Original Research Article

Effect of tillage methods, farmyard manure and potassium rates on cassava yield and root quality in Kagera region, Tanzania

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ABSTRACT

A study was conducted in Bukoba, Missenyi and Biharamulo districts in Kagera region, Tanzania during the 2018/19 and 2019/20 cropping seasons to determine the effect of tillage methods, farmyard manure (FYM) and potassium (K) rates on cassava yield and root quality. Three tillage methods (flat tillage, tied ridging and open ridging) and eleven fertilizer rates (FYM at 4 or 8 MT ha^{-1}, $N_{40}P_{30}$ + K at 40, 80 or 120 kg ha^{-1}, FYM at 4 or 8 MT ha^{-1} + K at 40, 80 or 120 kg ha^{-1}) and the control, were arranged in Randomized Complete Block Design (RCBD) with three replications using a split-plot design. Tillage methods were the main plots and fertilizer rates were the subplots. Farmyard manure was applied at planting while inorganic fertilizers (DAP and MOP), were applied in two splits (1 and 3 months after planting). Plot size was 6 m x 5 m with spacing of 1 m x 1 m. Root yield ha^{-1} were collected during harvesting. About 500 g of cassava roots from each treatment were oven dried at 105 ^{o}C to constant weight for determining dry matter content using the equation by Benesi *et al.* (2008). Root starch content in each treatment was determined using the method by Kawano *et al*. (1987). The results indicate that cassava planted on ridges gave significantly (P <.001) higher (18.98 - 34.84 MT ha^{-1}) cassava root yields than on flat tillage (16.86 - 29.74 MT ha^{-1}). Combined use of at 4 MT ha^{-1} or FYM at 8 MT ha^{-1} and potassium at 40, 80 or 120 kg K ha^{-1} significantly (P <.001) increased cassava root yield (14.56 - 39.94 MT ha^{-1}) as compared to other fertilizer rates (8.90 – 29.63 MT ha^{-1}). Combined use of inorganic $N_{40}P_{3}0K_{120}$ or combined use of FYM at 8 MT ha^{-1} and potassium at 80 or 120 kg K ha^{-1} gave significantly (P <.001) higher starch (28. 04 - 34.06 %) and dry matter (39.57 - 44.93 %) in cassava roots than other fertilizer rates. Therefore, planting cassava on ridges together with use of FYM at 4 MT ha^{-1} and potassium at 40, 80 or 120 kg K ha^{-1} is desirable for increasing cassava root yield. Moreover, combined use of inorganic $N_{40}P_{30}K_{120}$ fertilizers or combined use of FYM at 8 MT ha^{-1} and potassium at 80 or 120 kg K ha^{-1} is desirable for increasing starch content and dry matter in cassava roots in the study area.

Keywords: Tillage methods, farmyard manure, potassium rates, cassava yields, root quality, starch and dry matter content, Kagera region.

1. INTRODUCTION

In Tanzania, cassava (Manihot esculenta, Crantz) is the second food security crop after maize [1]. Cassava production is estimated to support 37% of rural farmers in the country [2]. The crop is grown in the Coastal zone, Lake zone and shores of Lake Nyasa and Tanganyika [1]. Cassava roots produce at least 30% of starch on dry weight basis, which is the major source of dietary energy [3], industrial products (sugar, alcohol, textile products) and animal feeds [4]. Despite the importance of cassava in food systems, there is decreasing productivity [5, 6]. For example, the national average root yield is 10 MT ha-1 compared to the potential yield of 25 to 80 MT ha^{-1} [4, 7]. In Kagera Region, the average root yield in farmers' fields is 7.8 MT ha-1 [8, 6].

The low yield is due to two major constraints namely, diseases mainly cassava mosaic disease (CMD) and cassava brown streak disease (CBSD), which cause yield losses ranging from 70 to 100% [9] and declining soil fertility [10, 11], which causes yield losses ranging from 46 to 56% [12]. Declining soil fertility is caused by continual cultivation without fertilizer application [10, 8] and loss through soil erosion [10]. In Kagera Region, about 12.5% of smallholder farmers use inorganic fertilizers mainly nitrogen at the rates of 40 to 60 kg N ha^{-1} and phosphorus at the rates of 20 kg P ha^{-1} mostly, in maize production [8]. Very few farmers use potassium fertilizers [8, 13], though the soils of Kagera are low in potassium [12]. This is due to inadequate knowledge on fertilizer use such as appropriate type, rate, time and method of application and benefits [10, 8]. Other factors leading to low fertilizer uses are unavailability, farmers' financial constraints, high prices of fertilizers, and transportation problems of manure due to its bulkiness per unit area [14].

Cassava responds well to farmyard manure (FYM) and mineral fertilizers and requires fairly high level of K and N especially when grown for many years on the continuously cultivated land [15]. Other researchers for example, [16] reported that cassava crop producing a yield of 30 MT ha^{-1} extracts 187 kg N ha^{-1}, 33 kg P ha^{-1} and 233 kg K ha^{-1}. A demonstration field study conducted in Kagera region with blanket fertilizer rates of FYM and inorganic P and K indicate that the combination of FYM at 6 MT ha^{-1} + P and K both at 50 kg ha^{-1}, gave significantly (P = .05) higher cassava root yields (36 MT ha^{-1}) than FYM alone (25 MT ha^{-1}) and inorganic fertilizers alone (28 MT ha^{-1}) [12]. However, the previous study did not include different rates of FYM and mineral K fertilizers, which this study researched on. Other researchers [17, 18, 19], reported the importance of potassium in cassava production because its deficiency leads to low root dry matter and starch content which signifies low root quality, high root cyanogen level and low root yields. This justifies the use of potassium fertilizer for improving cassava productivity and root quality in the soils of Kagera region, which have low potassium contents [12].

Several studies for example, [20] in Ethiopia on sorghum; [21] in Nigeria on cassava, [22] in Mwanza, Tanzania on upland rice, and [23] in Hombolo, Dodoma, Tanzania on sorghum, all on the effects of tillage methods (flat and ridge tillage) on the growth and yields of the respective crops reported different results but with common findings of significantly higher yields in the tied ridging than in the flat tillage and open ridging. However, none of the above studies looked on the combined effects of tillage methods and different rates of FYM and K fertilizers on the yields and quality of the respective crops. In Kagera region, many farmers plant cassava on flat tillage and few farmers plant cassava on ridges; however, scanty information exist on the performance of cassava when planted on the flat tillage or on the ridges.

Despite the importance of fertilizers and tillage methods on improving crop productivity, there is little information on the effects of tillage methods and use of different rates of FYM and K fertilizers on cassava yield and root quality based on Kagera region's soils and climate. It is therefore envisaged that the use of integrated soil fertility management and moisture conservation practices can improve soil fertility, conserve soil moisture and improve cassava productivity. Thus, the current study aimed to determine the effects of tillage methods and different rates of FYM and potassium fertilizers on cassava yield and root quality in Kagera region.

2. MATERIAL AND METHODS

2.1 Description of the study area

2.1.1 Location of the study area

Kagera Region is located in the north-western corner of Tanzania on the western shore of Lake Victoria between latitudes 1°00′ and 3°45′ south of Equator and between longitudes 30°25′ and 32°40′ east of Greenwich. It is the fifteenth largest region in Tanzania with an area of about 3 568 600 ha of land, which accounts for approximately 3.3% of Tanzania's total land area. Out of the region's area, 10 173 ha are covered by water of the Lake Victoria, Ikimba and Burigi, and of the river Kagera and Ngono [24, 25]. Administratively, the region has seven districts, namely Biharamulo, Bukoba, Karagwe, Kyerwa, Missenyi, Muleba and Ngara, and borders four countries, namely Uganda, Rwanda, Burundi, and Kenya across Lake Victoria. However, this study was conducted in three districts, namely Bukoba, Missenyi and Biharamulo The selection of these districts were based on the representative of agro-ecological zones of Kagera region and the potential for cassava production. The representative study sites were Tanzania Agricultural Research Institute (TARI), Maruku Centre in Butairuka village (Bukoba district), Mabuye Primary School in Mabuye village (Missenyi district) and Rukaragata Farmers' Extension Centre in Rukaragata village (Biharamulo district).

Bukoba district covers an area of 284,100 ha and is situated between latitudes 1° 00′ and 3° 00′ S and between longitudes 30° 45′ and 31° 00′ E with altitude between 1200 - 1400 meters above sea level. Missenyi district covers an area of 270 875 ha and is situated between latitudes 1° 00′ and 1° 30′ S and between longitudes 30° 48′ and 31° 49′ E with attitude between 1100 - 1400 meters above sea level. Biharamulo district covers an area of 374 400 ha and is situated between latitudes 2° 15′ and 3° 15′ S and between longitudes 31° 00′ and 32° 00′ E with altitude ranging from 1100 - 1700 meters above sea level (masl) [24, 25]. Based on rainfall, three agro-ecological zones namely high, medium and low rainfall zones are found in Kagera region [26, 27, 25], which in this study are represented by Bukoba district (high rainfall), Missenyi district (medium rainfall) and Biharamulo district (low rainfall).

2.1.2 Climate and soils of the study area

The districts in Kagera region experience bimodal rainfall distribution between September and December (short rains) and between March and June (long rains). The mean annual rainfall ranges from 900 - 2400 mm in Bukoba district, 600 - 2000 mm in Missenyi district and 700 - 1000 mm in Biharamulo district [26, 6]. The mean annual temperature ranges from 16 - 28 °C, Missenyi having higher annual temperature (28 °C) than Bukoba and Biharamulo (26 °C). In terms of soil texture, the soils range from sandy clay loam to sandy clay and clay [26, 28]. However, the soils of the study area indicate that P, K and Mg deficiencies were widely spread in Bukoba district while N and S deficiencies were widely spread in Missenyi district and N, P and K deficiencies were widely spread in Biharamulo district [28].

2.1.3 Farming systems of the study area

The farming systems of the study area are largely banana/coffee based [29], with three distinct land use types classified in local parlance "Haya" as *Kibanja* (*Bibanja* in plural). This is the most fertile land that usually surrounds the residential houses, and is permanently planted with the perennial crops, mainly banana (*Mussa spp*,), and coffee (*Coffee canephora*). The permanent crops are seasonally intercropped with annual crops, mainly beans (*Phaseolus vulgaris*), maize (*Zea mays*), taro (*Colocasia esculent*), cassava (*Mahihot esculenta*, Crantz) and various types of trees but the major crops being banana, coffee and beans. Another land use type is *Kikamba,* the area for annual crop cultivation found near *Kibanja*. Crops grown in *Kikamba* include cassava (*Manihot esculenta*, Crantz), maize (*Zea mays*), sweet potato (*Ipomea batatas*), yams (*Dioscorea spp*.) and occasionally taro, which are grown solely or mixed. The last land use type is *Rweya,* the grassland further away, serving as communal grazing land, source of mulch, thatch grass and area for shifting cultivation. Crops cultivated on *Rweya* under shifting cultivation include cassava, sweet potato, yams while tea (*Cammelia sinensis*), and trees like *Eucalyptus spp*. and *Pinus spp*. are permanently grown [27, 29, 25]. In this study therefore, experimental trials were established in the *Kikamba* land use type, as it is the land where annual crops are largely grown.

2.2 Site selection

This study was conducted in Bukoba, Missenyi and Biharamulo districts. In each district, one ward and one village in each ward were selected. In each selected village, one site was selected for the establishment of the experimental trial. The selected experimental sites were Tanzania Agricultural Research Institute (TARI)-Maruku Centre, Mabuye Primary School, and Rukaragata Extension Centre in Bukoba, Missenyi and Biharamulo districts, respectively. The representative experimental trial sites were located by international coordinates using the Global Positioning System (GPS) (model GARMIN etrex 20). The locations of the experimental trial sites are presented in Figure 1.

2.3 Experimental layout and treatments application

Three field experimental trials, one in each study site were established in two consecutive seasons (2018/19 and 2019/20) in Bukoba, Missenyi and Biharamulo districts. In each trial site, land was prepared by clearing of bushes and trees before trial establishment, followed by ploughing and harrowing. Ridges were prepared by heaping up the soil to about 60 cm within 1 m wide (0.5 m from each side of the ridge top) using hand hoe; so that the spacing from the top-canter of one ridge to the top-center of another ridge was 1 m wide. Plot size was 6 m x 5 m and the separation between plots and blocks was 1.5 m and 2 m apart, respectively.
The size of the trial at each site was 0.52 ha. For the tied ridges, the soil was raised at each end of the ridges and at the center (2.5 m from each end of the ridge) to form three ties. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications using the split-plot Design; with tillage methods (flat tillage, open ridging and tied ridging) as the main plots and fertilizer rates [Control, FYM at 4 MT ha^{-1}, 8 MT ha^{-1}, (N + P at 40 kg N ha^{-1} and 30 kg P ha^{-1}) + potassium at 40, 80 or 120 kg K ha^{-1}, combination of FYM at 4 MT ha^{-1} or 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1}] as the subplots (Table 1). The combinations of N at 40 kg N ha^{-1} + P at 30 kg P ha^{-1} [30] + potassium at 40, 80, or 120 kg K ha^{-1}; were applied as inorganic fertilizer treatments and FYM at 4 MT ha^{-1} or 8 MT ha^{-1} + potassium at 40, 80 or120 K kg ha^{-1} were applied as the combinations of organic and inorganic fertilizer treatments.

Farmyard manure was applied at planting along the planting rows in the flat tillage treatment and along the ridges in the open and tie-ridging treatments followed by incorporation into the soils. Farmyard manure applied in each experimental site was collected from one farmer in each site. In all districts, the distance from the source of manure to the experimental sites ranged from 20 – 30 km. Inorganic fertilizers, namely di-ammonium phosphate (DAP) for N and P and muriate of potash (MOP) for K were applied in two splits; the first split at one month after planting for allowing fibrous roots development on cassava cuttings for nutrients uptake since sprouting of cassava cuttings starts at 2 – 3 weeks after planting. The second split of inorganic fertilizer was applied at three months after planting by banding the fertilizers around each cassava plant. Inorganic fertilizers, namely di-ammonium phosphate (DAP) for N and P and muriate of potash (MOP) for K were applied in two splits; the first split at one month after planting for allowing fibrous roots development on cassava cuttings for nutrients uptake since sprouting of cassava cuttings starts at 2 – 3 weeks after planting. The second split of inorganic fertilizer was applied at three months after planting by banding the fertilizers around each cassava plant.

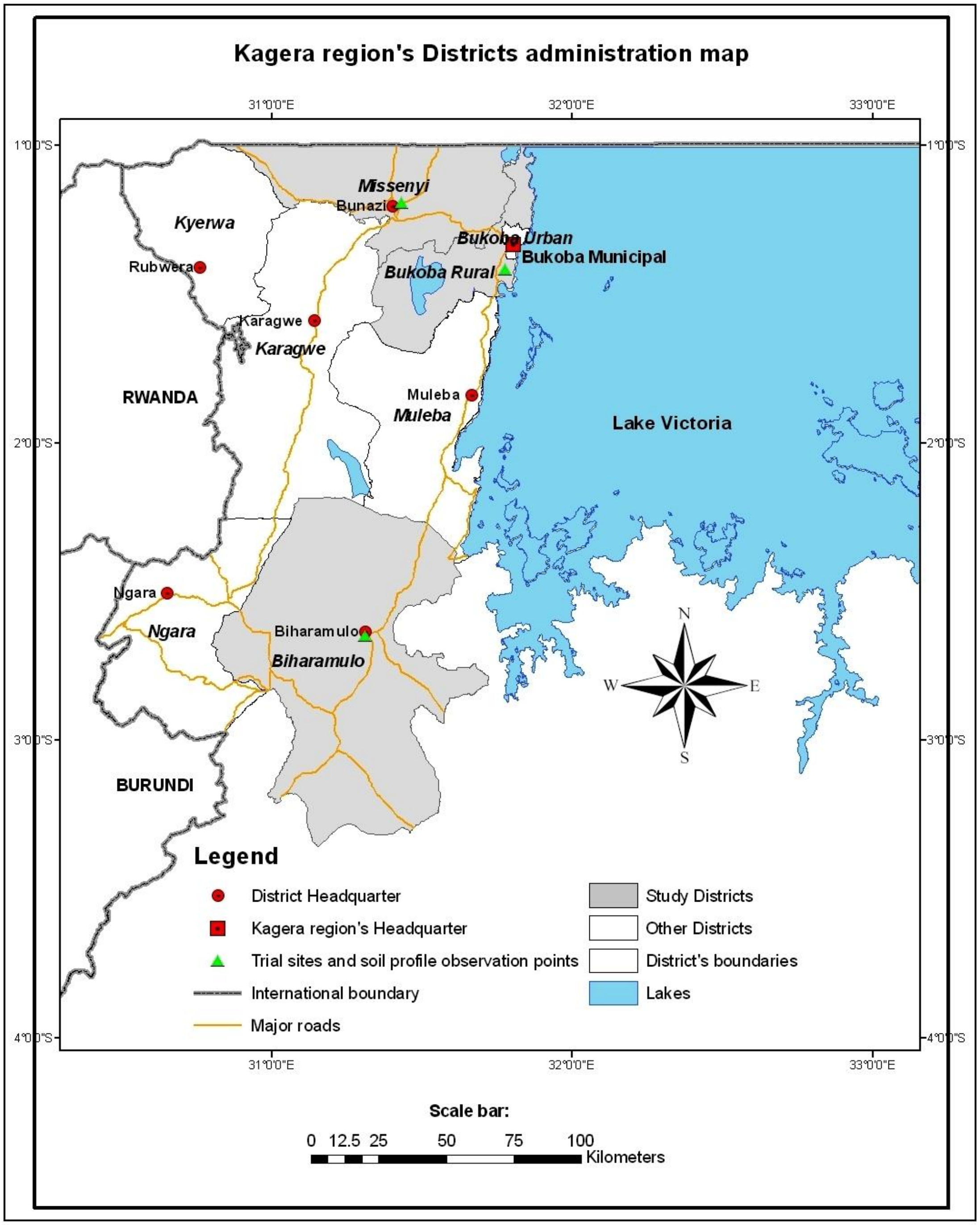

Figure 1. Location of experimental trial sites in Bukoba, Missenyi and Biharamulo districts

Source: [25]

Improved cassava variety (*Mkumb*a), was the test variety. Cassava cuttings of 25 to 30 cm length were planted at a spacing of 1 m x 1 m in the flat tillage and ridging treatments. The duration (cassava growing period) of trial from planting to harvesting was 12 months. The experimental plots were maintained free from weeds, throughout the growing period, and repeated in the following season while maintaining the same plots.

Table 1. Experimental treatments in the split-plot design

	Main plots	
Flat tillage	**Open ridge tillage**	**Tied ridge tillage**
	Sub plots	
Co	Co	Co
FYM_4	FYM_4	FYM_4
FYM_8	FYM_8	FYM_8
$K_{40}\ N_{40}P_{30}$	$K_{40}\ N_{40}P_{30}$	$K_{40}\ N_{40}P_{30}$
$K_{80}\ N_{40}P_{30}$	$K_{80}\ N_{40}P_{30}$	$K_{80}\ N_{40}P_{30}$
$K_{120}N_{40}P_{30}$	$K_{120}N_{40}P_{30}$	$K_{120}N_{40}P_{30}$
FYM_4K_{40}	FYM_4K_{40}	FYM_4K_{40}
FYM_4K_{80}	FYM_4K_{80}	FYM_4K_{80}
FYM_4K_{120}	FYM_4K_{120}	FYM_4K_{120}
FYM_8K_{40}	FYM_8K_{40}	FYM_8K_{40}
FYM_8K_{80}	FYM_8K_{80}	FYM_8K_{80}
FYM_8K_{120}	FYM_8K_{120}	FYM_8K_{120}

CO = control (no fertilizer application); FYM4 = farmyard manure at 4 MT ha-1; FYM8 = farmyard manure at 8 MT ha-1; K40N40P30 = potassium at 40 kg K ha-1, nitrogen at 40 kg N ha-1 and phosphorus 30 kg P ha-1; K80N40P30 = potassium at 80 kg K ha-1, nitrogen at 40 kg N ha-1 and phosphorus 30 kg P ha-1; K120N40P30 = potassium at 120 kg K ha-1, nitrogen at 40 kg N ha-1 and phosphorus 30 kg P ha-1; FYM4K40 = farmyard manure at 4 MT ha-1 and potassium at 40 kg K ha-1; FYM4K80 = farmyard manure at 4 MT ha-1 and potassium at 80 kg K ha-1; FYM4K120 = farmyard manure at 4 MT ha-1 and potassium at 120 kg K ha-1; FYM8K40 = farmyard manure at 8 MT ha-1 and potassium at 40 kg K ha-1; FYM8K80 = farmyard manure at 8 MT ha-1 and potassium at 80 kg K ha-1; FYM8K120 = farmyard manure at 8 MT ha-1 and potassium at 120 kg K ha-1.

2.4 Data collection

Data on daily rainfall (mm) were collected in each experimental site during the two cropping seasons (2018/19 and 2019/20) to understand the monthly and annual rainfall during the cropping seasons. Data on root weight per plot were collected from the net plot (4 m x 3 m) during harvesting (12 months after planting). Cassava root weight in each treatment was recorded after detaching the roots from the plants and weighed using a weighing balance. About 500 g of cassava roots were weighed using a portable digital balance, peeled, packed in paper bags, labelled and placed in drying oven at 105 oC until constant weight of cassava roots was recorded. The contents of dry matter in cassava roots in each treatment were determined gravimetrically as dry matter content percentage (DM %) = (W1/W2) x 100. Where; W1 is the weight of oven dry cassava roots and W2 is the weight of fresh cassava roots in each treatment [31]. Root starch content in each treatment was determined using the method by [32]. whereby, at least 3 kg of cassava roots were weighed using a weighing balance (Wa-weight in air) followed by weighing the same cassava roots in a 200 mm-drum full of water (Ww-weight in water). Specific gravity of cassava root (x) was calculated as (x) = Wa/(Wa-Ww) and the contents of starch in cassava roots from each treatment were determined using the equation: cassava root starch (%) = 112.1x–106.4, where; x is the specific gravity of cassava roots.

2.5 Data analysis

<u>2.5.1 Analysis of farmyard manure samples</u>

Before being applied, farmyard manures used in each experimental site were sieved through 2 mm sieve, packed and labelled for laboratory analysis to determine their N, P and K contents at Sokoine University of Agriculture (SUA) Soil Science Laboratory. Total nitrogen (TN) was determined by macro-Kjeldahl digestion method [33]. Analysis of P and K was done by the wet digestion method using Multiwave Microwave 66230 digestion machine followed by color development for P and measurement of the contents of P in FYM using an ultraviolent visible (UV/VIS) spectrophotometer [34]. The contents of K in FYM were measured using flame emission spectrometer [35].

2.5.2 Statistical data analysis

The collected data were subjected to analysis of variance (ANOVA) based on the statistical model for the split-plot design [34] (Equation 1) using GENSTAT 15th edition statistical packages. Means differences were separated using the Tukey's test [Honestly Significant Difference (HSD)] at P =.05 level of significance.

$$Yijk = \mu + \beta i + Aj + \delta ij + Bk + ABjk + \varepsilon ijk \quad (1)$$

$$i = 1, 2, 3\ldots\ldots, r$$
$$j = 1, 2, 3\ldots\ldots, a$$
$$k = 1, 2, 3\ldots\ldots, b$$

Where: Yijk = Response level/Yield, μ = General effect or general error mean, βi = Blocking effect, Aj = Main plot effect, δij = Main plot random error (Error a), Bk = Sub-plot effect, ABjk = Interaction effect between the main plot and the sub-plots, εijk = Sub-plot random error (Error b), i = replication/blocking (r), j = main plot (a), k = sub-plot (b)

3. RESULTS AND DISCUSSION

3.1 Monthly and annual rainfall at the experimental sites during the cropping seasons

The representative study sites experience a bimodal rainfall distribution with short rains between September and December and long rains between March and June [26, 27]. Monthly rainfall in Bukoba experimental site ranged from 25 - 405 mm and from 110 - 606 mm during 2018/19 and 2019/20 cropping season, respectively. In Missenyi experimental site, monthly rainfall ranged from 0 - 289 mm and from 1 - 295 mm during 2018/19 and 2019/20 cropping seasons, respectively. In Biharamulo experimental site monthly rainfall ranged from 0 - 271 mm and from 0 - 203 mm during 2018/19 and 2019/20 cropping seasons, respectively (Figure 2).

In Both seasons, Bukoba experimental site experienced the highest monthly rainfall in January during both 2018/19 and 2019/20 cropping seasons, followed by Missenyi experimental site, in December during both 2018/19 and 2019/20 cropping seasons. Biharamulo experimental site experienced the lowest monthly rainfall during both 2018/19 and 2019/20 cropping seasons. In Bukoba experimental site, few rain events were experienced only in June but there was no month within the two cropping seasons that did not experience rainfall at all. In Missenyi experimental site, few rain events were experienced between June and July and the site did not experience rainfall at all in July during 2018/19 cropping season. In Biharamulo experimental site, few rain events were experienced from June to October during 2018/19 cropping season and from May to September during the 2019/20 cropping season.

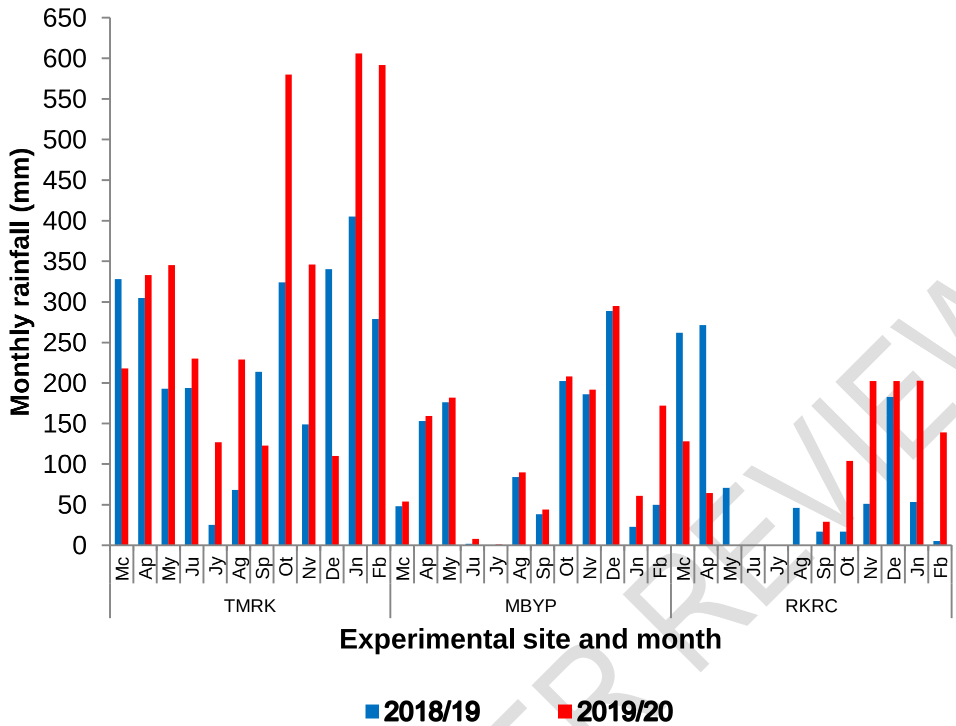

Figure 2. Monthly rainfall during the 2018/19 and 2019/20 cropping seasons at the experimental sites in Bukoba, Missenyi and Biharamulo districts

Location: TMRK = Tanzania Agricultural Research Institute-Maruku Centre in Bukoba district; MBYP = Mabuye Primary School in Missenyi district; RKRC = Rukaragata Extension Centre in Biharamulo district; Month: Jn = January, Fb = February, Mc = March, Ap = April, My = May, Ju = June, Jy = July, Ag = August, Sp = September, Ot = October, Nv = November, De = December

However, during the 2018/19 cropping season there were 2 months (June and July) and 4 months (May to August) during the 2019/20 that did not experience rainfall at all. The 4 months dry spell experienced in Biharamulo experimental site during the 2019/20 cropping season, just at 1 month after planting might have affected the performance of cassava given that cassava plants were planted in March in all sites. Other researchers [37] reported that cassava requires sufficient water supply during root and shoot initiation mostly, 1 - 5 months after planting and that water deficit during this period severely affects root development and lowering root yields but if cassava experiences water deficit later than 5 months after planting, there is no significant yield reduction [38].

In addition, during the cropping season there was variation in the amount of annual rainfall experienced in the representative experimental sites. In all sites, higher annual rainfall (1071 - 3384 mm) was recorded during 2019/20 cropping season than during the 2018/19 cropping season (1034 - 2824 mm). In both seasons, the highest annual rainfalls were recorded in Bukoba experimental site followed by Missenyi experimental site and lastly Biharamulo experimental site (Table 2). This conforms to the report by [27] and [29] who reported that Bukoba district is a high rainfall zone; Missenyi district a medium rainfall zone and Biharamulo district a low rainfall zone.

Table 1: Annual rainfall recorded at the experiment sites during 2018/19 and 2019/20 growing seasons in Bukoba, Missenyi and Biharamulo districts

District	Experimental Site	Annual rainfall (mm)	
		2018/19	2019/20
Bukoba	TARI Maruku	2824	3384
Missenyi	Mabuye Primary School	1252	1466
Biharamulo	Rukaragata Extension Centre	1034	1071

3.2 Nutrient contents of applied farmyard manure and amount added in soils during the 2018/19 and 2019/20 cropping seasons

Nutrient contents of applied farmyard manure and amount of N, P and K added annually in soils in each cropping season due to farmyard manure application in each experimental site are presented in Table 3. The laboratory analysis results indicate that N content of applied farmyard manure ranged from 0.50 - 0.58%, P ranged from 0.08 - 0.12% and K ranged from 1.21 - 1.83%. Farmyard manure of Biharamulo district had high N and K content followed by that of Missenyi district and the last was that of Bukoba district. However, farmyard manure of Missenyi district had high content of P followed by that of Bukoba district and last was that of Biharamulo district. The amount of nutrients added annually in soil from FYM ranged from 20.00 - 46.40 kg ha^{-1} for N, 3.0 - 9.60 kg ha^{-1} for P and 48.40 - 146.40 kg ha^{-1} for K. The low P content in the applied farmyard manure in the studied sites and thus low amount of added P in the soil from FYM as compared to N and K, might lead to nutrients imbalance in the soils, which might have then affected the availability and uptake of nutrients by inducing deficiencies of nutrients present in the soil in good quantities [39].

Table 2: Contents of N, P and K in the applied farmyard manure and annual addition of N, P and K in the soil from farmyard manure

Experimental site	Cropping season	Content of N, P and K in FYM (%)			Addition of N, P and K (kg ha^{-1}) in soil from FYM 4 MT			8 MT		
		N	P	K	N	P	K	N	P	K
Bukoba	2018/19	0.50	0.09	1.21	20.00	3.56	48.40	40.00	7.12	96.80
	2019/20	0.52	0.09	1.25	20.80	3.44	50.00	41.60	6.88	100.00
Missenyi	2018/19	0.54	0.12	1.51	21.60	4.80	60.40	43.20	9.60	120.80
	2019/20	0.56	0.11	1.54	22.40	4.40	61.60	44.80	8.80	123.20
Biharamulo	2018/19	0.58	0.08	1.78	23.20	3.04	79.20	46.40	6.08	142.40
	2019/20	0.57	0.08	1.83	22.80	3.00	73.20	45.60	6.00	146.40

3.3 Effect of applied treatments on cassava yields and root quality in Bukoba, Missenyi and Biharamulo districts

3.3.1 Effect of tillage methods on cassava root yield, root starch content and root dry matter during the 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts

Cassava root quality in this study was determined based on the content of starch and dry matter in cassava roots. Therefore, the results on the effects of different tillage methods (flat tillage, open ridging and tied ridging) on cassava yields, root starch content and root dry matter during 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts are presented in Table 4. During the 2018/19 cropping season, cassava root yields ranged from 16.86 - 20.30 MT ha^{-1} (Bukoba district), 28.92 - 33.36 MT ha^{-1} (Missenyi district) and 10.06 - 10.43 MT ha^{-1} (Biharamulo district) while the 2019/20 cropping season cassava root yields ranged from 20.16 - 22.55 MT ha^{-1} (Bukoba district), 29.74 - 34.84 MT ha^{-1} (Missenyi district) and 12.80 - 14.57 MT ha^{-1} (Biharamulo district). In addition, during the 2018/19 cropping season, the content of starch in cassava roots ranged from 24.68 - 35.78% (Bukoba district), 25.26 - 26.56% (Missenyi district) and 24.78 - 25.53% (Biharamulo district) while during the 2019/20 cropping season, the content of starch in cassava roots ranged from 25.41 - 26.24% (Bukoba district), 28.30 - 28.71% (Missenyi district) and 26.29 - 26.78% (Biharamulo district). Moreover, during the 2018/19 cropping season cassava root dry matter ranged from 37.42 - 38.29% (Bukoba district), 37.09 - 37.92% (Missenyi district) and 36.62 - 37.08% (Biharamulo district) while during the 2019/20 cropping season, cassava root dry matter ranged from 38.80 - 38.98% (Bukoba district), 38.91 - 39.14% (Missenyi district) and 35.82 - 36.75% (Biharamulo district).

Table 3. Tillage methods effect on cassava yields, root starch content and root dry matter during 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts

Season	Treatment	Location								
		1	2	3	1	2	3	1	2	3
		Parameter								
		RY (MT ha^{-1})			RSC (%)^{j}			RDM (%)		
2018/19	Flat tillage	16.86^{a}	28.92^{a}	10.06^{a}	24.68^{a}	25.26^{a}	24.78^{a}	37.42^{a}	37.09^{a}	36.62^{a}
	Open ridging	18.98^{b}	31.81^{b}	10.13^{a}	25.22^{a}	26.02^{a}	24.76^{a}	37.14^{a}	37.92^{ab}	36.96^{a}
	Tied ridging	20.30^{b}	33.36^{b}	10.43^{a}	25.78^{a}	26.56^{a}	25.53^{a}	38.29^{a}	37.99^{ab}	37.08^{ab}
	SED	0.69	0.72	0.38	0.21	0.44	1.40	0.57	0.38	0.59
	CV (%)	22.80	13.70	22.10	5.90	10.00	32.00	7.20	6.00	13.40
2019/20	Flat tillage	20.16^{a}	29.74^{a}	12.80^{a}	25.41^{a}	28.66^{a}	26.29^{a}	38.91^{a}	35.82^{a}	38.91^{a}
	Open ridging	22.45^{b}	34.28^{b}	14.43^{b}	25.96^{a}	28.30^{a}	26.77^{a}	39.01^{a}	36.56^{a}	39.01^{a}
	Tied ridging	22.55^{b}	34.84^{b}	14.57^{b}	26.24^{a}	28.71^{a}	26.78^{a}	39.14^{a}	36.75^{a}	39.14^{a}
	SED	0.65	0.60	0.32	0.36	0.54	0.22	0.47	0.37	0.47
	CV (%)	17.90	11.40	14.30	10.90	10.70	5.00	7.30	7.00	7.30

Means within a column (for a particular parameter) followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test

SED = standard error of differences of means; CV = coefficient of variation; Location: 1 = Tanzania Agricultural Research Institute (TARI), Maruku Centre in Bukoba district, 2 = Mabuye primary school in Missenyi district, 3 = Rukaragata Extension Centre in Biharamulo district; Parameter: RY = root yield, RSC = roots starch content, RDM = root dry matter,

In both cropping seasons, the low yields were recorded in the flat tillage and high yields and were recorded in the tied ridging. There was significant (P = .05) difference in root yields among the tested tillage methods in Bukoba and Missenyi district, whereas there was no significant (P = .07) difference in root yields among the tested tillage methods in Biharamulo district. However, in Bukoba and Missenyi districts, tied ridging and open ridging treatments gave significantly (P = .05) higher root yields than flat tillage treatment, implying that planting cassava on ridges gave significantly higher cassava root yield than on flat tillage. Moreover, there was no significant (P =.51) difference in the content of starch and dry matter in cassava roots among the tested tillage methods in all districts and in both cropping seasons, which signify that the tillage methods used in this study had no significant effects on the content of starch and dry matter in cassava roots. These results therefore implied that planting cassava on flat tillage or on ridges had no effects on the content of starch and dry matter in cassava roots.

The results of cassava root yields from this study conform to the finding by [40] who reported higher root yield when cassava was planted on ridges than on flat tillage. In addition, [41] working on yam in Nigeria reported significant increase in yam tuber yield by 34% when planted in mound ridges as compared to flat tillage. [42] reported that ridging of the soil improved nutrient availability and increased yields of root and tuber crops such as yam and cassava due to decreased soil bulk density, increased soil porosity, increased soil aeration and water infiltration.

The observed insignificant difference, and lower cassava root yields, starch content and dry mater in cassava roots in Biharamulo district than in Bukoba and Missenyi districts was attributed to poor performance of cassava plants in Biharamulo district. This was attributed to low rainfall accompanied by dry spells at early stages of pant establishment, at 1 - 2 months after planting (Figure 2 and Table 2). Another reason was probably high soil penetration resistance of 3.3 - 3.4 MPa [25], recorded between 20 - 90 cm soil depth in this experimental site, which might have affected the performance of cassava plants since the ridges used in this study were raised up to 60 cm high. Other researchers [43, 44] reported that soil penetration resistance of > 3.0 MPa signifies compaction that can impair growth and development of crops.

3.3.2 Effect of fertilizer rates on cassava yields and the content of starch and dry matter in cassava roots during 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts

The results on the effects of different fertilizer rates on cassava yields and the content of starch and dry matter in cassava roots during 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts are presented in Tables 5 and 6, respectively. During the 2018/19 cropping season, cassava root yield ranged from 9.26 - 23.98 MT ha^{-1} (Bukoba district), 12.16 - 38.16 MT ha^{-1} (Missenyi district) and 5.37 - 15.72 $MTha^{-1}$ (Biharamulo district) while during the 2019/20 cropping season, cassava root yield ranged from 8.48 - 27.80 MT ha^{-1} (Bukoba district), 12.13 - 39.94 MT ha^{-1} (Missenyi district) and 5.78 - 18.51 $MTha^{-1}$ (Biharamulo district). In addition, during the 2018/19 cropping season, the content of starch in cassava roots ranged from 20.40 - 31.09% (Bukoba district), 20.76 - 33.13% (Missenyi district) and 21.76 - 33.91% (Biharamulo district) while during the 2019/20 cropping season, the content of starch in cassava roots ranged from 19.95 - 31.73% (Bukoba district), 20.02 - 34.06% (Missenyi district) and 20.78 - 30.27% (Biharamulo district). Moreover, during 2018/19 cropping season the content of dry matter in cassava roots ranged from 27.64 - 41.89% (Bukoba district), 26.20 - 41.93% (Missenyi district) and 25.30 - 40.69% (Biharamulo district) while during 2019/20 cropping season the content of cassava root dry matter ranged from 25.31 - 43.18% (Bukoba district), 26.79 - 43.10% (Missenyi district) and 24.65 - 44.93% (Biharamulo district).

In both cropping seasons, low root yields were recorded in the control and high root yields were recorded in the combination of FYM at 8 MT ha^{-1} + potassium at 80 or 120 kg K ha^{-1}, signifying that addition of nutrients in the soil significantly increased cassava root yields. In addition, low starch and dry matter content in cassava roots were recorded in the control, whereas, high starch and dry matter content in cassava roots were recorded in the combination of FYM at 8 MT ha^{-1} + potassium at 120 kg K ha^{-1}. This was due to relatively high quantity of added nutrients, especially K from both FYM (Table 3) and inorganic K fertilizer. These results conform to the findings by [18] and [45], who reported that addition of K in the soil improves cassava root yield and quality.

Other researchers for example, [45] reported the positive response of cassava root yield due to N and K application, which could be directly linked to increased photosynthetic and physiological activities leading to production of assimilates translocated and utilized in rapid tuber development and production. Both N and K are necessary for cassava root initiation and increased number and size of tubers [15]. Potassium on the other hand, promotes CO_2 assimilation and the translocation of carbohydrates from leaves to the tuberous roots where carbohydrates are mainly stored [46]. Thus, adequate supply of K is important for starch synthesis and translocation, increases yield and improves root quality [45].

In all studied sites, there was significant ($P < .001$) difference in cassava root yields between the control and fertilizer treatments, signifying that use different fertilizers (organic and inorganic) at different rates had significant effects on cassava root yields. In addition, there was significant ($P < .001$) difference in cassava root yields among the fertilizer types and rates. These results conform to the finding by [47], who reported significant increase in cassava root yields due to combined application of FYM and inorganic N, P and K fertilizers over the control, which lead to addition of N, P and K and other essential nutrients from FYM. Use of FYM also improves the physical, chemical, and microbial properties of the soil [48, 49].

Table 4. Fertilizers rates effect on cassava yields during 2018/19 cropping season in Bukoba, Missenyi and Biharamulo districts

Treatment	Location								
	1	2	3	1	2	3	1	2	3
	Parameter								
	RY (MT ha^{-1})			RSC (%)			RDMC (%)		
Co	9.26^{a}	12.16^{a}	5.37^{a}	20.40^{a}	20.76^{a}	21.76^{a}	25.31^{a}	26.79^{a}	24.65^{a}
FYM_4	16.72^{b}	28.50^{b}	8.90^{b}	23.71^{b}	23.17^{b}	24.00^{b}	33.90^{b}	32.64^{b}	30.33^{b}
FYM_8	16.97^{b}	29.06^{b}	9.07^{b}	23.94^{b}	23.55^{b}	24.79^{b}	34.54^{b}	33.28^{b}	30.93^{b}
$K_{40}N_{40}P_{30}$	17.52^{bc}	30.27^{bcd}	10.22^{bc}	26.16^{c}	26.09^{c}	27.26^{c}	38.43^{c}	36.84^{c}	36.96^{c}
$K_{80}N_{40}P_{30}$	17.27^{bc}	30.46^{bcd}	11.82^{bc}	26.72^{c}	26.96^{c}	28.79^{c}	38.58^{c}	36.82^{c}	36.37^{c}
$K_{120}N_{40}P_{30}$	16.83^{bc}	29.62^{bc}	11.77^{bc}	28.98^{cd}	28.04^{cd}	30.56^{cd}	40.82^{d}	40.17^{d}	42.75^{d}
FYM_4K_{40}	19.91^{cd}	36.13^{de}	12.91^{cd}	28.86^{cd}	27.05^{cd}	30.62^{cd}	38.58^{c}	38.86^{cd}	39.96^{cd}
FYM_4K_{80}	20.00^{cd}	36.83^{de}	13.84^{d}	29.45^{cd}	27.19^{cd}	31.81^{cd}	39.41^{cd}	38.69^{cd}	39.71^{cd}
FYM_4K_{120}	22.21^{d}	36.47^{de}	14.02^{d}	29.42^{cd}	28.13^{cd}	31.60^{cd}	40.85^{d}	41.79^{de}	40.17^{cd}
FYM_8K_{40}	22.33^{d}	37.01^{de}	14.56^{d}	29.59^{cd}	30.36^{cd}	30.83^{cd}	39.63^{cd}	38.69^{cd}	39.49^{cd}
FYM_8K_{80}	23.98^{d}	37.96^{e}	15.35^{d}	30.39^{d}	32.46^{d}	33.52^{d}	42.77^{d}	42.28^{de}	43.32^{d}
FYM_8K_{120}	23.57^{d}	38.16^{e}	15.72^{d}	31.09^{d}	33.13^{d}	33.91^{d}	43.18^{d}	43.10^{de}	44.93^{d}
SED	1.38	1.44	0.75	0.42	0.87	0.81	1.07	0.94	0.75
CV (%)	22.8	13.70	22.10	5.90	10.00	12.00	7.70	7.30	7.00

Means within a column (for a particular parameter) followed by the same letter(s) are not significantly ($P = .05$) different according to Turkey's HSD Test

SED = standard error of differences of means; CV = coefficient of variation; Location: 1 = Tanzania Agricultural Research Institute(TARI), Maruku Centre in Bukoba district, 2 = Mabuye primary school in Missenyi district, 3 = Rukaragata Extension Centre in Biharamulo district; Treatment: Co = control (no fertilizer application), FYM_4 = farmyard manure at 4 MT ha^{-1}, FYM_8 = farmyard manure at 8 MT ha^{-1}, $K_{40}N_{40}P_{30}$ = potassium at 40 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}, $K_{80}N_{40}P_{30}$ = potassium at 80 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}, $K_{120}N_{40}P_{30}$ = potassium at 120 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}, FYM_4K_{40} = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_4K_{80} = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1}, FYM_4K_{120} = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1}, FYM_8K_{40} = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_8K_{80} = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}, FYM_8K_{120} = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; Parameter: RY = root yield, RSC = roots starch content, RDMC = root dry matter content

Other researchers [50], reported that application of FYM plays an important role in improving soil permeability, soil porosity and water-stable aggregates and decreasing soil bulk density thus improving soil properties and adding important nutrients in the soil for plant uptake, which in turn results in improving crop growth and development. Ultimately, improving crop growth and increasing crop yields. The results also indicated no significant ($P = .08$)) difference in cassava root yields, between use of FYM alone at 4 MT ha^{-1} or FYM alone at 8

MT ha^{-1} and combined use of inorganic N_{40} +P_{30} + K at 40, 80 or 120 kg ha^{-1}. The reason for this was addition of N, P and K in the soil from FYM (Table 3).

Table 5. Fertilizers rates effect on cassava yields during 2019/20 cropping season in Bukoba, Missenyi and Biharamulo districts

Treatment	Location								
	1	2	3	1	2	3	1	2	3
	Parameter								
	RY (MT ha^{-1})			RSC (%)			RDM (%)		
Co	8.48^{a}	12.13^{a}	5.78^{a}	19.95^{a}	20.02^{a}	20.78^{a}	25.31^{a}	26.79^{a}	24.65^{a}
FYM_4	19.81^{b}	28.63^{b}	11.31^{b}	24.18^{b}	24.26^{b}	25.11^{b}	33.90^{b}	32.64^{b}	30.33^{b}
FYM_8	20.56^{bc}	29.52^{bc}	12.54^{bc}	25.19^{b}	25.36^{b}	25.21^{b}	34.54^{b}	33.28^{b}	30.93^{b}
$K_{40}N_{40}P_{30}$	20.14^{bc}	28.93^{b}	11.65^{b}	27.66^{c}	28.00^{c}	27.70^{c}	38.43^{c}	36.84^{c}	36.96^{c}
$K_{80}N_{40}P_{30}$	20.46^{bc}	29.37^{bc}	12.44^{bc}	27.75^{c}	28.87^{c}	28.42^{c}	38.58^{c}	36.82^{c}	36.37^{c}
$K_{120}N_{40}P_{30}$	20.89^{bc}	27.91^{b}	12.04^{bc}	28.90^{cd}	30.60^{cd}	29.18^{cd}	40.82^{d}	40.17^{d}	42.75^{d}
FYM_4K_{40}	25.56^{cd}	34.60^{cd}	14.40^{cd}	28.42^{cd}	31.01^{cd}	29.29^{cd}	38.58^{c}	38.86^{cd}	39.96^{cd}
FYM_4K_{80}	25.09^{cd}	35.19^{cd}	14.69^{cd}	29.10^{cd}	30.52^{cd}	29.81^{d}	39.41^{cd}	38.69^{cd}	39.71^{cd}
FYM_4K_{120}	25.86^{cd}	35.80^{cd}	15.50^{cde}	29.76^{cd}	33.29^{d}	29.88^{d}	40.85^{d}	41.79^{de}	40.17^{cd}
FYM_8K_{40}	26.41^{d}	38.24^{d}	16.26^{def}	29.73^{cd}	30.32^{cd}	29.10^{cd}	39.63^{cd}	38.69^{cd}	39.49^{cd}
FYM_8K_{80}	27.36^{d}	39.94^{d}	18.51^{f}	30.18^{de}	33.69^{d}	30.22^{de}	42.77^{d}	42.28^{de}	43.32^{d}
FYM_8K_{120}	27.80^{d}	39.91^{d}	18.01^{ef}	31.73^{de}	34.06^{d}	30.27^{de}	43.18^{d}	43.10^{de}	44.93^{d}
SED	1.29	1.21	0.64	0.72	1.08	0.44	1.07	0.94	0.75
CV (%)	17.90	11.40	14.30	10.90	10.70	5.00	7.70	7.30	7.00

Means within a column (for a particular parameter) followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test

SED = standard error of differences of means; CV = coefficient of variation; Location: 1 = Tanzania Agricultural Research Institute(TARI), Maruku Centre in Bukoba district, 2 = Mabuye primary school in Missenyi district, 3 = Rukaragata extension Centre in Biharamulo district; Treatment: Co = control (no fertilizer application), FYM_4 = farmyard manure at 4 MT ha^{-1}, FYM_8 = farmyard manure at 8 MT ha^{-1}, $K_{40}N_{40}P_{30}$ = potassium at 40 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}, $K_{80}N_{40}P_{30}$ = potassium at 80 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}, $K_{120}N_{40}P_{30}$ = potassium at 120 kg K ha^{-1}, nitrogen at 40 kg N ha^{-1} and phosphorus 30 kg P ha^{-1}, FYM_4K_{40} = farmyard manure at 4 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_4K_{80} = farmyard manure at 4 MT ha^{-1} and potassium at 80 kg K ha^{-1}, FYM_4K_{120} = farmyard manure at 4 MT ha^{-1} and potassium at 120 kg K ha^{-1}, FYM_8K_{40} = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_8K_{80} = farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}, FYM_8K_{120} = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; Parameter: RY = root yield, RSC = roots starch content, RDMC = root dry matter content.

In addition, there was no significant (P = .08) difference in cassava root yields between combined use of FYM at 4 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1} and combined use of FYM at 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1}. This implies that combined use of FYM at 4 MT ha^{-1} or FYM at 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1} gave significantly similar and higher cassava root yields, than FYM alone at 4 MT ha^{-1}, FYM alone 8 MT ha^{-1} or combined use of inorganic N_{40} + P_{30} and K at 40, 80 or 120 kg ha^{-1}. This also might be attributed to the addition of nutrients in the soil from both FYM and inorganic K fertilizer (Table 3). These results conform to the findings by [12], who reported significantly higher cassava root yields due to combined use of FYM and inorganic P and K than use of FYM alone or inorganic fertilizers alone. [51] working on the soils of Southern Nigeria reported higher cassava root yield due to combined use of manure and inorganic N, P and K fertilizers than the use of inorganic N, P and K fertilizer alone. [51] stated that manure contains organically bound nutrients, which when mineralized increase the availability of nutrients in the soil for cassava uptake. Apart from being a source of N, P and K, manure is also an important source of Ca, S, and micronutrients and enhances the improvement of the soil physical conditions such as soil structure, texture, water infiltration and soil nutrient holding capacity, which favours root growth and development hence, increased yield.

A long-term experiment on cassava in India indicated that combined use of FYM and N, P and K gave significantly higher cassava root yield compared to FYM alone, inorganic N, P and K fertilizer alone and the control treatments [52]. In addition, [53] observed significantly higher cassava root yield due to combined application of manure and inorganic fertilizers as compared to application of FYM alone or inorganic fertilizer alone. [45] also reported that addition of K into the soil increases cassava root yield due to ability of K to increase synthesis and translocation of carbohydrates from the leaves to the roots for storage and [19] reported significant increase in cassava root yield due to application of K fertilizer as compared to the control.

Moreover, in all studied sites, there was significant ($P < .001$) difference in the content of starch and dry matter in cassava roots between the control and fertilizer types and rates, signifying that different fertilizer types and rates used in this study had significant effects in the content of starch and dry matter in cassava roots. These results conform to the findings reported by [53] that fertilization of cassava with either manure alone, inorganic fertilizers alone or combination of manure and inorganic fertilizers increases starch content in cassava roots over the control. In addition, there was significant ($P < .001$) difference in the content of starch and dry matter in cassava roots among the fertilizer types and rates, which also signifying that different fertilizer types and rates used in this study had significant effects on the content of starch and dry matter in cassava roots. In addition, there was significant ($P < .001$) difference in the contents of starch and dry matter, in cassava roots between FYM alone at 4 MT ha^{-1} or FYM alone at 8 MT ha^{-1} and combined use inorganic $N_{40}P_{30}$ + potassium at 120 kg K ha^{-1} or combined use of FYM 8 MT ha^{-1} + potassium at 80 or 120 kg K ha^{-1}.

High starch and dry matter contents were recorded in combined use of FYM at 8 MT ha^{-1} + K at 80 or 120 kg ha^{-1} and combined use inorganic $N_{40}P_{30}$ + K at 120 kg ha^{-1}. This implies that combined use of high rates of FYM and inorganic K fertilizers, or combined use inorganic N, P and high rate of K, increased the content of starch and dry matter in cassava roots. This was probably attributed increased amount of important nutrients in the soil. Findings by [54], indicated that combined use of FYM and inorganic N, P and K fertilizers gave significantly higher dry matter (25.02%) and starch (11.43%) contents in the tubers of yam. Other researchers for example, [18] and [19] reported that adequate amount of K in the soil once taken up by cassava plants enhanced formation of starch and dry matter in cassava roots. Potassium stimulates net photosynthetic activity and increases the translocation of photosynthates to the tuberous roots [12]. In addition, [55] reported that cassava requires relatively large amounts of K for starch formation and root development compared to other crops. Thus, application of K fertilizers in the soil not only increases starch content in cassava roots but also increases cassava root yields [18, 56].

The lower cassava root yield in Biharamulo district than in Bukoba and Missenyi districts were attributed to poor performance of casava due to low rainfall, accompanied by dry spells at 1 - 2 months after planting (Figure 2 and Table 2), Other researchers [37, 38] reported that cassava requires significant water supply during shoot and root initiation phase, at 1 - 5 months after planting and water deficit for at least 2 months during this stage, affects cassava growth and decreases root yield by 30 to 60% [57]. Based on this situation therefore, early planting of cassava is desirable in Biharamulo experimental site for avoiding the dry spells for good growth and optimal cassava yield.

4. CONCLUSION

Planting cassava on ridges gave higher cassava root yield than planting cassava on flat tillage. However; planting cassava on flat tillage or on ridges had no effect on the content of starch and dry matter in cassava roots. In addition, Combined use of FYM at 4 MT ha^{-1} or FYM at 8 MT ha^{-1} with potassium at 40, 80 or 120 kg K ha^{-1} increased cassava root yields as compared to use of FYM alone at 4 MT ha^{-1}, FYM alone at 8 MT ha^{-1} or combined use of inorganic N at 40 kg ha^{-1} + P at 30 kg ha^{-1} + K at 40, 80 or 120 kg ha^{-1}. These results, therefore, imply that cassava productivity can be sustained with the integration of FYM and inorganic K fertilizer as a viable alternative to the sole application of either FYM or organic fertilizers. Moreover, the interaction of tillage methods against combined use of FYM at 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1} gave higher cassava yield than the interaction of tillage methods against FYM alone at 4 MT ha^{-1}, FYM alone at 8 MT ha^{-1} or combined use of inorganic $N_{40}P_{30}$ + K at 40, 80 or 120 kg ha^{-1}.Moreover, Combined use of inorganic N at 40 kg N ha^{-1} + 30 kg P ha^{-1} + K at 120 kg K ha^{-1} or combined use of FYM at 8 MT ha^{-1} and potassium at 80 or 120 kg K ha^{-1} increased the content of starch and dry matter in cassava roots as compared to use of FYM alone at 4 MT ha^{-1}, FYM alone at 8 MT ha^{-1} or combined use of inorganic N at 40 kg N ha^{-1} + 30 kg P ha^{-1} + K at 40 or 80 kg ha^{-1}.Therefore, from the results of this study we recommend that planting cassava on ridges together with combined use of farmyard manure at 4 MT ha^{-1} and potassium fertilizer at 40, 80 120 kg K ha^{-1} is desirable for improving cassava growth and increasing cassava root yield in the study area. In addition, combined use of inorganic $N_{40}P_{30}$ and K at 20 kg K ha^{-1} or combined use of FYM at 8 MT ha^{-1} together with potassium at 80 or 120 kg K ha^{-1} is desirable for increasing the content of starch and dry matter in cassava roots. Moreover, for good performance of cassava and thus optimum cassava yield in Biharamulo district and specifically in Biharamulo ward, we recommend to plant cassava during the short rainfall season starting from October to December to avoid dry spell period experienced starting from April to May.

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ACRONYMS, ABBREVIATIONS

AGRA	Alliance for Green Revolution in Africa
ANOVA	Analysis of variance
CO_2	Carbon dioxide
CV	Coefficient of variation
^oC	Degree Celsius
DAP	Di-ammonium phosphate
et al.	and others
FAO	Food and Agricultural Organization
FYM	Farmyard manure
GENSTAT	General Statistics
g	Gram
GPS	Global positioning system
HSD	Honestly Significant Difference
ICAR-CTCRI	Indian Council of Agricultural Research-Central Tuber Crops Research Institute
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
masl	meter above sea level
m	meter
mm	millimeter
MOP	Muriate of potash
MT ha^{-1}	Metric ton per hectare
N, P, K, Ca, S	Nitrogen, Phosphorus Potassium, Calcium, Sulphur
OC	Organic Carbon
%	Percent
RCBD	Randomized Complete Block Design
SUA	Sokoine University of Agriculture
TARI	Tanzania Agricultural Research Institute
TN	Total nitrogen
URT	United Republic of Tanzania

UV/VIS	Ultraviolent visible spectrophotometer