CONCLUSIONS AND RECOMMENDATIONS

Obtained results showed that, initial soil characteristics were sandy loam textured, with slightly acidic reaction, low levels of exchangeable P, K, S, Bo, and Cu, Bo, CEC, TN and OC. Levels of Ca, Mg, Fe, Na, Mn and Zn in the soils were optimal.

Sorghum growth and yield was observed to vary with applied amendment with manure + fertilizer promoting significantly better crop growth and yield. Sole manure was observed to contribute 30% and 50% increase in plant height for Silla and Gadama respectively and insignificant effect on grain yield. Sole fertilizer on the other hand did not significantly affect plant height, leaf development and grain yield. Whilst, combination of manure and fertilizer was observed to significantly improve plant height by 14% and 28%, number of leaves per plant by 28% and 29%, panicle length by 18% and 8%, dry matter by 30% and 40% for Gadama and Silla varieties respectively compared to unfertilized plots, the treatments did not significantly affect shoot and root dry matter accumulation in both varieties during the two cropping seasons. Combination of manure and inorganic fertilizer significantly ($P \leq 0.05$) improved grain yield by 50% for both Gadam and Silla varieties compared to control and the grains yield from all the varieties were within the national recommended potential. Additionally, grain yields from manure applied and unfertilized soils were not significantly ($P \leq 0.05$) different.

Owing to the fact that the soils have sandy loam texture with compromised profile, water and nutrient retention capacity, sustainable sorghum production calls for application of appropriate levels of quality organic amendments to improve soil carbon skeletons, aggregate stability and biotic activities. Application of balanced proportions of inorganic fertilizers to supplement all deficient nutrients is also critical.On account that this was a two cropping season study, long term trials and simulation models are required to ascertain optimal sorghum production while ensuring sustainable soil health management in such soils.

6.0. REFERENCES

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