INFLUENCE OF COMPOST AND FARMYARD MANURE ON CASSAVA GROWTH, YIELD AND DRY MATTER PARTITIONING AT MVOMERO AND MASASI DISTRICTS -TANZANIA

.

ABSTRACT

Aims: Field experiments were conducted for two seasons: 2019/20 and 2020/21 under rain fed cropping seasons to determine yield response of cassava to compost (CP) and farmyard manure (FYM) application
Study design: The experiments were laid out in a RCBD with three replications
Place and Duration of Study: Vianzi village in Mvomero District and Mumbaka village in Masasi district between December 2019 to November 2021.
Methodology: At each site, Treatments involving CP and FYM tested separately at four different levels; 2.5 t ha^{-1}, 5 t ha^{-1}, 7.5 t ha^{-1} and a control (0 t $ha^{-1)}$ was included. Both CP and FYM treatment rates were applied by broadcasting method followed by incorporation into the soil prior to cassava planting. Data on cassava plant height and cassava stem girth were collected for assessment of cassava growth and data on number of tubers per plant, cassava root fresh and dry biomass were recorded for assessment of cassava yield.
Results: At Mvomero site, a maximum significant (P=.01) cassava fresh weight (19.18 t ha^{-1}) were obtained from the plots treated with 5 t ha^{-1} FYM giving yield advantage of 67.5% above the control in 2020/21. In the CP treated plots, a maximum significant (P =.001) yield (22.2 t ha^{-1}) was obtained giving 69% yield advantage above the control in 2020/21. At Masasi site, a maximum of 24.3 t ha^{-1} cassava fresh weight were obtained in 2020/21 giving 77.7% yield advantage over the control. In the CP treated plots in 2020/21, 18.7 t ha^{-1} cassava fresh weight was obtained giving 34.6% yield advantage over control.
Conclusion: Application of CP and FYM not only improve cassava yields as it is for inorganic fertilizers but also, they have an added advantage of improving soil health conditions in season and over years. For best results application of CP or FYM should be 5.0 t ha^{-1} .

Key words: *cassava, compost, farmyard manure, dry matter partitioning, Tanzania*.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz.) is the second most important source of calories in Africa [1]. Cassava is originated in Latin America and it is grown in many parts of the world as source of food, livestock feed and it is used as raw materials for alcohol and pharmaceutical industries [2,3]. According to [1] and [4], Sub-Saharan Africa (SSA) is among the largest producers of cassava in the world, contributing about 57% of total cassava produced globally. Cassava is a drought tolerant crop and thus, it has a greater potential to mitigate food insecurity and hunger in the face of climate variability [4, 5]. In Tanzania, cassava plays an important role in food security especially in dry and less fertile areas contributing about 19 % of total calories [6]. Although cassava is among the main staple food crops in Tanzania, its productivity is far below the attainable yield levels. The average cassava yield in Tanzania is 8 t ha^{-1} compared to the potential of 20 t ha^{-1} [7]. Among the factors accounting for the low productivity of cassava are diseases, mostly, Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD) that account for cassava yield losses of about 70 to 100% if left unmanaged [5,8]. Furthermore, low soil fertility levels contribute to reduced land productivity exacerbated by continuous farming without the use of fertilizers [9,10] and lack/inadequate purchasing power for inputs including fertilizers by smallholder farmers [10, 11, 12, 13].

Research works for improving cassava yields in Tanzania have been focusing mainly on the use of synthetic fertilizers and or combination of fertilizers and FYM for soil fertility management [10, 14]. Furthermore, industrial chemical inputs including pesticides and synthetic fertilizers have raised concern globally due to their associated side effects on the environment and ecosystem [15, 16]. Agroecological practices saves as a better option for food production and thus researches on their performance need special attention [17, 18, and 19]. Although Agroecological farming approach has been reported to increase crop yields, its performance has mostly been well documented in temperate countries, but generally hardly documented in some sub-Saharan countries [20].

Soil fertility amendments such as FYM, poultry manure, goat manure and CP have been reported to improve soil organic carbon (OC) and the availability of nutrients in soil for improved crop yields [11, 21, 22]. According to [4, 23], cassava responds well to FYM. A study by [14] at Bukoba, Misenyi and Biharamulo districts in Tanzania indicated significant increase of cassava root yields from16.9 to 34.8 t ha^{-1} following application of FYM at the rate of 8 t ha^{-1} and 29.62 t ha^{-1} when mineral fertilizers were applied alone. However, there is limited studies on the effective rates of FYM and CP for improving cassava production especially in the Eastern and Southern Zones of Tanzania [24]. Therefore, the present study was undertaken with the aim to evaluate the influence of different rates of FYM and CP on the growth, yield and cassava dry matter partitioning to generate area specific recommendations on its application in ecological soil fertility management in Mvomero and Masasi districts of Tanzania.

2. MATERIALS AND METHODS

2.1 Study Location and Duration

A rainfed field experiment was conducted between December 2019 to November 2021 at two sites. The first site was Vianzi village in Mvomero District, Morogoro region (06˚44' 33.8″ to 06 ˚44' 34.7″ S and 037˚33′ 00.4″ to 037˚33′ 00.8″ E) at 547 meters above sea level (m.a.s.l.). The second site was Mumbaka village in Mtwara region (10˚47' 25.1″ to 10 ˚47' 25.9″ S and 038˚53′ 35.4″ to 038˚53′ 36.8″) E at 293 m.a.s.l. The two sites represents Mvomero and Masasi Districts where cassava is important staple food crop but with serious limitations of soil fertility. Mvomero receives average of 975 mm of rainfall per annum and temperature averages at 25˚C [25]. Masasi is characterized by sandy clay soils classified as Veti-Acric Ferralsols-Rhodic [26]. Mvomero is dominated by Tropical Savanna Climate [27] while Masasi is characterized by Tropical wet and dry or savanna climate. The average annual rainfall at Masasi fluctuates between 538 mm in dry years and 1550 mm in wet years. Lowest temperatures (24 °C) are experienced in June and highest temperatures (27.5 °C) are noticed in December [26].

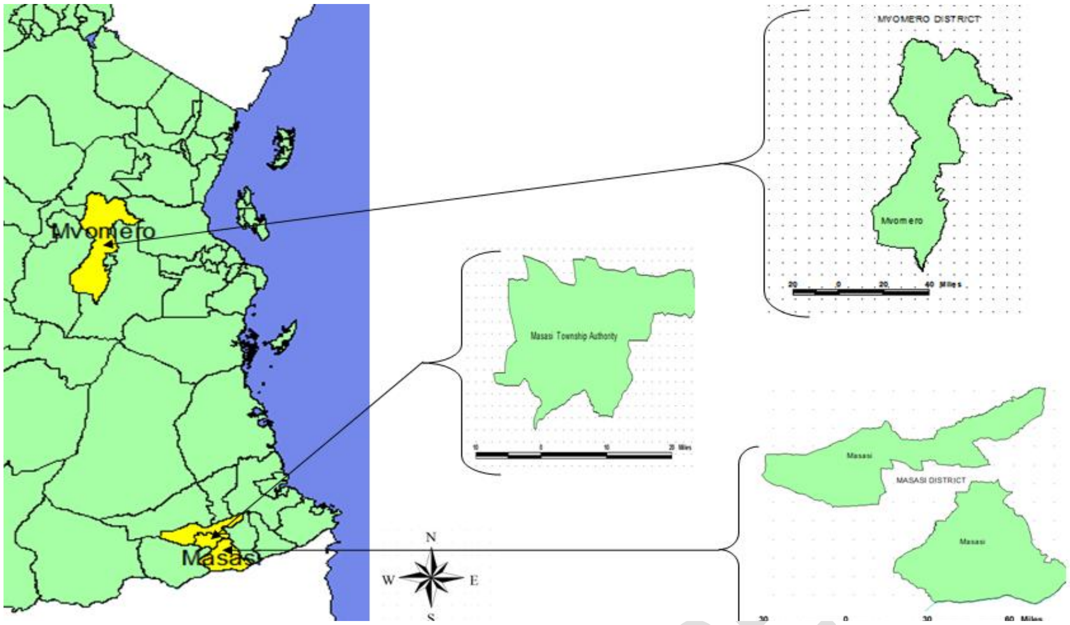


Figure 1: Section map of Tanzania showing location of research sites

2.2 Source of Planting Materials

A cassava variety "Kiroba" registered in Tanzania was used as the test crop. The variety is characterised by high yielding potential (31 t ha^{-1}) and low susceptibility to Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD).

2.3 Preparation of Farmyard Manure and Compost

Fresh FYM was collected from cattle sheds at each research site and left to decompose under shade for six months to give ample time for the manure to be converted to a more stable form for use as a soil amendment before being applied to the field. During manure decomposition, heat is generated that kill weed seeds, parasites and bacteria which cause plant diseases. Standard procedures [28] for pit method of CP preparation were employed in preparation of CP at both Mvomero and Masasi sites with some modification. In the current modification, the materials used for CP making were rice straws, gliricidia leaves (*Gliricidia sepium*), cow dung, soil and ash. The rice straws and *G. sepium* were chopped to less than 10 cm long prior to ensiling. The pit was then ensiled by first putting a layer of rice straws followed by a layer of *G. sepium* both at 15 cm layer thickness, followed by thin layers of cow dung (5 cm thick), ash (0.5 kg) and lastly soil (3 cm thick). Water was then sprinked to maintain moisture content of the materials at 60% [22]. Other layers were then arranged following the same procedure. After filling the pit to the top, a stick was inserted at the centre of the pit for temperature checking. The pit was turned at an interval of three weeks (21days) for three months. Water was sprinkled at every turn to maintain the moisture at 60%. By the end of three months, the CP was mature ready for use. Composite samples of FYM and CP were collected from each site and transferred to the Soil Science Laboratory at SUA for nutrient analysis prior to application in the field. Prior to analysis, FYM and CP samples were air-dried ground and sieved to pass through a 0.5 mm sieve.

2.4. Laboratory Analysis of Manure and Compost Used in the Study

Processed samples were analyzed for pH, Total Nitrogen, Organic carbon, Total P and K content. pH was determined in a 1:2.5 (w/v): water using pH meter [29]. Total nitrogen (TN) was analyzed by the macro-Kjeldahl digestion method [30], Organic carbon by the Walkley and Black wet oxidation method [31]. Analysis of Total P by Olsen method (32) and Total K was determined by NH4OAc saturation method [33]

2.5 Land Preparation

Following preliminary soil sampling and analysis, the experimental field was tilled using a tractor followed by breaking of soil clods and levelling using hand hoes.

2.6 Experimental Design and Treatments

The experiments were laid out in a RCBD with three replications at each site. The Individual plots of 4 m × 4 m were established separated by a 1.5 m alley between plots and 2 m alley between blocks. Treatments involving CP and FYM tested separately at four different levels each were randomly assigned to experimental plots. For both CP and FYM the application rates were; 2.5 t ha^{-1}, 5 t ha^{-1}, 7.5 t ha^{-1} and a control (0 t ha^{-1}) was included to depict a common farmers' practice. The application rates were equivalent to 4, 8 and 12 kg $plot^{-1}$ respectively. Both CP and FYM treatment rates were applied on dry weight basis by broadcasting method followed by incorporation into the soil prior to cassava planting. Cassava cuttings of 30 cm length each were planted at a spacing of 1 m × 1 m resulting into a plant population of 10,000 plants ha^{-1}. Weeding was performed on regular basis to keep the field free from weeds.

2.7 Data Collection

2.7.1 Weather data

Data on daily rainfall (mm) was collected at each site in both 2019/20 and 2020/21 cropping seasons.

2.7.2 Cassava growth data

To assess cassava growth in response to soil fertility amendments, cassava plant height (cm) was measured from the base to the top of the highest shoot at the 3rd and 6th month after planting (MATP) using a tape measure for all plants in a net plot (2 m × 2 m). Cassava stem girth was also measured using a plastic Vernier calliper (American Scientific LLC), 50 cm above the ground from the plants in the net plot.

2.7.3 Cassava yield data

To determine cassava yield in response to soil fertility amendment, all cassava plants in the net plot(2 m × 2 m) were harvested 9 months after transplanting planting (MATP) by uprooting. Following uprooting, the plant parts were separated into root tubers, leaf, and stem. The fresh weight of each fraction was measured and recorded right in the field using a Portable Electronic Scale (Manomano.co.uk). Thereafter, subsamples of root tubers (0.5 kg), leaves (0.3 kg) and stems (0.5 kg) were dried in the oven to constant moisture for determination of dry biomass (t ha^{-1}) following a procedure described by [4]. Before oven drying, cassava tubers were peeled, chopped and air withered (4 days) prior to oven drying at 70˚C for 72 hours and dry matter yield (DM) was expressed in t ha^{-1}. The dry matter contents of cassava roots, leaves and stems in each treatment were determined gravimetrically as percentage dry matter content using equation (1) proposed by [34];

$$\text{Percentage DM} = (W1/W2)\ 100 \qquad (1)$$

Where; W1 is the weight of oven-dry cassava roots and W2 is the weight of fresh cassava roots, leaves or stems in each treatment

Cassava harvest index (HI) was calculated according to the formula proposed by [35] (Equation 2).

$$\text{Harvest index (HI)} = \frac{\text{root dry matter}}{\text{Total dry matter}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

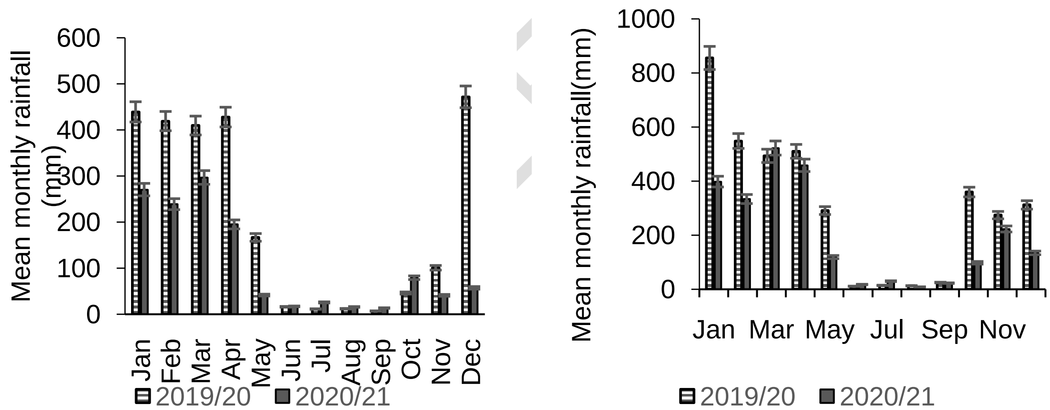
2.8 Data Analysis

Crop response data obtained from each site were subjected to one-way Analysis of Variance (ANOVA) using Genstat software 15th edition. Treatment means were separated using Duncan's New Multiple Range Test (DNMRT) at P ≤ 0.05.

3. RESULTS

3.1 Monthly and Annual Rainfall at Masasi and Mvomero Sites in 2019/20 and 2020/21 Cropping Seasons

At Masasi site, rainfall ranged between 6.9 to 471.7 mm and 13.4 to 296.8 mm for 2019/20 and 2020/21 seasons respectively with the highest rainfall being recorded in 2019/20 than in 2020/21 (Fig. 2). At Mvomero site, rainfall ranged from 12.64 to 855.0 mm and from 8.5 to 521.9 mm for 2019/20 and 2020/21 seasons respectively. In both sites, higher annual rainfall (2521 - 3703 mm) was recorded during the 2019/20 cropping season (Table 1) than during the 2020/21 (1291.8 – 2362.4 mm).



Rainfall at Masasi site   Rainfall at Mvomero site

Figure 2: Mean monthly rainfall during the 2019/20 and 2020/21 cropping seasons at Masasi and Mvomero experimental sites

3.2 Physical and Chemical Characteristics of Soils, FYM and CP used at the two study sites

Results of selected chemical and physical characteristics of soils of the two study sites were as indicated in Table 1. Results indicated that soil total Nitrogen, P, K and OC of both sites were low except for Mvomero site where soil K was high. Laboratory analytical results for nutrient content of FYM and CP at each site were as depicted in Table 2. Total Nitrogen of the FYM from Mvomero exceeded that of Masasi by 8% while OC of FYM from Masasi surpasses that of Mvomero by 17.7%. Total P of FYM from Masasi was 19% higher than that of Mvomero while K from FYM of Mvomero exceeded that of Masasi by 41.3%. Results also indicated that, CP total Nitrogen from Masasi was 8.3% higher than that of Mvomero while OC from Masasi CP was 20.8% higher than that of Mvomero. Total P and K from Mvomero were above that of Masasi by 18.8 and 25.9% respectively.

Table 1: Selected chemical and physical characteristics of soils of the studied sites

Experimental Site	Soil Characteristic	Value	Rating	Reference
Masasi	pH	6.60	Slightly acidic	[36]
(MBV)	Total N (%)	0.08	Very low	[37]
	Organic carbon (%)	1.60	Low	[37]
	Available P (mg/kg)	2.18	Low	[36]
	Exchangeable K (Cmol (+)/kg)	0.30	Low	[37]
	Exchangeable Ca(Cmol (+)/kg)	5.80	Very high	[36]
	Exchangeable Mg (Cmol (+)/kg)	1.48	Medium	[36]
	Exchangeable Na(Cmol (+)/kg)	0.08	Very low	[37]
	CEC Cmol (+)/kg	17.00	Medium	[37]
	Sand (%)	69.00		
	Silt (%)	4.00		
	Clay (%)	27.00		
	Textural class	Sandy clay loam		[38]
Mvomero	pH	6.38	Slightly acidic	[36]
(VV)	Total N (%)	0.08	Very low	[37]
	Organic carbon (%)	1.01	Low	[37]
	Available P (mg/kg)	4.38	Low	[36]
	Exchangeable K (Cmol (+)/kg)	0.53	High	[37]
	Exchangeable Ca(Cmol (+)/kg)	2.13	Medium	[36]
	Exchangeable Mg (Cmol (+)/kg)	1.96	Medium	[36]
	Exchangeable Na(Cmol (+)/kg)	0.12	Low	[37]
	CEC Cmol (+)/kg	4.80	Very low	[37]

Sand (%)	59.12	
Silt (%)	6.56	
Clay (%)	34.32	
Textural class	Sandy clay loam	[38]

Key: MBV=Mumbaka Village; VV= Vianzi village

Table 2: Chemical properties of applied manure and compost

Source	Chemical Properties	Concentration (%)		t-test Analysis	
		Mvomero	Masasi	Mean	p-value
	pH (1:2.5) in H_2O	8.14	8.01	8.075	0.005
	TN	1.75	1.61	1.68	0.027
FYM	OC	23.23	28.21	25.72	0.061
	Total P (Olsen)d	0.21	0.17	0.19	0.067
	K	0.46	0.27	0.36	0.162
	C:N	13.14	17.52	15.33	0.09
CP		7.85	7.19	7.52	0.028
	pH(1:2.5) in H_2O				
	TN	0.77	0.84	0.81	0.028
	OC	7.88	9.96	8.92	0.074
	Total P (Olsen)	0.16	0.13	0.15	0.066
	K	0.58	0.43	0.51	0.094
	C:N	10.23	11.86	11.05	0.047

3.3 Effects of FYM and CP on Cassava Growth Variables at Masasi and Mvomero Sites in 2019/20 and 2020/21

3.3.1 Effects of FYM on cassava growth variables at Masasi and Mvomero

At Masasi site, the effect of different rates of FYM on cassava plant height at 3 MAP and 6 MAP in 2019/20 and 2021 seasons varied significantly (P =.05) (Table 3). In 2019/20, the highest mean plant height (135.6 cm) was recorded in the plots treated with FYM at the rate of 7.5 t ha^{-1} and the lowest (81.6cm) was obtained from control plots. In 2020/21, the effects of treatments showed significant difference (P=.05). At 6MAP, the highest cassava plant height was recorded in the highest FYM application rate of 7.5 t ha^{-1}, which was 193.5 cm and the lowest was recorded in untreated plots.

Table 3: Effects of farmyard manure on cassava plant height at Masasi site

CP application	2019/20		2020/21	
rates in t ha^{-1}	3MATP	6MATP	3MATP	6MATP
0.0	81.6 a	98.0 a	93.3 a	133.3a
2.5	83.5 a	99.8 a	117.8ab	154.9a
5.0	105.1b	132.1b	109.8ab	148.5a
7.5	124.7b	135.6b	141.5b	193.5b
CV (%)	20.6	9.0	4.4	13.7
SE	20.33	10.45	13.1	21.53
P –Value	0.022	0.008	0.09	0.036

Means in the same column followed by similar letters are not significantly different at p =.05 as per DNMRT

Key: MATP=Months after transplanting

Farmyard manure application rates significantly (P =.05) increased cassava stem girth (Fig. 3). The highest mean stem girth recorded 6 MATP was obtained in the highest FYM application rate of 7.5 t ha^{-1} which was 3.5 cm while the lowest (1.6 cm) was observed in untreated plots.

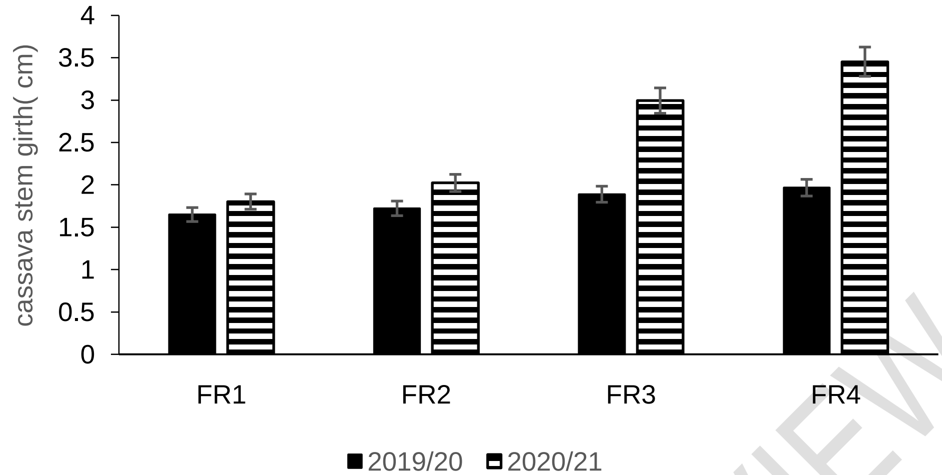


Figure 3: Effects of FYM application rates on cassava stem girth at Masasi site

Key: FR1= 0.0 (Control), FR2= Farmyard manure application rate of 2.5 t ha^{-1}, FR3 = Farmyard manure application rate of 5 t ha^{-1}, FR4= Farmyard manure application rate of 7.5 t ha^{-1}

At Mvomero site, in 2019/20 the mean plant height recorded at 6MAP was highest (128.7cm) in the highest rate of FYM application (7.5 t ha^{-1}). The lowest mean plant height (85 cm) was recorded in untreated plots (Table 4). In 2020/21 season, the highest (132.2 cm) mean plant height at 6 MAP was obtained in the highest rate of FYM application while the lowest was recorded in untreated plots.

Table 4: Variation of cassava pant height with FYM application rates at Mvomero site

CP application	2019/20		2020/21	
rates in t ha^{-1}	3MATP	6MATP	3MATP	6MATP
0.0	55.9 a	83.2 a	85.0 a	92.6 a
2.5	62.9 a	104.3 ab	126.2 a	126.3 ab
5.0	67.2 a	123.9 ab	130.8 a	141.4 b
7.5	70.8 a	128.7 b	132.2 a	155.6 b
CV (%)	1.7	16.6	4.6	6.4
SE	1.1	18.3	5.4	8.21
P -Value	0.414	0.122	0.18	0.042

Means in the same column followed by similar letters are not significantly different at $p \leq 0.05$ as per DNMRT

Key: MATP= Months after transplanting

Farmyard manure application rates shown significant effect (P=.05) on average cassava stem girth (Fig. 4). The mean cassava stem girth recorded 6 MAP was highest at the highest application rate while the lowest was recorded in the control.

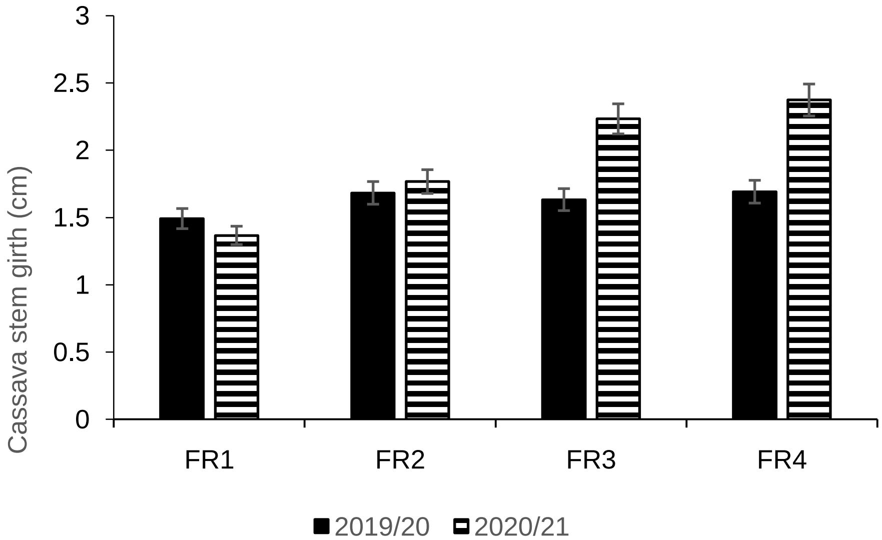


Figure 4: Effects of Farmyard manure on cassava stem girth at Mvomero site

Key: FR1= 0.0 (Control), FR2= Farmyard manure application rate of 2.5 t ha^{-1}, FR3 = Farmyard manure application rate of 5 t ha^{-1}, FR4= Farmyard manure application rate of 7.5 t ha^{-1}

3.3.2 Effects of compost on cassava growth variables at Masasi and Mvomero sites in 2019/20 and 2020/21

Compost application significantly increased cassava plant height (P =.05) at both Masasi and Mvomero sites. Results in Table 5 indicated that, at Masasi site in 2019/20, the highest average cassava plant height (118.9 cm) recorded 6 MAP was obtained at CP application rate of 5 t ha^{-1} while in 2020/21 the highest (135.1 cm) cassava plant height was recorded in the at 7.5 t ha^{-1} CP application rate. In both seasons, the lowest cassava plant heights were recorded in the untreated plots.

Table 5: Effects of CP on cassava plant height at Masasi site

CP application rates in t ha^{-1}	2019/20		2020/21	
	3MATP	6MATP	3MATP	6MATP
0.0	82.3 a	96.3 a	70.7a	109.4a
2.5	91.3 ab	95.7 a	91.7a	116.3a
5.0	104.4 c	118.9 b	104.5 ab	127.6a
7.5	97.8 bc	110.0ab	101.1 b	135.1a
CV (%)	10.9	8.0	10.4	15.3

SE	10.2	8.44	5.07	18.22
P -Value	0.012	0.032	0.06	0.543

Means in the same column followed by similar letters are not significantly different at p ≤ 0.05 as per DNMR

Key: MATP= Months after transplanting, CP= Compost

CP application rates significantly (P =.05) increased cassava stem girth at Masasi site. In both 2019/20 and 2020/21 seasons there was increase in cassava stem girth with increase in CP application rates (Fig. 5).

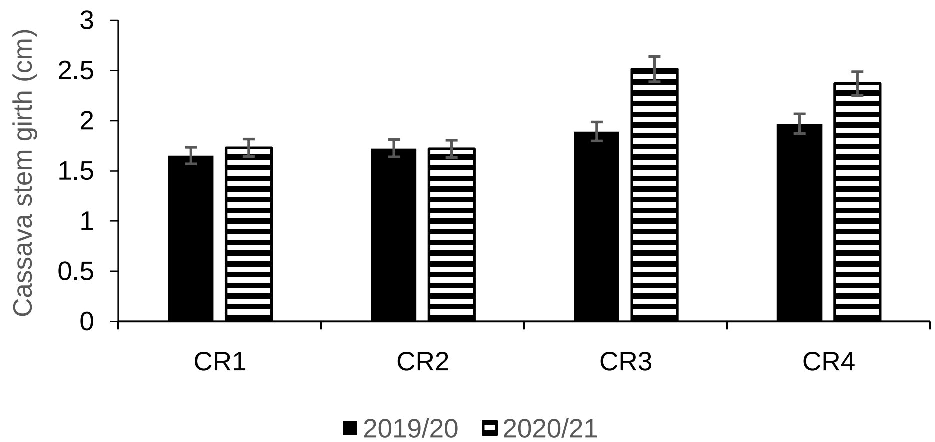


Figure 5: Effects of CP application rates on cassava stem girth at Masasi site
Key: CR1= 0.0 (Control), CR2= Compost application rate of 2.5 t ha^{-1}, CR3 = Compost application rate of 5 t ha^{-1}, CR4= Compost application rate of 7.5 t ha^{-1}

Compost application rates did not significantly increase cassava plant height at Mvomero site in both 2019/20 and 20220/21 cropping seasons (Table 6). However in both seasons cassava plant height recorded 6MAP indicated increase in cassava plant height with increase in CP application rates. In both seasons, the lowest cassava plant heights were recorded in untreated plots.

Table 6: Effects of Compost on cassava plant height at Mvomero site

CP application rates in t ha^{-1}	2019/20		2020/21	
	3MATP	6MATP	3MATP	6MATP
0.0	57.3 a	115.9 a	111.8 a	125.3 a
2.5	57.8 a	119.0 a	123.0 a	130.3 ab
5.0	63.5 a	148.4 a	136.7 a	154.5 ab
7.5	66.5 a	144.8 a	134.2 a	158.9 b

CV (%)	4.7	3.5	3.1	2.6
SE	2.85	4.6	3.94	3.76
P -Value	0.78	0.085	0.168	0.068

Means in the same column followed by similar letters are not significantly different at $p \leq 0.05$ as per DNMRT

KEY: MATP= Months after transplanting

Application of CP at different rates had significant effect (P=.05) on cassava stem girth in both seasons at Mvomero site. The highest mean stem girth (1.9 cm) in 2019/20 was recorded in the CP application rate of 5 t ha^{-1} while in 2020/21 the highest mean stem girth (2.5 cm) was observed in the highest rate of 7.5 t ha^{-1}. In both seasons, the lowest mean stem girth were recorded in the untreated plots.

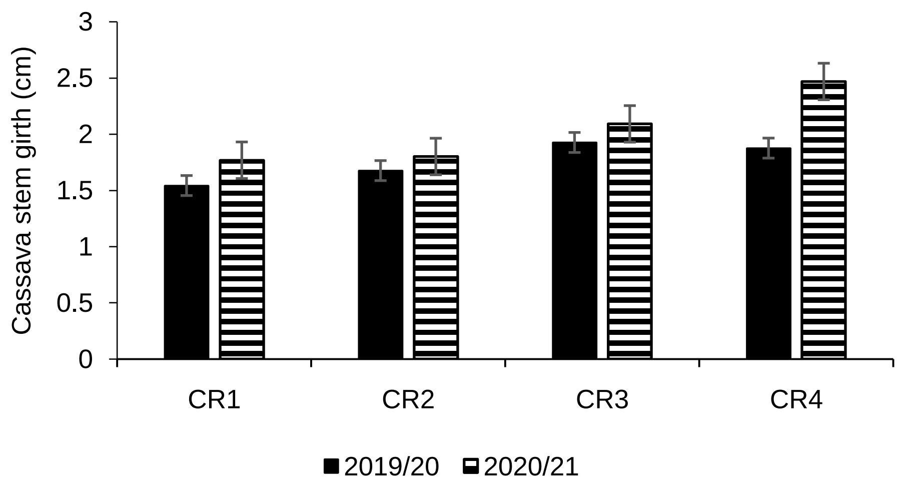


Figure 6: Effects of compost application rates on cassava stem girth at Mvomero site

Key: CR1= 0.0 (Control), CR2= Compost application rate of 2.5 t ha^{-1}, CR3 = Compost application rate of 5 t ha^{-1}, CR4= Compost application rate of 7.5 t ha^{-1}

3.4 Effects of Farmyard Manure on cassava yield in 2019/20 and 2020/21 at Mvomero and Masasi sites

The mean number of cassava tubers per plant and cassava tuber fresh weight at the two study sites were as shown in Table 7. Results indicated that, FYM significantly (P=.05) increased the number of cassava tubers per plant as well as cassava tuber fresh weight. At Mvomero site, the lowest number of cassava tubers per plant (5.8) and average cassava fresh weight (4.3 t ha^{-1}) were recorded from the untreated plots. The highest number of cassava tubers per plant and average cassava tuber weight were obtained from the plots treated with FYM at a rate of 5 t ha^{-1}, which were 8.1, and 6.4 t ha^{-1}, respectively. At Masasi, the effect of FYM on the number of tubers per plant was significant (P =.05). The highest average number of tubers per plant (13.1) was recorded from plots that had received FYM at a rate of 7.5 t ha^{-1} while the lowest mean number (9.8) was obtained from plots that received FYM at a rate of 2.5 t $ha^{-1.}$

Table 7: Effects of FYM application rates on cassava growth and yield at Masasi and Mvomero sites

FYM application rates t ha^{-1}	Mvomero				Masasi			
	Number of tubers $plant^{-1}$		Cassava FW (t ha^{-1})		Number of tubers $plant^{-1}$		Cassava FW (t ha^{-1})	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
0.0	5.8 a	9.0 a	4.3 a	6.23 a	10.1 a	11.4 a	12.3 a	15.40 a
2.5	7.8 a	11.5 a	5.5 a	9.67 a	9.8 a	13.0 a	11.7 a	15.70 a
5.0	9.5 a	10.2 a	10.2 b	19.18 b	12.6 b	12.3 a	15.7 a	24.28 a
7.5	8.1 a	11.7 a	6.4ab	11.65 a	13.1 b	17.0 b	11.1 a	18.73 a
CV	8.4	5.3	9.2	23.9	18.7	17.5	19.3	34.5
SE	0.65	0.56	0.61	2.787	2.13	2.4	9.85	6.3
P- VAlue	0.274	0.281	0.05	0.01	0.023	0.027	0.542	0.225

Means in the same column followed by similar letters are not significantly different at p =.05 as per

DNMRT

Key: FYM= farmyard manure, FW= fresh weight

3.5 Effects of Compost on Cassava Yield in 2019/20 and 2020/21 at Masasi and Mvomero

Significant difference (P =.05) were observed between treatment means with regards to numbers of tubers per plant at both Masasi and Mvomero sites (Table 8). The highest number of tubers were recorded from the highest rate of CP application rate, which were 10.5 and 13.4 for Mvomero and Masasi respectively. However, in both sites there was no significant difference between treatment means on cassava fresh weight.

Table 8: Effects of CP application rates on cassava yield at Momero and Masasi sites

CP application rates t ha^{-1}	Mvomero				Masasi			
	Number of tubers $plant^{-1}$		Cassava FW (t ha^{-1})		Number of tubers $plant^{-1}$		Cassava FW (t ha^{-1})	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
0.0	6.8 ab	7.7 a	7.9 a	6.8 a	9.0 b	10.2 a	8.0 a	12.2 a
2.5	5.6 a	9.3 a	5.8 a	10.8 ab	7.4 a	11.2 a	7.5 a	14.6ab

5.0	10.2 bc	9.2 a	9.2 a	22.2 c	11.8 c	9.9 a	10.5 a	18.6bc
7.5	10.5 c	8.5 a	8.6 a	16.2 b	13.4 d	11.7 a	11.8 a	20.5 c
CV	8.0	18.0	8.9	9.7	2.1	20.2	20	55.5
SE	0.66	1.56	0.7	1.366	0.22	2.2	1.88	9.16
P- VAlue	0.037	0.762	0.418	0.001	<.001	0.933	0.176	0.015

Means in the same column followed by similar letters are not significantly different at p =.05 as per DNMRT

3.6 Cassava Shoot and Root Biomass (t ha^{-1}) in Response to Farmyard Manure and Compost Application

At both Mvomero and Masasi sites, there was a significant (p =.05) difference between the different levels of FYM on cassava shoot and root weight. At Mvomero and Masasi sites (Table 9 and Table 10), the highest cassava root weight were observed in the plots treated with FYM at a rate of 5 t ha^{-1} which were 19.18 and 24.28 t ha^{-1} respectively. In both sites, the lowest values of cassava root fresh weighs were recorded in untreated plots.

Table 9: Cassava fresh biomass in response to FYM at Mvomero site

FYM application in t ha^{-1}	Stem	Leaves	Root	Above Ground Biomass	Total Biomass
0.0	5.66 a	0.05a	6.23 a	5.70 a	11.93 a
2.5	8.30 ab	0.08 a	9.67 a	8.38 a	18.06 a
5.0	11.28 b	1.07 b	19.18 b	12.35 b	31.53 b
7.5	15.03 c	1.74 c	11.65 a	16.77 c	28.42 b
CV (%)	14.4	27.4	23.9	15.3	18.3
SE	1.45	0.201	2.787	1.65	4.12
P- value	0.001	0.002	0.01	0.001	0.001
Sign.	***	**	*	***	***

Means in the same column followed by similar letters are not significantly different at p =.05 as per DNMRT

Table 10: Cassava fresh biomass in response to FYM at Masasi site

FYM application in t ha^{-1}	Stem	Leaves	Root	Above Ground Biomass	Total Biomass
0.0	3.99 a	0.67 a	15.40 a	4.66 a	20.07 a
2.5	4.83 ab	0.78 a	15.70 a	5.61 ab	21.31a
5.0	7.42 b	1.20 b	24.28 a	8.62 b	32.89 b
7.5	14.77 c	2.37 c	18.73 a	17.14 c	35.87 b
CV (%)	10.7	12.6	34.5	11	24
SE	0.833	0.158	6.3	0.987	6.621
P- value	<.001	0.004	0.225	<.001	0.024
Sign.	***	**	Ns	***	*

Means in the same column followed by similar letters are not significantly different at p =.05 as per (DNMRT)

3.7 Cassava Shoot and Root Biomass (t ha^{-1}) in Response to CP Application

Results indicated that different CP application rates imposed significant variations (P =.05) between treatment means with regards to cassava fresh biomass accumulation at both sites. At Mvomero site, the highest (22.21 t ha^{-1}) mean cassava root fresh weight were obtained from the plots treated with CP at a rate of 5 t ha^{-1} while the lowest root fresh weight (6.87 t ha^{-1}) were recorded from the control (Table 11). At Masasi site, the highest cassava root fresh weigh (20.48 t ha^{-1}) was recorded from the plots treated with the highest rate of CP application (7.5 t ha^{-1}) while the lowest was recorded in the control (Table 12).

Table 11: Cassava shoot and root biomass in response to CP application rates at Mvomero

CP application in t ha^{-1}	Stem	Leaves	Root	Above Ground Biomass	Total Biomass
0.0	6.25 a	0.56 a	6.87 a	6.81 a	13.95 a
2.5	7.37 a	0.84 a	10.82 ab	8.19 a	19.34 a
5.0	12.96 b	2.15 b	22.21 c	15.11 b	35.60 b

7.5	16.78 c	2.61 b	16.21 b	19.39 c	37.34 b
CV (%)	17.4	31.3	9.7	16.4	12.6
SE	1.883	0.482	1.366	2.024	3.352
P- value	<.001	<.001	0.001	<.001	0.001
Sign.	***	***	***	***	***

Means in the same column followed by similar letters are not significantly different at $p \leq 0.05$ as per DNMR

Table 12: Cassava shoot and root biomass in response to CP application at Masasi

CP application in t ha^{-1}	Stem	Leaves	Root	Above Ground Biomass	Total Biomass
0.0	3.72 a	0.54 a	12.20 a	4.26 a	16.46 a
2.5	4.31 ab	0.62 ab	14.61ab	4.93 ab	19.53 a
5.0	5.37 b	0.81 bc	18.67bc	6.18 b	24.84 b
7.5	6.80 c	0.98 c	20.48 c	7.78 c	28.27 b
CV (%)	34.3	36	55.5	34.6	49.8
SE	1.734	0.265	9.16	1.999	11.09
P- value	0.005	0.009	0.015	0.005	<.001
Sign.	**	**	*	**	***

Means in the same column followed by similar letters are not significantly different at $p \leq 0.05$ as per DNMRT

4.6.8 Correlation between cassava root and shoot weight (t ha^{-1}) in 2020/21 season

Regression analysis indicating relationship between cassava leaves fresh weight, stems, total above ground biomass and root fresh yield was as presented in Table 13. For Mvomero site, there was a strong positive relationship between cassava fresh yield and leaves, stems and total above ground biomass following application of FYM. There was also a positive significant relationship between cassava root fresh weight and leaves (R =0.55) and stems (R=0.54) fresh weight while there was no significant relationship between root fresh weight and total above ground biomass following application of CP. There was a negative relationship between root fresh weight and leaves (R=-0.06), stems (R= -0.7) and Total above ground fresh biomass (R=-0.69) following application of FYM at Masasi site. However application of different levels of CP shown highly significant relationship between root yield and above ground plant parts.

Site	Treatments	Leaves		Stems		Total AG biomass	
		R	P	R	P	R	P
Mvomero	FYM	0.64	0.001***	0.66	0.001***	0.67	0.001***
	Compost	0.55	0.004**	0.54	0.004**	0.18	0.094 ns
Masasi	FYM	-0.61	0.602 ns	-0.70	0.609 ns	-0.69	0.602 ns
	Compost	0.70	0.000***	0.70	0.001***	0.72	0.001***

Table 13: Correlation between cassava root and shoot biomass (t ha^{-1}) in 2020/21 season

3.9 Cassava Root and Shoot Dry Matter

At both Mvomero and Masasi sites there was significant variations (P =.05) between FYM application levels on cassava shoot and root dry matter accumulation. At Mvomero site, highest proportion of root dry matter accumulation (8.32 t ha^{-1}) was recorded from the plants received FYM at a rate of 5.0 t ha^{-1}, while the lowest proportions (2.70 t ha^{-1}) were recorded in the control (Table 14). At Masasi site, the highest proportion of root dry matter (10.42 t ha^{-1}) was obtained in plots treated with FYM at the rate of 5.0 t ha^{-1} while the lowest (6.61 t ha^{-1}) was recorded in untreated plots (Table 15).

Table 14: Effects of Farmyard manure on cassava shoot and root biomass at Mvomero

FYM Application rates t ha^{-1}	Stem DW	Leaves DW	Root DW	Total AGDW	Total DW
0.0	1.72 a	0.01 a	2.70 a	1.73 a	4.43 a
2.5	2.52 ab	0.02 a	4.19 a	2.54 a	6.74 a
5.0	3.42b	0.27 b	8.32 b	3.69 b	12.01 b
7.5	4.56c	0.43 c	5.06 a	4.99 c	10.06 b
CV	14.4	27.4	24	15.1	19.3
SE	0.44	0.05	1.22	0.49	1.6
P-Value	0.001	0.002	0.01	0.001	0.002

Sign	***	**	*	***	**

Means in the same column with similar letters are not significantly different at (p≤ 0.05) as per DNMRT

Table 15: Effects of Farmyard manure on cassava shoot and root at Masasi

FYM application rates t ha^{-1}	Stem DW	Leaves DW	Root DW	Total AGDW	Total DW
0.0	1.80 a	0.87 a	6.61 a	1.89 a	8.50 a
2.5	2.17 ab	0.20 b	6.74 a	2.37 ab	9.11 a
5.0	3.34 b	0.27 bc	10.42 a	3.60 b	14.02 b
7.5	6.64 c	0.33 c	8.03 a	6.97c	15.01 b
CV	10.9	13.4	34.5	10.6	23.9
SE	0.379	0.03	2.74	0.374	2.79
P-Value	<.001	0.005	0.225	<.001	0.025
Sign	***	**	Ns	***	*

Means in the same column with similar letters are not significantly different at (p≤ 0.05) as per DNMRT

Key: FYM=farmyard manure, DW= dry weight, AGDW= above ground dry weight

3.10 Effects of Compost on Shoot and Root Dry Biomass at Mvomero and Masasi

At both sites, the application of different rates of CP significantly (P =.05) affected the accumulation of dry biomass between different plant parts. At Mvomero site, the highest proportion of root dry matter (9.72 t ha^{-1}) was recorded from cassava plants that received CP at the rate of 5.0 t ha^{-1}, while the lowest (3.00 t ha^{-1}) dry matter was recorded from the control (Table 16). At Masasi site, the highest root dry matter (8.79 t ha^{-1}) was accumulated in the plants treated with CP at the rate of 7.5 t ha^{-1} while the lowest (5.23 t ha^{-1}) was recorded in the untreated plots (Table 17).

Table 16: Effects of Compost application rates on cassava root and shoot dry matter at Mvomero

CP Application rates t ha^{-1}	Stem DW	Leaves DW	Root DW	Total AGDW	Total DW
0.0	1.89 a	0.16 a	3.00 a	2.06 a	5.06 a
2.5	2.23 a	0.24 a	4.73 a	2.45 a	7.19 a
5.0	3.93 b	0.61 b	9.72 c	4.54 b	14.26 b

7.5	5.09 c	0.74 b	7.09 c	5.83 c	12.92 b
CV	17.4	31.2	9.7	16.4	12.2
SE	0.571	0.138	0.6	0.61	1.2
P-Value	<.001	0.002	0.001	<.001	<.001
Sign	***	**	***	***	***

Means in the same column with similar letters are not significantly different at ($p \leq 0.05$) as per DNMRT

Key: FYM=farmyard manure, DW= dry weight, AGDW= above ground dry weight

Table 17: Effects of Compost application rates on cassava shoot and root dry biomass at Masasi

CP application rates t ha^{-1}	Stem DW	Leaves DW	Root DW	Total AGDW	Total DW
0.0	1.56 a	0.15 a	5.23 a	1.71 a	6.94 a
2.5	1.97 a	0.18 a	6.27 ab	2.15ab	8.42 a
5.0	2.62 b	0.22 a	8.01 bc	2.84 bc	10.85 b
7.5	3.22 b	0.30 b	8.79 c	3.52 c	12.31 b
CV	32.7	32.1	55.5	32.6	49.4
SE	0.765	0.069	3.93	0.833	4.76
P-Value	0.003	0.016	0.015	0.003	0.001
Sign	**	*	*	**	***

Means in the same column with similar letters are not significantly different at (p=.05) according to DNMRT

Key: CP=compost, DW= dry weight, AGDW= above ground dry weight

3.11 Cassava Harvest Index

The mean values of cassava HI as affected by varying rates of FYM and CP application are presented on Figure 7. At Mvomero, the highest ($p \leq 0.05$) HI value was obtained in the plots treated with 5 t ha^{-1} (0.7) while the lowest (0.5) was obtained in the plots treated with 7.5 t ha^{-1} FYM. Similarly, at Masasi, application of different rates of FYM had significant differences (P=.05) between treatments. The lowest HI value was obtained from plots treated with 7.5 t ha^{-1} FYM while the control did not differ significantly to the plots treated with 2.5 and 5 t ha^{-1}.

At Mvomero, the highest (P =.05) value of HI was recorded in the plots treated with CP at a rate of 5.0 t ha^{-1} (0.68) while the lowest value (0.54) was recorded in plots treated with 7.5 t ha^{-1}. At Masasi, there were no significant difference of different rates of CP on cassava HI.

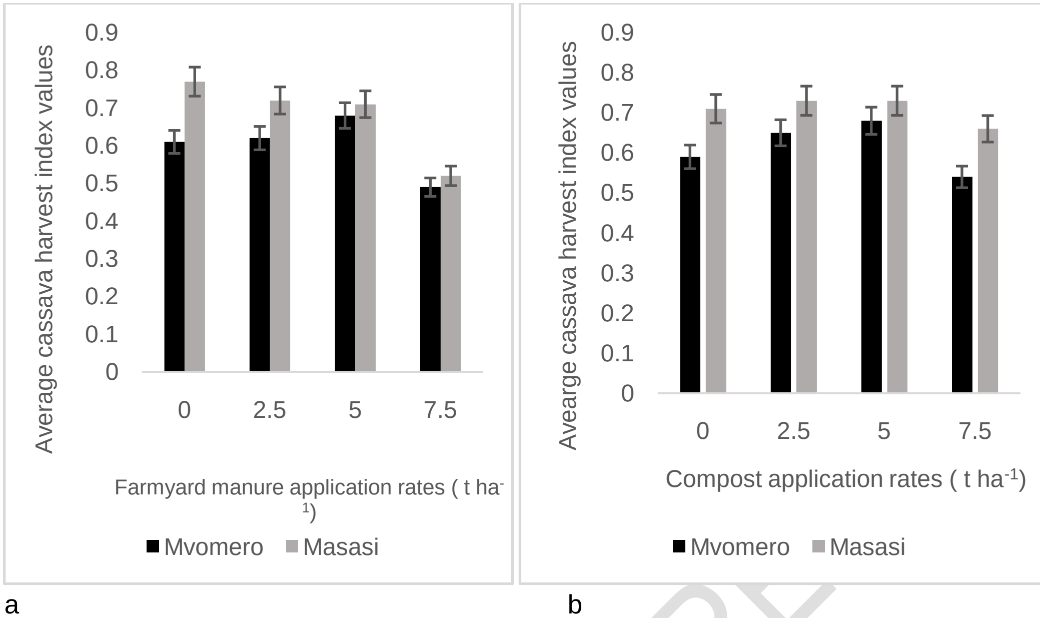


Figure 7: Effects of FYM application rates on cassava harvest index (HI) at Mvomero and Masasi

4. DISCUSSION

Soil pH for Masasi and Mvomero were rated as neutral and slightly acidic respectively, and thus were considered to be within a good range for performance of most crops including cassava according to [36] and [39]. According to [37], the critical level of pH for cassava is 5.2 to 7.0. However, the values of Nitrogen (N) in both sites was 0.08%, hence rated as low. The soils of both sites were rated as medium (2.75 %) and low (1.73 %) in terms of organic matter (OM) content as per [36] whereas values for Phosphorous (P) content of soils in both sites were 2.18 and 4.38 respectively, which were rated as low.

The values of soil Potassium (K) content in both sites for Masasi and Mvomero were 0.3 and 0.53 respectively, which were rated as medium. According to [39] specified the levels of nutrients as medium for cassava production; such levels include Phosphorus 4-15 ppm, Potassium 0.15 - 0.25 meq/100 g and organic matter of 2-4% and 0.2% N. Generally, soil nutrient levels of the two study sites were low and therefore justified the use of fertilizers for improved cassava productivity. The two study sites, Masasi and Mvomero are dominated by sand clay loamy soils that are said to be suitable for cassava owing to their water retention capacity and good root penetration as reported by [40].

Although total rainfall recorded in 2020/21 season was lower than that of 2019/20 season in both sites, but still cassava yields recorded in 2020/21 season surpassed that of 2019/20. This was attributed to improved ability of soil to retain moisture following application of either CP or FYM. However, the total cassava fresh biomass recorded at Masasi was higher than that of Mvomero and this was associated to differences in rainfall in the initial six months. Masasi had enough rainfall in five initial months from January to May but less in June, while at Mvomero where planting was done in early March, rainfall ended at May hence three months of shortage of rainfall compared to Masasi. According to [41] cassava requires enough rainfall in the first 6 months of growth with at least 50 mm rainfall per month.

Cassava plant height and stem girth are among the good indicators of cassava growth and development [42]. Generally, in both CP and FYM treated plots, the greatest improvement of these variables were recorded in the application rates of 5 to 7.5 t ha^{-1} at both sites. According to [4, 43], cassava plant height ranging between 120 to 350 cm and stem girth ranging from 2 to 8 cm indicates good cassava development for optimum yields. However, cassava plant height > 120 cm was also recorded in the plots treated with FYM at a rate of 2.5 t ha^{-1} in 2020/21 season at both sites (Table .3 and .4). Similar response of cassava plant height (>120 cm) was recorded from plots treated with CP at the rate of 2.5 t ha^{-1} at Mvomero in 2020/21 season (Table 4. & 6). This indicates the cumulative effect of FYM and CP soil fertility amendments on improving the availability of nutrients to plants from one season to another.

Results indicated that application of CP or FYM had a significant increase in average number of cassava tubers per plant (Table .7 and .8) in 2019/20. However, no significant difference was observed on cassava root yield in 2019/20 at both sites. But in 2020/21 there was significant difference in cassava root yield at both sites. This suggests that, continuous application of either CP or FYM increased the availability of both macro and micronutrients required for cassava growth and tuberization from one season to another. Similar results on improvement of soil nutrient content and hence significant increase in growth and yield of cassava was reported by [44] where application of manure resulted into increased soil organic carbon (OC) and Total Nitrogen (TN) as opposed to application of mineral fertilizers that resulted to reduced OC and TN after cassava harvesting. According to [39], although cassava can perform well under poor or degraded soils, it is believed to be a “scavenger crop” due to its highly efficient nutrient absorption from the soil and, thus, leaving the soil even poorer. Soil fertility amendment especially by using organic sources such as CP or FYM may be vital to account for this situation. Results from this study therefore shows the potential of FYM and CP as a soil amendment to address the low levels of nutrients and organic matter in the soils. Furthermore, under Tanzanian situation where the use of chemical fertilizers is low (16.4 kg ha^{-1}) compared to global average of 1000 kg ha^{-1} [13] application of fertilizers like CP or FYM that have a long term residual effect is important as most smallholder farmers may not have ability to apply fertilizers to the soil continuously.

Positive relationship between cassava fresh weight and leaves, stems and total above ground biomass signified that there was balance of carbon assimilation between roots and above ground parts. These results corroborates with those previously reported by [45 and (46) Bayou (2020) that the growth and yield parameter of cassava have some profound effect on the final tuber yield. The negative relationship between root fresh weights, leaves, stems and total above ground biomass was a result of preferential partitioning of more assimilates to the above ground plant parts, leading to reduction of assimilates translocated to the roots as also supported by findings by [4].

Dry matter production and partitioning is an important aspect in cassava research. To achieve good yield in cassava dry matter partitioning to shoots and roots is important to consider as the two develop simultaneously and compete for carbon assimilation. Hence, management of the plants including fertilization should focus on balancing of shoot and root growth to attain high cassava yield. Results from this study have indicated that when soil fertility in the study sites are amended by either CP or FYM, most of the dry matter are allocated to the stems and roots. However, most of the dry matter at the plots treated with either FYM or CP at a rate of 5.0 t ha^{-1} were preferably allocated to roots, the most important cassava plant part. This was exception to Masasi site where highest root fresh and dry matter were recorded in the plots treated with compost at a rate of 7.5 t ha^{-1}. Furthermore, this study indicated that when cassava plants are supplied with excess FYM or CP they enhance excessive vegetative growth resulting into consumption of carbon assimilates that would have otherwise be partitioned into roots. These findings corroborate with those reported by [4].

Cassava HI values in this study ranged from 0.49 to 0.77. According to [4,43] this range is obtained when cassava is harvested between 10 to 12 MAP but this study has indicated that for varieties like Kiroba, this range can also be obtained from 9 MATP. Previous studies indicated that HI values falling within this range are acceptable for cassava. According to [39], HI values greater than 5 are acceptable for cassava. In this case HI values in both CP and FYM fallen within the acceptable range.

Although the use of FYM or CP has proved to be successful in improving cassava growth and yields, still there are challenges in adoption of this technology by smallholder farmers. Previous study [24] at Mvomero and Masasi districts indicated that, most of the smallholder farmers do not keep livestock and therefore adoption of the use of FYM by smallholder farmers may be low due to limited access to manure. Therefore, there should be interventions to encourage farmers who do not have access to FYM to use CP that can be prepared by using small amount of manure from small ruminants and poultry. Another challenge is that the Government is mostly focusing on the use of inorganic fertilizers to ensure that citizens are food secured without considering the long-term consequences of using inorganic fertilizers to the environment. Hence, farmers should be educated on how to make organic fertilizers like CP, the benefits of using them in line with the use of chemical fertilizers.

5. CONCLUSIONS AND RECOMMENDATIONS

This study examined the effect of application of FYM and CP on cassava growth and yield and concludes that, the use of FYM and CP improve cassava growth and yield. Continuous application of FYM or CP on the same land improves further soil fertility and hence improved cassava growth and yield. Application of CP or FYM above 5 t ha^{-1} affects the cassava crop negatively through enhancing vegetative growth at the expense of root tuberization. However, most farmers in the studied areas do not keep animals and therefore limited access to FYM. Therefore, the use of CP seems to be a better alternative. Further studies are required to upscale and out scale these research findings to enhance wider adoption of the use of CP and FYM as ecological soil fertility amendments.

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