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Influence of Tillage Methods, Farmyard Manure and Potassium Rates on Soil Moisture and Relationship with Cassava Root Yields in Kagera, Tanzania

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Authors' contributions

This work was carried out in collaboration among all authors. Author MSM designed the study, laid out the experimental field trial, collected data, performed statistical analysis, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Authors JMS, ES and BMM approved the protocol and design of this study, and proofread the manuscript. Author JSB managed the experimental field trials and collected data. Authors MSM, JMS, ES and BMM read and approved the final manuscript.

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ABSTRACT

Field experimental trial was established in Biharamulo, Bukoba and Missenyi districts, Tanzania in two consecutive (2018/19 and 2019/20) cropping seasons, aimed at determining the effects of tillage methods, farmyard manure (FYM) and potassium rates on soil moisture conservation and the relationship between soil moisture and cassava root yield using the split-plot design with three replications. Treatments: Tillage methods (flat tillage, open ridging and tie ridging) as the main plots and; the fertilizer rates [farmyard manure alone at 4 MT ha^{-1} or FYM alone at 8 MT ha^{-1}, nitrogen (40 kg N ha^{-1}) + phosphorus (30 kg P ha^{-1}) + potassium at 40, 80 or 120 kg K ha^{-1} and the combination of FYM at 4 or 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1}] and the control as the sub-plots were arranged in Randomized Complete Block Designed (RCBD). Farmyard manure was applied at planting and inorganic fertilizers were applied in two splits. Soil moisture was monitored starting from one week after the last rain event at an interval of two weeks up to the first rain event of the following season. Soil moisture samples (0 - 30 cm) were collected from the rows and ridges using a soil auger, placed in cores, weighed, oven-dried at 105 ^oC and reweighed after 24 hours to constant weight. The soil moisture content (%) in each soil sample was determined gravimetrically. Cassava root yields were recorded from each treatment during harvesting. The results indicated that the use of ridges conserved significantly ($P < .001$) more soil moisture (24 - 58%) than the use of flat tillage (7 - 27%) in both cropping seasons. The use of tie ridges conserved significantly ($P \leq .01$) more soil moisture (11 - 58%) than the use of open ridges (10 - 57%) in the medium and high rainfall areas as opposed to the low rainfall area, which both conserved similar soil moisture. There was a significant ($P < .001$) difference in soil moisture conservation between the control and fertilizer types and rates. The use of FYM conserved significantly ($P < .001$) more soil moistures (16.54 - 63.48%) than the combined use of inorganic N, P and K fertilizer rates (12.27 - 53.60%). The use of FYM at 8 MT ha^{-1} conserved significantly ($P < .001$) more soil moisture (19.94 - 62.16%) than FYM at 4 MT ha^{-1} (16.80 - 58.33%). However, there was no significant ($P = .33$) different in soil moisture conservation between the combined use of inorganic N, P and K fertilizers and; the control. Results from regression analysis indicated significant ($P < .001$) association between soil moisture conservation and changes in cassava root yields. Thus, planting cassava on ridges, concurrently with the application of FYM at 8 MT ha^{-1} is recommended for adequate soil moisture conservation and increasing cassava root yield.

Keywords: Tillage methods; farmyard manure; potassium rates; soil moisture conservation; cassava root yields; regression analysis.

ABBREVIATIONS

AGRA : Alliance for Green Revolution in Africa
ANOVA : Analysis of Variance
CO2 : Carbon Dioxide
cm : Centimeter
^oC : Degree Celsius
FYM : Farmyard Manure
GENSTAT : General Statistics
HSD : Honestly Significant Difference
ha^{-1} : Per Hectare
kg : Kilogram
kg ha-1 : Kilogram Per Hectare
masl : Meter Above Sea Level
m : Meter
mm : Millimeter
MOP : Muriate of Potash
MPa : Mega Pascal
MT ha^{-1} : Metric ton Per Hectare
N, P, K, Mg : Nitrogen, Phosphorus Potassium, Magnessium
% : Percent

RCBD : Randomized Complete Block Design
SUA : Sokoine University of Agriculture
TARI : Tanzania Agricultural Research Institute
URT : Untied Republic of Tanzania

1. INTRODUCTION

In Tanzania, cassava contributes about 15% in the national food basket and is the second staple food crop after maize in term of production volume and per capital consumption and supports the livelihood of 37% smallholder rural farmers [1]. In the Lake zone, cassava is an important food crop grown in all regions accounting for about 23.70% of the total cassava production in Tanzania [2]. Its roots have at least 30% of starch on dry weight basis, which is the major source of dietary energy and can be used to produce different industrial products like sugar, pharmaceutics, alcohol and textile products and used as animal feed [1, 3]. For optimum yield, cassava requires annual rainfall ranging from 1000 - 3000 mm, but the crop can tolerate low rainfall if the rainfall is well distributed throughout the growing season [4, 5]. Sufficient water supply is required during roots and shoots initiation, mostly 1 - 5 months after planting and water deficit for at least 2 months during this period, severely affects root development and lowering root yield from 30 to 62%, the extent being dependent on the stage of plant maturity [6-9]. However, several studies have demonstrated that if cassava experiences water deficit later than 5 months after planting, there is no significant yield reduction [10].

In the Lake zone areas, the low rainfall, unreliable, unevenly distribution rainfall and low soil fertility are the important crop production constraints which contribute to low crop yields [11] and insecure household food security [12]. However, Kagera region (one of the regions in the Lake zone) has three agro-ecological zones based on rainfall pattern namely high, medium and low rainfall zones [13, 14]. Annual rainfalls are > 2500 mm in high rainfall zone, 700 - 1300 mm in medium rainfall zone and 600 - 1000 mm in the low rainfall zone [15, 16]. This study was conducted in each of the three-agro ecological zones of the region, whereby Bukoba, Missenyi and Biharamulo districts presented the high, medium and low rainfall zones, respectively. There is no doubt that due to the existing differences in annual rainfall in these areas, there are also differences in the amount and distribution of soil moisture, which concurrently affect the growth, development and yields of crops differently.

Moisture availability is one of the most important limiting factors, which affects plant growth and crop yields in rain fed areas. Seedling germination, crop growth, development and yields are more influenced by the available soil water than any other single factor [17]. The available soil water is highly associated with the amount of rainfall and its distribution during the growing season. Crop stresses become severe when the available soil water is reduced mostly during the dry spells or in areas with low rainfall pattern, leading to seasonal crop production variation and unstable yields. Therefore, appropriate tillage practice is one of the agronomic measures to ensure optimum soil moisture content, and consistent optimum crop yield in some location and soil type [17]. The roles of any tillage method, among others are to conserve soil moisture, improve soil characteristic (soil porosity, bulk density and consistency) and reduce soil erosion and nutrient losses for improving crop production through timely land preparation and weed control [18, 19]. Likewise, crops respond to the application of farmyard manure and inorganic fertilizers due to effects on improving soil fertility, soil structure, nutrient holding capacity, moisture retention capacity and soil aeration [20] For example, [21] working on soils of western cotton growing areas of Tanzania, reported significant yield increases of sorghum and maize planted on tied ridges. Other researchers [20, 22], reported increased cassava root yield due to combined application of organic and inorganic fertilizers.

In the lake zone, some of researches have been done on the effect of tillage practices mostly on cereal crops [21, 23] and in few places mainly in Shinyanga and Mwanza regions. In the Kagera region, many farmers plant cassava on flat tillage and few plant cassavas on the ridges, but the relative effects of planting cassava on the ridges or on the flat land on soil moisture conservation and cassava crop growth and yields have received limited research attention. Yet such studies are necessary to provide the necessary information for recommending appropriate tillage practices for sustainable crop production in different agro-ecologies. However, little information exists on the effects of different tillage methods and the combined use of organic and inorganic fertilizers on soil moisture conservation in root and tuber crops, specifically cassava. Likewise, scanty information exists on the relationship between soil moisture and cassava root yield based on the soils and climate of Kagera region. Therefore, this study aimed at determining the effects of tillage methods (Flat tillage, open ridging and tie ridging) and FYM and potassium rates on soil moisture conservation and the relationship between soil moisture and cassava root yields in the Kagera region.

2. MATERIALS AND METHODS

2.1 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′ S and between longitudes 30°25′ and 32°40′ E [15, 16]. The region has seven districts, namely Biharamulo, Bukoba, Karagwe, Kyerwa, Missenyi, Muleba and Ngara. This study was conducted in Bukoba, Missenyi and Biharamulo districts. The representative study sites were Tanzania Agricultural Research Institute (TARI), Maruku Centre in Bukoba district, Mabuye Primary School in Missenyi district, and Rukaragata Farmers' Extension Centre in Biharamulo district [16]. Bukoba district 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 (masl) while, Missenyi district is situated between latitudes 1° 00′ and 1° 30′ S and between longitudes 30° 48′ and 31° 49′ E, with attitude between 1100 - 1400 masl and Biharamulo district 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 masl [15, 16].

2.2 Climate and Soils of the Study Area

Kagera region experiences a bimodal rainfall distribution regime of short rains between September and December and long rains between March and June. In the study districts, the mean annual rainfall ranges from 900 - 3000 mm in Bukoba district, 700 - 1300 mm in Missenyi district and 600 - 1100 mm in Biharamulo district [15]. Therefore, based on the rainfall distribution, three agro-ecological zones are found and named as: the high rainfall zone, which in this study was represented by Bukoba district, the medium rainfall zone which was represented by Missenyi district, and the low rainfall zone, which was represented by Biharamulo district [16,24,25]. The mean annual temperature ranges from 16 - 28 °C thereby; the Missenyi site has higher annual temperature (28 °C) than the Bukoba and Biharamulo (26 °C) sites. Soil fertility statuses of the study area are poor fertility, of which; N, K and Mg are the limiting nutrients in Bukoba experimental site, N and S are the limiting nutrients in Missenyi experimental site and N, P and K are the limiting nutrients in Biharamulo experimental site [26]. The soil textures of the study area are sandy clay loam in Bukoba experimental site, sandy loam in Missenyi experimental site and sandy clay in Biharamulo experimental site [24,16,26].

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 cutting of trees before trial establishment. Thereafter, land was ploughed followed by harrowing. Ridges were prepared using a hand hoe by heaping up the soil within 1-metre wide ridge (0.5 m from each end of the ridge top) so that the spacing from the top-center of one ridge to the top-center of another ridge was 1 m. Plot size was 6 m x 5 m. Separation between plots and blocks was 1.5 m and 2 m apart, respectively. For the tie ridges, the soil was raised at each ends of two adjacent ridges and at the centers (3 m from each end of the ridge) to form three ties between two ridges.

The treatments were arranged in Randomized Complete Block Design (RCBD), in three replications using the split-plot design; with tillage methods (flat tillage, open ridging and tie ridging) as main plots and fertilizer types and rates (FYM alone at 4 MT ha^{-1}, FYM alone 8 MT ha^{-1}, nitrogen at 40 kg N ha^{-1} + phosphorus at 30 kg P ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1} and the combination of FYM at 4 or 8 MT ha^{-1} + inorganic K at 40, 80 or 120 kg ha^{-1}) as subplots (Table 1). The combination of nitrogen at 40 kg N ha^{-1} + phosphorus at 30 kg P ha^{-1} [27] together with potassium at 40, 80, or 120 kg K ha^{-1} were applied as inorganic fertilizer treatments while the combination of FYM alone at 4 MT ha^{-1} or FYM alone at 8 MT ha^{-1} + potassium at 40, 80 or 120 K kg ha^{-1} were applied as organic and inorganic fertilizers combined 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. Inorganic fertilizers were applied in two splits; the first split, one month after planting, and the second split, three months after planting by banding method around each cassava plant. Improved cassava variety, *Mkumba*, was the test variety. Cassava cuttings of 25 to 30 cm length were planted at the spacing of 1 m x 1 m in the flat land and ridging treatments. The duration (cassava growing period) of the trial from planting to harvesting was 12 months. The experimental plots were maintained free from weeds throughout the growing period. The same trial was repeated in the following season while maintaining the same plots.

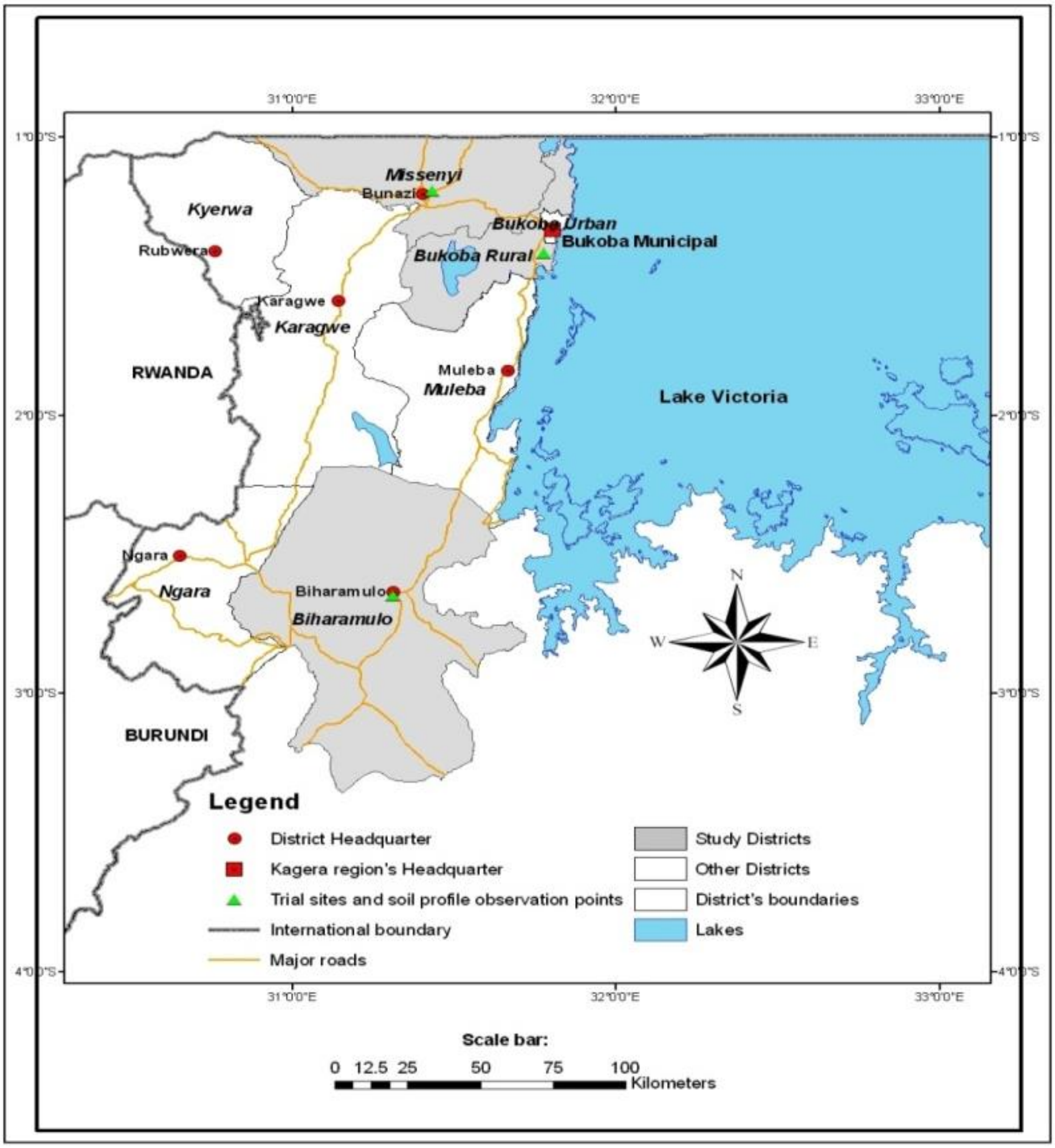

Fig. 1. Location of the field experimental trial sites in Bukoba, Missenyi and Biharamulo districts

Source: [16]

Table 1. Experimental treatments in the split-plot design

Main Plots		
Flat Tillage	**Open Ridge Tillage**	**Tie Ridge Tillage**
Sub Plots		
Co	Co	Co
FYM_4	FYM_4	FYM_4
FYM_8	FYM_8	FYM_8
$K_{40} + N_{40} + P_{30}$	$K_{40} + N_{40} + P_{30}$	$K_{40} + N_{40} + P_{30}$
$K_{80} + N_{40} + P_{30}$	$K_{80} + N_{40} + P_{30}$	$K_{80} + N_{40} + P_{30}$
$K_{120} + N_{40} + P_{30}$	$K_{120} + N_{40} + P_{30}$	$K_{120} + N_{40} + P_{30}$
$FYM_4 + K_{40}$	$FYM_4 + K_{40}$	$FYM_4 + K_{40}$
$FYM_4 + K_{80}$	$FYM_4 + K_{80}$	$FYM_4 + K_{80}$
$FYM_4 + K_{120}$	$FYM_4 + K_{120}$	$FYM_4 + K_{120}$
$FYM_8 + K_{40}$	$FYM_8 + K_{40}$	$FYM_8 + K_{40}$
$FYM_8 + K_{80}$	$FYM_8 + K_{80}$	$FYM_8 + K_{80}$
$FYM_8 + K_{120}$	$FYM_8 + K_{120}$	$FYM_8 + K_{120}$

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}

2.4 Data Collection

Data on soil moisture and cassava root yields were collected in two consecutive cropping seasons (2018/19 and 2019/20). The soil moisture in each applied treatment was monitored starting from one week after the last rain event of the season, at an interval of two weeks up to the first rain event of the following season. Using a soil auger, the soil moisture samples were collected from main plot treatments (flat tillage, open ridging and tie ridging) that received the same rates of fertilizers. In each plot of flat tillage treatment, 0 - 30 cm soil samples were collected along one row at each sampling time. Each plot had five rows and five ridges for flat tillage and ridging treatments, respectively. After sampling at the first row, the next row was sampled during the next sampling time, until all rows were sampled. This was done to avoid collecting soil samples from the already disturbed rows and ridges. The same soil moisture collection procedure was deployed to collect the soil samples in the open and tied-ridging treatments; Soil samples were collected at the top of each ridge at the same depth as in flat land treatment. The collected soil samples were placed in soil cores and covered to restrain evaporation. The empty sampling cores were weighed before to determine their weights. While still in the field, the collected soil samples were weighed using a potable digital balance and their weights (weight of moist soils + core) were recorded. The core samples were sent to the laboratory and placed in a drying oven at the temperature of 105 ^{o}C. After 24 hours, the cooled core samples were reweighed and their weights recorded. The core samples were then placed in the drying oven and reweighed after 24 hours. These actions of re-drying and re-weighing were repeated until a constant weight of each core sample was recorded. The percentage soil moisture content in each soil sample was calculated gravimetrically [28, 29], as the ratio of the mass of water present in the soil sample to the dry weight of the soil sample x 100, whereby, the water mass (weight) is the difference between the weight of the wet and oven dry samples. Soil moisture content in each treatment was calculated using the following formula:

Moisture content (%) = (weight of wet soil + core) - (weight of dry soil + core) * 100 / (weight of dry soil + core) - (weight of core)

Cassava plating materials were planted at the month of March in both cropping seasons. Cassava root yields were recorded in each treatment at 12 months after planting during physiological maturity (at harvesting), by uprooting the cassava plants in each plot and detaching the roots from the plants. The weight of cassava roots from each plot (treatment) was recorded after weighing the roots using a weighing balance.

2.5 Statistical Data Analysis

Data for soil moisture and cassava root yields were subjected to analysis of variance (ANOVA) based on the statistical model for the split-plot design [30], using the GENSTAT 16th Edition statistical packages. Means differences among the treatments were separated using the Tukey's test (Honestly Significant Difference, HSD) at the .05 level of significance. Regression analyses between cassava root yield (dependent variable) and soil moisture (independent variable) with respect to the main factors (tillage methods), sub factors (fertilizer rates) and interactions between main factors and sub factors were performed using the Excel spreadsheet statistical package to determine the relationship between cassava root yield and soil moisture status with respect to the applied treatments in this study.

3. RESULTS AND DISCUSSION

3.1 Effects of Tillage Methods on Soil Moisture Conservation during the 2018/19 and 2019/20 Cropping Seasons, in Bukoba, Missenyi and Biharamulo Districts

Data on the percentage soil moisture conserved with respect to tillage methods (flat tillage, open ridging and tie ridging) within seven and eleven weeks between the last rain event and the first rain event in the following season during the 2018/19 and 2019/20 seasons, respectively showed decreased trend of soil moisture with increased time of sampling, up to the first rain event in the following season (Figs 2 and 3). The decrease in soil moisture with increased time of sampling was due to soil evaporation and evapotranspiration. This was so because in both cropping seasons, there was a five weeks dry spell after the last rainfall event up to the first rain event in the following season in both Bukoba and Missenyi sites. In the Biharamulo site, there were seven- and nine-weeks dry spells after the last rainfall event up to the first rainfall event in the following season during the 2018/19 and 2019/20 seasons, respectively. Thus, Bukoba and Missenyi districts had shorter period of dry spell than Biharamulo district. There was a significant ($P < .01$) difference in the amount of soil moisture conserved among the tillage treatments in all experimental sites and in both cropping seasons. In all experimental sites, tie ridging treatment conserved significantly ($P < .001$) more soil moisture than flat tillage or open ridging treatments and the least conservation was in the flat tillage treatment. These findings conform to the results by Guzha [31] who reported significantly ($P = .05$) higher soil moisture in tied ridges than in flat tillage due to its ability to conserve rain water in the formed bands, increased infiltration and reduction of run-off hence reduced erosion [32]. However, there was no significant ($P = .33$) difference in soil moisture conservation between tied ridges and open ridges in Biharamulo experimental site, as opposed to the same treatments in Bukoba and Missenyi experimental sites. This was due to the reason that Biharamulo experimental site is characterized as a low rainfall area [13,16] since during the two growing seasons, the site received annual rainfall ranging from 1034 - 1070.90 mm as compared to, for example, Bukoba experimental site which received annual rainfall ranging from 2824.30 - 3383.60 mm (Table 2). These results revealed that a significant ($P < .001$) difference in soil moisture between the tie ridging and open ridging is observed in areas with medium to high rainfall as recorded in Missenyi and Bukoba experimental sites.

The amount of soil moisture conserved with respect to tillage methods ranged from 22 to 58% in Bukoba district, from 8 to 36% in Missenyi district and from 13 to 32 % in Biharamulo district during the 2019/20 cropping season (Fig. 2) and from 25 to 52% in Bukoba district, from 18 to 45% in Missenyi district and from 7 to 23% in Biharamulo district during the 2019/20 cropping season (Fig. 3). These results indicated that Bukoba experimental site conserved more soil moisture than Biharamulo or Missenyi experimental sites. The differences in soil moisture among the experimental sites were due to variations in the amount of rainfall, and soil texture. It should be noted that the soil textures of the experimental sites are sandy clay loam to clay in Bukoba district, sandy loam in Missenyi district and sandy clay in Biharamulo district [16]. The soils with heavy texture (high clay content) conserve more soil moisture than those with light soil texture (low clay content) [33]. Among the three experimental sites, the soils of Bukoba site has high clay content ranging from 21.90 - 63.92% followed by Biharamulo site with clay content ranging from 40.64 - 50.64% and the last is Missenyi site with clay content ranging from

10.64 - 27.64% [16]. In addition, Merumba et al [16] working on these soils, reported more drastic decease in soil moisture with increased soil moisture suction in the soils of Missenyi site than in the soils of Bukoba or Biharamulo sites. However, the low soil moisture in Biharamulo site during 2019/20 season was due to low rainfall (Table 2) accompanied by the 4 months of dry spell, starting just at 1- 2 months after planting (Fig. 4), given that cassava plants were planted in March in all experimental sites.

3.2 Effects of Fertilizer Types and Rates on Soil Moisture Conservation during the 2018/19 and 2019/20 Cropping Seasons, in Bukoba, Missenyi and Biharamulo Districts

The percentage soil moisture conserved with respect to different rates of FYM, N+P+K and the combination of FYM and K fertilizer between the last rain event and the first rain event in the following season during the 2018/19 and

Table 2. Annual rainfall recorded at the experiment sites during the 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts

District	Experimental Site	Annual Rainfall (mm)	
		2018/19	2019/20
Bukoba	TARI Maruku	2824.30	3383.60
Missenyi	Mabuye Primary School	1251.50	1466.40
Biharamulo	Rukaragata Extension Centre	1034.00	1070.90

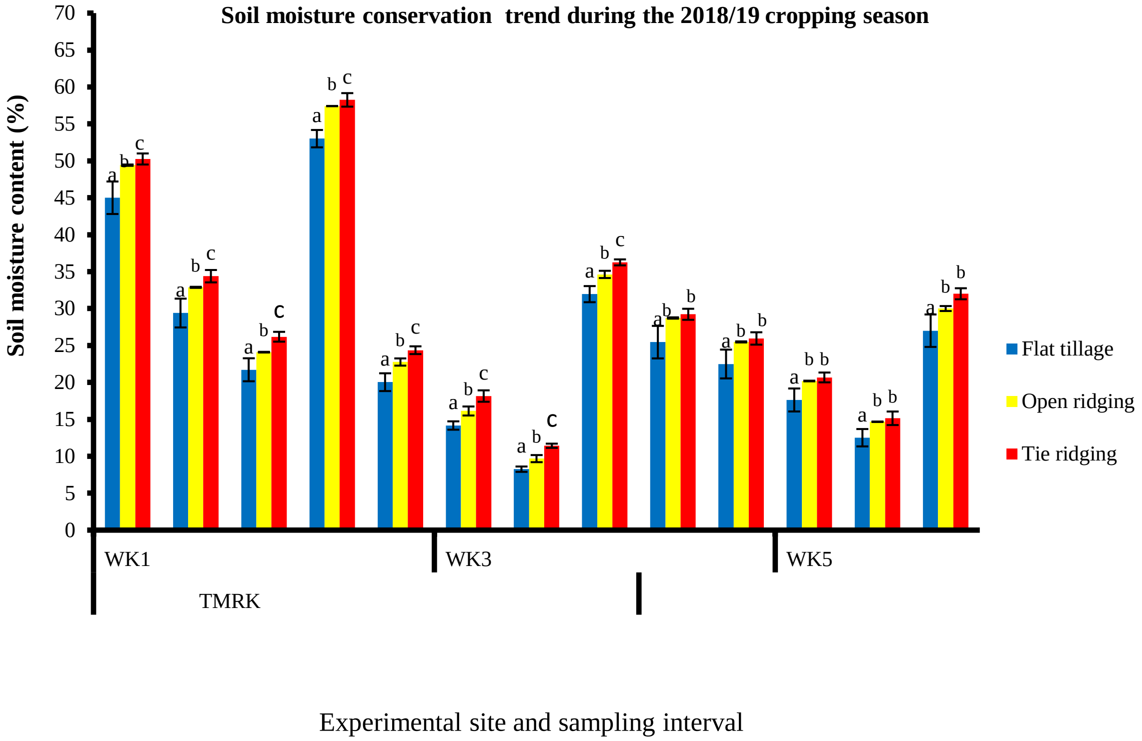

Fig. 2. Tillage methods effects on soil moisture conservation within seven to nine weeks during the 2018/19 cropping season in Bukoba, Missenyi and Biharamulo districts

Means within the sampling interval (weeks) for soil moisture followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test; Experimental site: TMRK = Tanzania Agricultural Research Institute-Maruku Centre in Bukoba district; MBYP = Mabuye Primary School in Missenyi district; RKRC = Rukaragata Extension Centre in Biharamulo district; Sampling interval: Wk1 = one week; Wk3 = three weeks; Wk5 = five weeks; Wk7 = seven weeks

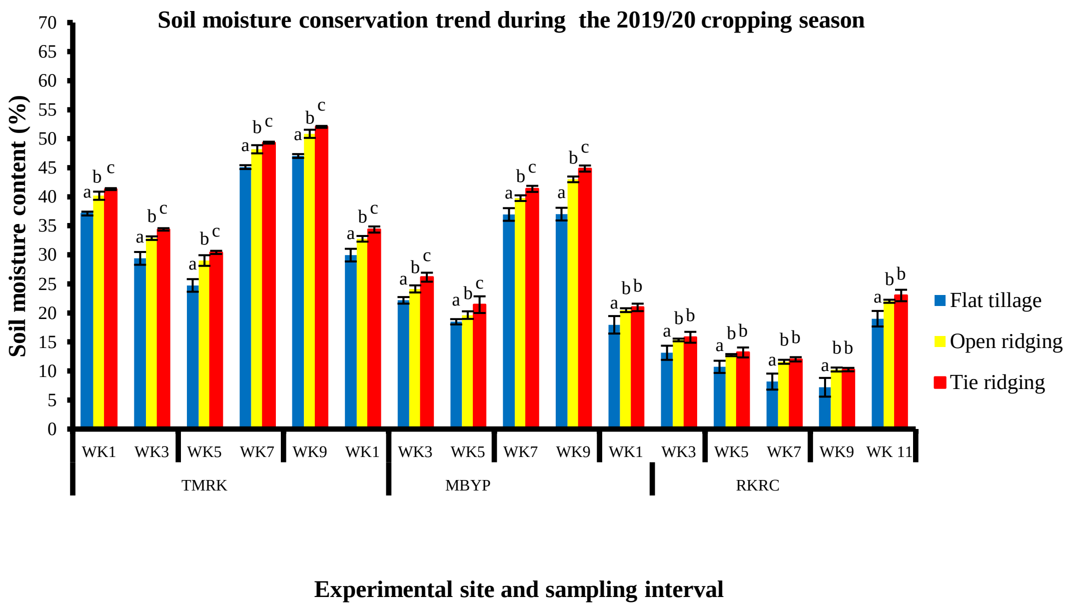

Fig. 3. Tillage methods effects on soil moisture conservation within nine to eleven weeks during the 2019/20 cropping season in Bukoba, Missenyi and Biharamulo districts

Means within the sampling interval (weeks) for soil moisture followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test; Experimental site: TMRK = Tanzania Agricultural Research Institute-Maruku Centre in Bukoba district; MBYP = Mabuye Primary School in Missenyi district; RKRC = Rukaragata Extension Centre in Biharamulo district; Sampling interval: Wk1 = one week; Wk3 = three weeks; Wk5 = five weeks; Wk7 = seven weeks

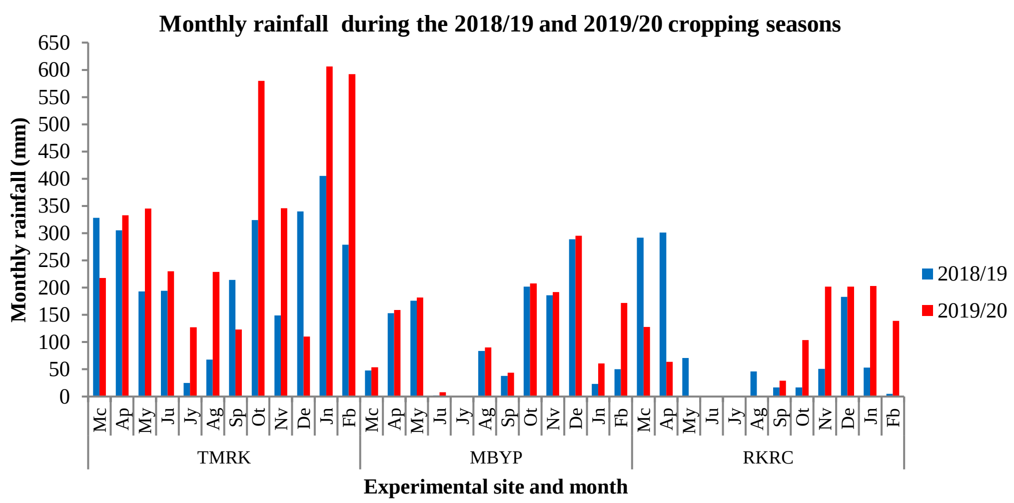

Fig. 4. Monthly rainfall during 2018/19 and 2019/20 seasons at the experimental sites in Bukoba, Missenyi and Biharamulo districts, Tanzania

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

2019/20 cropping seasons are presented in Tables 3 and 4. The results indicated that soil moisture decreased with time of sampling. The decrease in soil moisture was caused by soil surface evaporation and evapotranspiration. During the two cropping seasons, Bukoba and

Missenyi experimental sites experienced dry spells for five weeks while the Biharamulo site experienced a dry spell for seven and nine weeks during the 2018/19 and 2019/20 cropping seasons, respectively. This implied that Biharamulo site experienced a long dry spell as compared to Bukoba and Missenyi experimental sites (Fig. 4).

The amount of soil moisture conserved with respect to types (inorganic or organic) and rates of fertilizer (Tables 3 and 4) varied significantly (P <.001) with weeks of sampling. Soil moisture conserved ranged from 25.73 to 60.48% in Bukoba district, from 15.35 to 42.33% in Missenyi district and from 10.41 to 33.80% in Biharamulo district during the 2018/19 cropping season (Table 3), and from 28.58 to 53.60% in Bukoba district, from 14.02 to 47.98% in Missenyi district and from 15.90 to 32.88% in Biharamulo district during the 2019/20 cropping season (Table 4). The results indicated that Bukoba site conserved more soil moisture than Missenyi experimental site and last was Biharamulo site. This was due to the fact that Bukoba district is characterized as a high rainfall zone while Missenyi district is characterized as a medium rainfall zone and Biharamulo district is characterized as a low rainfall zone [13,14,16]. During the 2018/19 cropping season, Bukoba site received 2824 mm annual rainfall while Missenyi site received 1252 mm annual rainfall and Biharamulo site received 1034 mm during the 2019/20 cropping season, Bukoba sites received 3350 mm annual rainfall while Missenyi site received 1466 mm annual rainfall and Biharamulo site received 1071 mm, and all the experimental sites have the Udic soil moisture regime (SMR). In addition, higher soil moisture at Bukoba experimental site than at Missenyi site was due to the differences in soil texture between the two sites thereby, Bukoba site has sandy clay loam soil texture while the Missenyi site has sandy loam soil texture, which loses water faster than sandy clay loam [16].

There was a significant (P <.001) difference in the amount of soil moisture conserved between the control and fertilizer types and rates or among the fertilizer rate treatments in all experimental sites, during both seasons. However, there was no significant (P = .33) difference in the amount of soil moisture conserved between the control and the combined use of inorganic N, P and K at different rates (i.e. $N_{40}P_{30}K_{40}$, $N_{40}P_{30}K_{80}$ or $N_{40}P_{30}K_{120}$). This indicated that combined use of inorganic fertilizers, specifically, N and P, at 40 kg N ha^{-1} and P at 30 kg P ha^{-1}, respectively, together with K at 40, 80 or 120 kg ha^{-1} (N, P and K) had no significant a (P <.001) effects on soil moisture conservation. In all experimental sites, use of FYM at 8 MT ha^{-1} alone or the combined use of FYM at 8 MT ha^{-1} and K at 40, 80 or 120 kg ha^{-1} conserved significantly (P <.001) higher and similar soil moisture than use of FYM alone at 4 MT ha^{-1} or the combined use of FYM at 4 MT ha^{-1} and potassium at 40, 80 or 120 kg K $ha^{-1.}$ These results indicated that use of high rates of FYM conserved higher soil moisture regardless the rates of K, the results also revealed that different rates of K had no significant (P = .06) effect on soil moisture conservation. The results from this study, therefore, conform to the findings reported by Khan et al [34] and Mwende [35] who reported significant (P < .01) increases in soil moisture content upon application of FYM due to the fact that FYM enhances the formation of water stable aggregates, hence improves water holding capacity, increases water percolation, porosity and reduces soil crusting and compaction [35, 36].

3.3 Effects of Interaction of Tillage Methods and Fertilizer Rates on Soil Moisture Conservation during the 2018/19 and 2019/20 Cropping Seasons in Bukoba, Missenyi and Biharamulo Districts

It should be noted that the combination of tillage methods and fertilizer rates (i.e. FYM, N + P + K, FYM + K fertilizer) gave a total of 36 individual combinations. However, only 12 combinations are presented in this paper. Therefore, the interaction of tillage methods and the control treatment together with the interaction of tillage methods and combined application of FYM at 8 MT ha^{-1} and K applied as MOP at 40, 80 or 120 kg K ha^{-1} were presented due to the reason that significant (P < .001) difference among the fertilizer types and rates were observed at the high rate of FYM (i.e. 8 MT ha^{-1}). The results indicated that the amount of soil moisture conserved with respect to interaction of tillage methods and different rates of FYM, N, P and K within seven and nine weeks, between the last rain event and the first rain event in the following season during the 2018/19 and 2019/20 cropping seasons, respectively, decreased with time of sampling, up to the first rain event in the following season. It was observed during the two consecutive cropping seasons, Bukoba and Missenyi sites experienced dry spells for five weeks while Biharamulo site experienced a dry spell for seven and nine weeks during the 2018/19 and 2019/20 cropping seasons, respectively. This is the evidence that Biharamulo site experienced a longer dry spells as compared to Bukoba and Missenyi sites (Fig. 4). The percentage soil moisture conserved with respect to the interaction of tillage methods and different types and rates of fertilizers (FYM, N + P + K, FYM + K fertilizer) varied significantly (P < .001) with time of sampling. Soil moisture conserved ranged from 22.75 to 61.61% in Bukoba district, from 14.27 to 44.94% in Missenyi district and from 10.40 to 35.94% in Biharamulo district during 2018/19 cropping season (Table 5) and from 27.12 to 57.09% in Bukoba district, from 23.21 to 51.86% in Missenyi district and from 15.0 to 35.65% in Biharamulo district during 2019/20 cropping season (Table 6). The data showed that Bukoba site conserved more soil moisture followed by Missenyi site and the last was Biharamulo site. The reason for these differences as explained before was due to the fact that Bukoba district is a high rainfall zone while Missenyi district is a medium rainfall zone and Biharamulo district is a low rainfall zone [13,14,16], and longer dry spell was experienced in Biharamulo site as compared to Bukoba and Missenyi sites.

There was a significant (P < .01) difference in the amount of soil moisture conserved between the interactions of tillage methods and the control, and between the interaction of tillage methods and the combined application of FYM and K at different rates. However, there was no significant (P = 33) difference in the amount of soil moisture conserved between the interaction of tillage methods and the control, and between the interaction of tillage methods and combined application of inorganic fertilizers at different rates [i.e. $N_{40}P_{30}K_{40}$, $N_{40}P_{30}K_{80}$ or $N_{40}P_{30}K_{120}$] (Tables 5 and 6).This indicates that the interactions between the tillage methods and the control, and the interactions between the tillage methods and the combined application of inorganic fertilizers, specifically N and P, at 40 kg N ha^{-1} and P at 30 kg P ha^{-1}, respectively together with K at 40, 80 or 120 kg ha-1 (N, P and K fertilizers) had no significant (P = 33) effects on soil moisture conservation. Therefore, these results implied that the use of inorganic fertilizers alone had no significant effects on soil moisture conservation in all experimental sites during both cropping seasons. The results also indicated that in Bukoba and Missenyi sites, the interactions between flat tillage or open ridging against FYM alone at 8 MT ha^{-1}, and the interactions between flat tillage or open ridging against combined use of FYM at 8 MT ha^{-1} and K at 40, 80 or 120 kg ha^{-1} had no significant (P = .06) difference in soil moisture conservation, and both conserved significantly lower soil moisture than the interaction between the tie ridging and the combined use of FYM at 8 MT ha^{-1} and K at 40, 80 or 120 kg ha^{-1} thereby, the interaction between the tie ridging and the combined use of FYM at 8 MT ha^{-1} and potassium fertilizer at 40, 80 or 120 kg K ha^{-1} conserved significantly (P < .001) more soil moisture than the other two tillage methods (flat tillage and open ridging). This conforms to the findings reported by Chepkemoi et al [29] that the interaction between tie ridges and FYM significantly (P .01) increased soil moisture in intercrop plots of dolichos and sorghum and those of dolichos and sweet potato. However, the results indicated that in Biharamulo site, there was no significant (P = .33 difference in soil moisture conserved with respect to the interaction between the tillage methods (flat tillage, open ridging and tie ridging) and the combined use of FYM at 8 MT ha^{-1} and K at 40, 80 or 120 kg ha^{-1}(Table 5). This could be attributed to the low rainfall recorded at Biharamulo site as compared to Bukoba and Missenyi sites. Based on this study therefore, it was observed that the differences in soil moisture conservation among the tested tillage methods (flat tillage, open ridging and tie ridging) can be observed in areas with medium to high rainfall as opposed to the areas with low rainfall based on the Kagera region rainfall regime. This inference may also be applied to other areas with similar contrasting rainfall regimes.

3.4 Relationships between Soil Moisture and Cassava Root Yields with Respect to Tillage Methods, Fertilizer Rates and Interaction of Tillage Methods against Fertilizer rates in Biharamulo, Bukoba and Missenyi Districts

3.4.1 Tillage methods

The regression analyses between soil moisture conserved with respect to tillage methods (flat tillage, open ridging and tie ridging) and fertilizer types and rates (FYM alone at 4 MT ha^{-1}, FYM alone at 8 MT ha^{-1}, nitrogen at 40 kg N ha^{-1} + phosphorus at 30 kg P ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1} and the combined use of FYM at 4 or 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1}) during the 2018/19 and 2019/20 cropping seasons are presented in Tables 7, 8 and 9. In

Bukoba district, the results indicated strong (multiple R = 0.78) and very strong (multiple R = 0.97) correlations between soil moisture conserved with respect to tillage methods and cassava root yields during the 2018/19 and 2019/20 cropping seasons, respectively, and about 61% and 94% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 cropping seasons, respectively. In Missenyi district, the results indicated very strong correlations during the 2018/19 cropping season (multiple R = 0.99) and the 2019/20 cropping season (multiple R = 0.95), between soil moisture conserved with respect to tillage methods and cassava root yield, and about 91% and 91% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 seasons, respectively. In Biharamulo district, the results indicated strong (multiple R = 0.75) and very strong (multiple R = 0.99) correlations between soil moisture conserved with respect to tillage methods and cassava root yields during the 2018/19 and 2019/20 cropping seasons, respectively, and about 56% and 99% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 cropping seasons, respectively.

In all districts and both cropping seasons, the results indicated no significant correlations between soil moisture conserved with respect to tillage methods and cassava root yield, which signified that the changes in soil moisture conserved with respect to the tillage methods were not associated with the changes in cassava root yields. This may be attributed to low soil moisture conserved with respect to tillage methods as opposed to high soil moisture conserved with respect to fertilizer rates or the interaction of tillage methods and fertilizer rates. The insignificant correlation between soil moisture with respect to tillage methods and cassava root yields implied that apart from soil moisture, there are other factors such plant nutrients that are associated with the changes in cassava root yields.

3.4.2 Fertilizer rates

In Bukoba district, the results indicated very strong correlations between soil moisture conserved with respect to fertilizer rates and cassava root yields during the 2018/19 cropping season (multiple R = 0.95) and 2019/20 cropping season (multiple R = 0.84), and about 90% and 71% of the variability in cassava root yield were explained by soil moisture during the 2018/19 and 2019/20 cropping seasons, respectively. In Missenyi district, the results indicated very strong correlations between soil moisture conserved with respect to fertilizer types and rates and cassava root yield during the 2018/19 cropping season (multiple R = 0.84) and 2019/20 cropping season (multiple R = 0.80), and about 71% and 64% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 seasons, respectively. In Biharamulo district, the results indicated very strong correlations between soil moisture conserved with respect to fertilizer types and rates and cassava root yields during the 2018/19 cropping season (multiple R = 0.96) and 2019/20 cropping season (multiple R = 0.87), and about 92% and 76% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 seasons, respectively.

In all districts and both copping seasons, the results indicated significant ($P < .001$) correlations between cassava root yields and soil moisture conserved with respect to fertilizer types and rates, which signified that the changes in soil moisture with respect to fertilizer types and rates were associated with the changes in the cassava root yields. These results are similar to the findings report by Rossato et al [37] that, average cassava yield is directly associated with soil moisture at the depth of the root systems.

3.4.3 Interaction of tillage methods and fertilizer rates

In Bukoba district, the results indicated very strong correlations between moisture conserved with respect to the interaction (tillage methods vs fertilizer rates) and cassava root yields during the 2018/19 cropping season (multiple R = 0.94) and 2019/20 cropping season (multiple R = 0.96), and about 88% and 92% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 cropping seasons, respectively. In Missenyi district, the results indicated very strong correlations between moisture conserved with respect to the interaction (tillage methods vs fertilizer rates) and cassava root yields during the 2018/19 cropping season (multiple R = 0.91) and 2019/20 cropping season (multiple R = 0.90), and about 82% and 81% of the variability in cassava root yields were explained by soil moisture during the 2018/19 and 2019/20 seasons, respectively. In Biharamulo district, the results indicated very strong correlations between moisture conserved with respect to the interaction (tillage methods vs fertilizer rates) and cassava root yields during the 2018/19 cropping season (multiple R = 0.98) and 2019/20 cropping season (multiple R = 0.96), and about 95% and 92% of the variability in cassava root yields were explained by soil moisture in 2018/19 and 2019/20 seasons, respectively. In all districts and both seasons, the results indicated significant (P < .001) correlations between cassava root yields and soil moisture conserved with respect to the interaction between tillage methods and fertilizer types and rates. This signified that the changes in soil moisture conserved with respect to the interactions between tillage methods and fertilizer types and rates were associated with the changes in cassava root yields as observed in the fertilizer treatments (without interaction).

3.5 Soil Moisture Conservation and Cassava Root Yields Across the Study Area

The results of the soil moisture conservation and cassava root yields across the experimental sites during the 2018/19 and 2019/20 cropping seasons are presented in Fig. 5. The results indicated that soil moisture ranged from 20.65 to 40.28% during the 2018/19 cropping season and from 20.28 to 43.90% during the 2019/20 cropping season, whereas cassava root yields ranged from 15.31 to 31.39 MT ha^{-1} during the 2018/19 cropping season and from 13.30 to 33.50 MT ha^{-1} during the 2019/20 cropping season. There was a significant (P < .001) difference in soil moisture conservation and cassava root yields across the sites in both cropping seasons. During the 2018/19 cropping season, Bukoba site conserved significantly (P < .001) higher soil moisture than Biharamulo site and the least was Missenyi site. This was due to the fact that Bukoba site is a high rainfall area, of which during the 2018/19 cropping season, the site received high annual rainfall (2824 mm) and has sandy clay loam to clay soil texture with higher clay content (51.90 to 63.92%) than Biharamulo site, which has sandy clay soil texture with clay content ranging from 40.64 to 50.64% and is a low rainfall area, of during the 2028/29 cropping season, the site received low annual rainfall (1034 mm), whereas Missenyi site, is a medium rainfall area with sandy loam soil texture and low clay content (10.64 to 27.64%) [13]. Other researchers, for example, Brady and Weil [33] reported that the higher the content of clay in the soil, the higher the amount of soil moisture conserved.

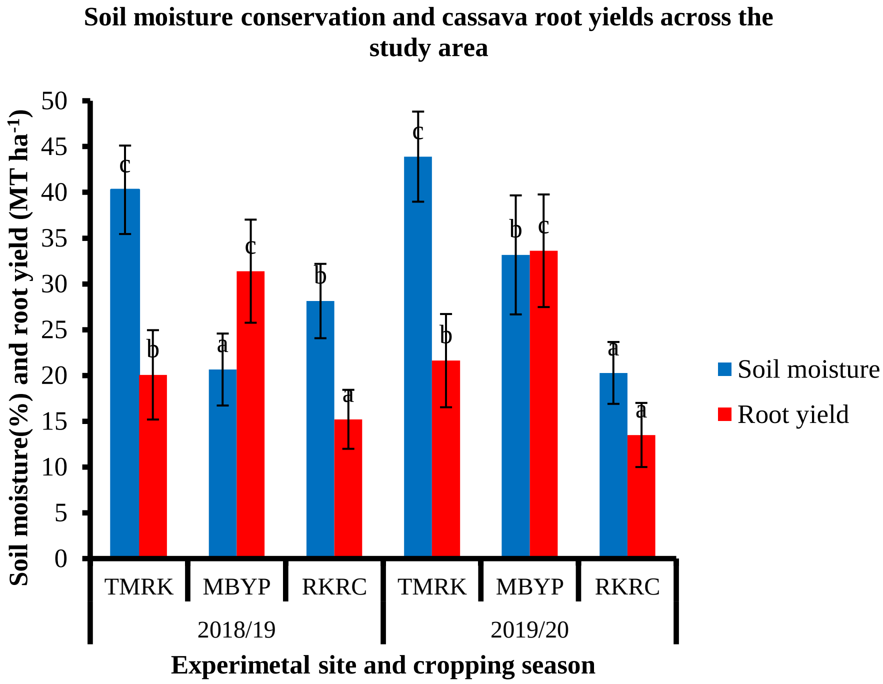

Fig. 5. Average soil moisture conservation and cassava root yields during 2018/19 and 2019/20 cropping seasons in Bukoba, Missenyi and Biharamulo districts

Means within the sites in a cropping season (for a particular parameter) followed by the same letter(s) are not significantly (P < .05) different according to Turkey's HSD Test; experimental site: TMRK = Tanzania Agricultural Research Institute (TARI), Maruku Centre in Bukoba District, MBYP = Mabuye Primary School in Missenyi district, RKRC = Rukaragata Extension Centre in Biharamulo district

Table 3. Farmyard manure and potassium rates effects on soil moisture conservation during the 2018/19 cropping season in Bukoba, Missenyi and Biharamulo districts

Treatment	Location											
	TARI Maruku				Mabuye Primary School				Rukaragata Extension Centre			
	Soil Moisture Content (%)											
	Wk1	Wk3	Wk5	Wk7	Wk1	Wk3	Wk5	Wk7	Wk1	Wk3	Wk5	Wk7
CO	47.43^{a}	32.35^{a}	25.73^{a}	45.43^{a}	21.34^{a}	18.54^{a}	15.35^{a}	23.23^{a}	21.63^{a}	18.83^{a}	13.24^{a}	10.41^{a}
FYM_4	58.33^{b}	43.63^{c}	36.57^{b}	57.53^{b}	35.26^{b}	28.54^{b}	21.18^{bc}	37.26^{b}	28.78^{bc}	25.56^{bc}	20.30^{a}	16.80^{bc}
FYM_8	62.16^{c}	47.66^{d}	39.26^{c}	59.26^{c}	39.32^{e}	30.99^{c}	23.30^{c}	41.32^{d}	32.37^{c}	28.99^{c}	24.48^{c}	19.94^{d}
$K_{40}N_{40}P_{30}$	47.55^{a}	35.35^{ab}	28.78^{a}	53.55^{a}	23.49^{a}	19.51^{a}	15.82^{a}	24.49^{a}	24.31^{a}	21.33^{a}	16.46^{a}	13.36^{a}
$K_{80}N_{40}P_{30}$	47.43^{a}	35.56^{ab}	28.30^{a}	52.43^{a}	22.39^{a}	19.08^{a}	16.02^{a}	24.17^{a}	24.38^{a}	21.13^{a}	15.85^{a}	12.35^{a}
$K_{120}N_{40}P_{30}$	47.60^{a}	37.33^{b}	27.57^{a}	53.60^{a}	23.05^{a}	19.51^{a}	16.00^{a}	25.05^{a}	22.96^{a}	20.05^{a}	15.28^{a}	12.27^{a}
FYM_4K_{40}	59.02^{b}	44.64^{cd}	36.35^{b}	56.33^{b}	37.36^{cd}	28.45^{b}	20.59^{b}	37.46^{bc}	28.29^{b}	25.13^{b}	19.95^{b}	16.54^{b}
FYM_4K_{80}	59.02^{b}	45.01^{cd}	36.85^{b}	57.02^{b}	36.36^{cd}	28.51^{b}	21.58^{bc}	37.36^{bc}	28.50^{bc}	25.39^{b}	20.31^{b}	16.99^{bc}
FYM_4K_{120}	59.20^{b}	45.18^{cd}	38.10^{b}	57.20^{b}	35.53^{bc}	28.92^{bc}	20.57^{b}	37.53^{bc}	29.08^{bc}	25.92^{bc}	20.75^{b}	17.35^{bc}
FYM_8K_{40}	62.21^{c}	47.41^{d}	40.34^{c}	59.21^{c}	39.24^{e}	30.70^{c}	23.27^{c}	41.94^{d}	33.80^{c}	28.53^{c}	24.17^{c}	19.58^{cd}
FYM_8K_{80}	63.48^{c}	47.52^{d}	39.56^{c}	60.48^{c}	39.41^{e}	30.67^{c}	23.29^{c}	42.28^{d}	32.24^{c}	29.06^{c}	23.61^{c}	20.01^{d}
FYM_8K_{120}	63.06^{c}	47.71^{d}	40.10^{c}	59.78^{c}	39.63^{e}	30.81^{c}	23.17^{c}	42.33^{d}	32.20^{c}	28.91^{c}	24.53^{c}	19.91^{d}
SEM	1.06	0.69	0.97	1.06	0.58	0.43	0.51	0.61	0.81	0.72	0.60	0.49
CV (%)	6.60	6.40	12.10	5.70	7.80	7.90	15.70	5.40	8.80	8.80	9.20	10.50

Means within a column (for a particular soil moisture) followed by the same letter(s) are not significantly (P =.05) different according to Turkey's HSD Test;SEM = standard error of the means; CV = coefficient of variation; Wk1 = one week; Wk3 = three weeks; Wk5 = five weeks; Wk7 = seven weeks; 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}

Table 4. Farmyard manure and potassium rates effects on soil moisture conservation during the 2019/20 cropping season in Bukoba, Missenyi and Biharamulo districts

Treatment	Location														
	TARI Maruku					Mabuye Primary School					Rukaragata Extension Centre				
	Soil Moisture Content (%)														
	Wk1	Wk3	Wk5	Wk7	Wk9	Wk1	Wk3	Wk5	Wk7	Wk9	Wk1	Wk3	Wk5	Wk7	Wk9
CO	43.82^{a}	32.35^{a}	28.58^{a}	43.82^{a}	44.28^{a}	21.23^{a}	16.54^{a}	14.02^{a}	28.23^{a}	29.12^{a}	23.61^{a}	19.99^{a}	17.70^{a}	16.58^{a}	15.90^{a}
FYM_4	50.75^{c}	43.63^{cd}	40.48^{b}	48.75^{c}	48.52^{b}	35.26^{b}	26.54^{b}	21.53^{bc}	42.26^{b}	44.71^{bc}	29.58^{b}	25.46^{b}	22.87^{bc}	21.16^{b}	20.14^{b}
FYM_8	54.67^{d}	47.86^{d}	43.76^{c}	48.98^{c}	51.17^{c}	39.32^{d}	28.79^{c}	23.48^{c}	46.32^{d}	47.76^{d}	32.73^{c}	28.63^{c}	26.22^{d}	23.77^{e}	22.22^{bc}
$K_{40}N_{40}P_{30}$	44.30^{ab}	35.35^{ab}	30.07^{a}	43.90^{ab}	44.76^{a}	23.49^{a}	17.65^{a}	14.59^{a}	30.49^{a}	30.94^{a}	25.80^{a}	21.97^{a}	19.56^{a}	17.75^{a}	16.02^{a}
$K_{80}N_{40}P_{30}$	45.00^{ab}	35.56^{ab}	30.19^{a}	44.00^{ab}	44.75^{a}	22.17^{a}	17.08^{a}	14.28^{a}	29.17^{a}	31.42^{a}	25.13^{a}	21.01^{a}	18.43^{a}	17.52^{a}	16.03^{a}
$K_{120}N_{40}P_{30}$	45.74^{ab}	36.33^{ab}	30.79^{a}	44.17^{ab}	45.74^{a}	23.05^{a}	17.51^{a}	14.98^{a}	30.05^{a}	31.35^{a}	24.63^{a}	20.87^{a}	18.50^{a}	17.51^{a}	16.05^{a}
FYM_4K_{40}	50.98^{c}	43.63^{c}	40.01^{b}	48.98^{bc}	50.76^{bc}	37.36^{cd}	26.75^{bc}	20.59^{b}	44.36^{bcd}	45.01^{cd}	29.24^{b}	25.19^{b}	22.63^{b}	21.38^{bc}	20.25^{b}
FYM_4K_{80}	51.13^{c}	45.01^{cd}	41.58^{bc}	49.13^{bc}	50.98^{bc}	36.36^{bc}	26.91^{bc}	20.78^{b}	43.36^{bc}	44.63^{bc}	29.62^{b}	25.63^{b}	23.11^{bc}	21.64^{bcd}	20.57^{b}

Treatment	Location														
	TARI Maruku					Mabuye Primary School					Rukaragata Extension Centre				
	Soil Moisture Content (%)														
	Wk1	Wk3	Wk5	Wk7	Wk9	Wk1	Wk3	Wk5	Wk7	Wk9	Wk1	Wk3	Wk5	Wk7	Wk9
FYM_4K_{120}	51.45^{c}	45.18^{cd}	41.41^{bc}	49.45^{bc}	51.01^{bc}	35.53^{bc}	26.92^{bc}	21.62^{bc}	42.53^{bc}	43.36^{bc}	30.05^{b}	26.00^{b}	23.44^{bc}	22.03^{cd}	20.79^{b}
FYM_8K_{40}	54.67^{d}	47.41^{d}	43.69^{c}	50.67^{c}	52.88^{c}	39.24^{d}	28.70^{c}	23.50^{c}	46.24^{d}	47.65^{d}	32.44^{c}	28.55^{c}	26.11^{d}	24.75^{e}	23.35^{c}
FYM_8K_{80}	54.60^{d}	47.52^{d}	43.91^{c}	50.85^{c}	53.60^{c}	39.31^{d}	28.67^{c}	23.46^{c}	46.31^{d}	47.98^{d}	32.88^{c}	28.69^{c}	26.05^{d}	24.89^{e}	23.68^{c}
FYM_8K_{120}	54.85^{d}	37.71^{d}	44.18^{c}	51.60^{c}	52.86^{c}	39.33^{d}	28.71^{c}	23.57^{c}	46.23^{d}	47.70^{d}	32.80^{c}	28.59^{c}	26.24^{d}	24.76^{e}	23.22^{c}
SEM	0.32	0.34	0.60	0.64	0.64	0.59	0.43	0.55	0.32	0.59	0.58	0.50	0.47	0.47	0.49
CV (%)	4.90	6.40	6.40	4.10	3.90	5.50	5.30	8.30	4.50	4.40	9.30	10.20	11.40	12.90	15.00

Means within a column (for a particular soil moisture) followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test; SEM = standard error of the means; CV = Coefficient of Variation; Wk1 = One Week; Wk3 = Three Weeks; Wk5 = Five Weeks; Wk7 = Seven Weeks; Wk9 = Nine Weeks; 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}

Table 5. Tillage methods and fertilizers interaction effects on soil moisture conservation during 2018/19 season in Bukoba, Missenyi and Biharamulo Districts, Tanzania

Treatment	Location											
	TARI Maruku (Bukoba)				Mabuye Primary School (Missenyi)				Rukaragata Extension Centre (Biharamulo)			
	Soil Moisture Content (%)											
	Wk1	Wk3	Wk5	Wk7	Wk1	Wk3	Wk5	Wk7	Wk1	Wk3	Wk5	Wk7
FTxCO	42.96^{a}	30.88^{a}	22.75^{a}	40.96^{a}	20.56^{a}	17.00^{a}	14.27^{a}	21.23^{a}	20.19^{a}	17.50^{a}	12.07^{a}	10.40^{a}
ORxCO	48.36^{ab}	31.75^{ab}	25.46^{ab}	46.36^{ab}	21.61^{a}	19.21^{a}	15.05^{abc}	23.42^{a}	22.44^{ab}	18.49^{ab}	13.55^{ab}	11.60^{ab}
TRxCO	50.96^{ab}	34.43^{abc}	27.08^{abc}	48.96^{abc}	23.05^{a}	19.40^{a}	15.29^{abcd}	25.05^{a}	22.44^{ab}	18.51^{ab}	13.99^{ab}	11.84^{ab}
$FTxFYM_8K_{40}$	57.85^{cde}	$45.84^{ijklmno}$	35.87^{def}	54.85^{cd}	35.27^{bcd}	27.35^{bcde}	20.95^{fghij}	39.27^{def}	27.22^{cdef}	$24.05^{cdefghij}$	$18.87^{cdefghij}$	$15.45^{cdefghi}$
$ORxFYM_8K_{40}$	61.85^{e}	48.89^{mno}	39.25^{gh}	59.85^{e}	41.53^{fg}	32.51^{fgh}	22.17^{hijkl}	43.53^{fg}	32.64^{defgh}	29.22^{hijkl}	23.63^{ijklm}	19.82^{hijkl}
$TRxFYM_8K_{40}$	61.86^{e}	49.13^{mno}	39.91^{gh}	58.92^{cde}	42.92^{g}	33.77^{h}	25.58^{l}	44.92^{g}	35.38^{gh}	29.31^{hijkl}	24.01^{jklm}	20.45^{jkl}
$FTxFYM_8K_{80}$	57.93^{bcde}	$42.30^{efghijkl}$	36.15^{def}	54.83^{cd}	35.12^{bcd}	27.61^{bcde}	20.94^{efghij}	37.12^{cde}	28.83^{cdefgh}	$25.95^{cdefghijkl}$	$21.22^{fghijklm}$	$18.23^{fghijkl}$
$ORxFYM_8K_{80}$	62.91^{e}	49.53^{no}	39.43^{gh}	60.91^{e}	42.57^{fg}	32.59^{fgh}	24.49^{kl}	40.27^{def}	31.95^{defgh}	28.61^{ghijkl}	23.16^{ijklm}	`19.48^{hijkl}
$TRxFYM_8K_{80}$	63.61^{e}	50.75^{o}	40.09^{gh}	61.61^{e}	42.94^{g}	33.80^{h}	25.93^{l}	44.94^{g}	35.94^{h}	32.33^{l}	26.45^{m}	22.34^{l}
$FTxFYM_8K_{120}$	58.72^{bcde}	$43.28^{ghijklm}$	36.02^{def}	54.72^{cd}	35.01^{bcd}	27.90^{bcde}	22.41^{ijkl}	36.34^{bcd}	28.67^{cdefgh}	$28.10^{fghijkl}$	$20.31^{defghijkl}$	$18.23^{fghijkl}$
$ORx FYM_8K_{120}$	62.78^{e}	50.01^{no}	40.68^{h}	59.50^{e}	42.73^{fg}	33.18^{gh}	24.60^{kl}	42.73^{efg}	31.55^{defgh}	29.55^{ijkl}	23.96^{ijklm}	18.65^{ghijkl}
$TRxFYM_8K_{120}$	63.64^{e}	49.64^{no}	40.64^{h}	61.64^{e}	42.88^{g}	33.15^{gh}	25.67^{l}	44.89^{g}	33.37^{fgh}	30.11^{jkl}	24.78^{klm}	21.20^{kl}
SEM	1.84	1.19	1.68	1.84	1.00	0.74	0.89	1.06	1.41	1.25	1.03	0.85
CV (%)	6.60	6.40	12.10	5.70	7.80	7.90	15.70	5.40	8.80	8.80	9.20	10.50

Means within a column (for a particular soil moisture) followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test
SEM = standard error of the means; CV = Coefficient of Variation; Wk1 = One Week; Wk3 = Three Weeks; Wk5 = Five Weeks; Wk7 = Seven Weeks; Treatment: FTxCO = interaction of flat tillage and the control (no fertilizer application); ORxCO = interaction of open ridging and the control (no fertilizer application); TRxCO = Interaction of tie ridging and the control (no fertilizer application); $FTxFYM_8K_{40}$ = Interaction of Flat Tillage and Farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; $ORxFYM_8K_{40}$ = interaction of open ridging and farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; $TRxFYM_8K_{40}$ = interaction of tie ridging and farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; $FTxFYM_8K_{80}$ = Interaction of Flat tillage and farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; $ORxFYM_8K_{80}$ = interaction of open ridging and farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; $TRxFYM_8K_{80}$ = interaction of tie ridging and farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; $FTxFYM_8K_{120}$ = interaction of flat tillage and farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; $ORxFYM_8K_{120}$ = interaction of open ridging and farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; $TRxFYM_8K_{120}$ = interaction of tie ridging and farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}

Table 6. Tillage methods and fertilizers interaction effects on soil moisture conservation during 2019/20 season in Bukoba, Missenyi and Biharamulo Districts, Tanzania

Treatment	Location														
	TARI Maruku (Bukoba)					Mabuye Primary School (Missenyi)					Rukaragata Extension Centre (Biharamulo)				
	Soil Moisture Content (%)														
	Wk1	**Wk3**	**Wk5**	**Wk7**	**Wk9**	**Wk1**	**Wk3**	**Wk5**	**Wk7**	**Wk9**	**Wk1**	**Wk3**	**Wk5**	**Wk7**	**Wk9**
FTxCO	40.34[a]	30.88[a]	27.12[a]	38.34[a]	40.34[a]	29.23[a]	25.00[a]	23.21[a]	26.23[a]	27.47[a]	23.47[a]	18.97[a]	16.75[a]	15.86[a]	15.00[a]
ORxCO	41.19[ab]	31.75[ab]	28.78[a]	39.19[ab]	41.10[ab]	21.42[a]	27.21[a]	24.44[ab]	28.42[a]	30.82[a]	23.85[ab]	20.21[ab]	17.82[ab]	16.84[a]	15.50[a]
TRxCO	41.93[ab]	32.43[ab]	29.84[ab]	40.00[ab]	42.03[ab]	33.05[a]	27.40[a]	24.85[ab]	30.05[a]	31.52[a]	23.84[ab]	20.80[ab]	18.01[ab]	17.03[ab]	15.53[a]
$FTxFYM_8K_{40}$	50.61[ijklmn]	45.23[klmno]	40.28[fghi]	48.61[hijklm]	50.61[ijklm]	57.55[cde]	36.81[cdef]	31.95[hijk]	44.27[cdef]	45.00[cdef]	28.52[fghijk]	24.10[cdefg]	22.55[defgh]	20.17[cdefgh]	20.02[efgh]
$ORxFYM_8K_{40}$	52.92[klmn]	47.89[mno]	45.30[ijkl]	50.92[klmn]	52.11[jklmn]	47.53[cdef]	37.51[defgh]	32.17[hijk]	44.53[cdef]	45.33[cdef]	32.88[ijklm]	28.51[fghij]	25.78[hijk]	24.52[hij]	23.51[ghij]
$TRxFYM_8K_{40}$	54.48[lmn]	49.13[no]	45.50[ijkl]	52.48[lmn]	53.78[lmn]	52.92[f]	41.77[h]	34.58[jk]	49.92[f]	51.86[f]	33.28[jklm]	29.12[hij]	26.50[jk]	25.66[ij]	24.24[ij]
$FTxFYM_8K_{80}$	48.77[ghijkl]	42.30[hijkl]	37.47[def]	46.77[ghijkl]	49.12[hijkl]	45.12[cd]	35.61[cde]	32.20[hijk]	42.12[cd]	43.43[cd]	30.57[hijklm]	26.83[efghij]	24.46[ghijk]	22.90[fghij]	22.52[fghij]
$ORxFYM_8K_{80}$	56.79[n]	49.53[no]	46.19[kl]	54.79[n]	57.09[n]	48.27[def]	38.59[defgh]	32.24[hijk]	45.27[def]	26.36[bcd]	32.42[ijklm]	28.16[fghij]	25.48[hijk]	24.18[ghij]	22.5[fghij]
$TRxFYM_8K_{80}$	55.25[mn]	50.75[o]	48.06[l]	53.25[mn]	55.96[mn]	51.24[ef]	41.80[h]	36.93[k]	48.24[ef]	49.67[ef]	35.65[m]	31.07[j]	28.20[k]	27.32[j]	25.99[j]
$FTxFYM_8K_{120}$	49.71[hijklm]	43.48[hijklm]	39.07[efgh]	47.71[ghijklm]	50.43[ijklmn]	44.34[cd]	35.90[cde]	31.40[hijk]	41.34[cd]	42.54[cd]	29.67[ghijkl]	25.54[defghi]	23.98[fghij]	21.50[defgh]	20.32[efgh]
$ORxFYM_8K_{120}$	54.24[lmn]	50.01[no]	47.35[kl]	52.24[lmn]	51.76[mn]	48.73[ef]	39.18[efgh]	33.42[ijk]	45.73[def]	46.32[def]	31.72[hijklm]	27.35[efghij]	24.61[hijk]	23.98[ghij]	22.37[fghij]
$TRxFYM_8K_{120}$	54.61[lmn]	49.64[no]	46.11[jkl]	52.61[lmn]	55.12[lmn]	51.00[ef]	40.47[fgh]	34.68[jk]	48.00[ef]	49.87[ef]	34.06[klm]	29.87[ij]	27.24[jk]	25.82[ij]	23.75[hij]
SEM	1.12	1.19	1.04	1.12	1.12	1.02	0.74	0.96	1.07	1.02	1.00	0.87	0.81	0.81	0.84
CV (%)	4.90	6.40	6.40	4.10	3.90	5.50	5.30	8.30	4.50	4.40	9.30	10.20	11.40	12.90	15.00

Means within a column (for a particular soil moisture) followed by the same letter(s) are not significantly (P = .05) different according to Turkey's HSD Test; SEM = standard error of the means; CV = coefficient of variation; Wk1 = one week; Wk3 = three weeks; Wk5 = five weeks; Wk7 = seven weeks; Treatment: FTxCO = interaction of flat tillage and the control (no fertilizer application); ORxCO = interaction of open ridging and the control (no fertilizer application); TRxCO = interaction of tie ridging and the control (no fertilizer application); $FTxFYM_8K_{40}$ = interaction of flat tillage and farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; $ORxFYM_8K_{40}$ = interaction of open ridging and farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; $TRxFYM_8K_{40}$ = interaction of tie ridging and farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}; $FTxFYM_8K_{80}$ = interaction of flat tillage and farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; $ORxFYM_8K_{80}$ = interaction of open ridging and farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; $TRxFYM_8K_{80}$ = interaction of tie ridging and farmyard manure at 8 MT ha^{-1} and potassium at 80 kg K ha^{-1}; $FTxFYM_8K_{120}$ = interaction of flat tillage and farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; $ORxFYM_8K_{120}$ = interaction of open ridging and farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; $TRxFYM_8K_{120}$ = interaction of tie ridging and farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}

Table 7. Regression analyses between soil moisture and cassava root yields with respect to tillage methods, fertilizer rates and their interaction in Bukoba district

2018/19 Cropping Season					**2019/20 Cropping Season**			
Tillage Methods								
Multiple R	0.78				0.97			
R-square	0.61				0.94			
Standard error	1.71				0.39			
	Coefficients	**Std error**	**t-stat**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	-6.19	19.60	-0.32	0.81	0.01	4.83	0.00	0.99
X-variable (Moisture)	0.60	0.49	1.24	0.43	0.44	0.12	3.80	0.16
Farmyard manure and potassium rates								
Multiple R	0.95				0.84			
R-square	0.90				0.71			

2018/19 Cropping Season					**2019/20 Cropping Season**			
Tillage Methods								
Standard error	1.07				1.52			
	Coefficients	**Std error**	**t-stat**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	14.33	3.50	-4.09	0.001	-7.00	5.66	-1.24	0.001
X-variable (Moisture)	0.80	0.09	9.24	0.001	0.62	0.13	4.66	0.001
Interaction of tillage methods and farmyard manure and potassium rates								
Multiple R	0.94				0.96			
R-square	0.88				0.92			
Standard error	1.03				0.80			
	Coefficients	**Std error**	**t-stat**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	-16-35	2.33	-7.02	0.001	-8.90	1.46	-6.10	0.001
X-variable (Moisture)	0.85	0.06	15.10	0.001	0.66	0.03	19.38	0.001

Table 8. Regression analyses between soil moisture and cassava root yields with respect to tillage methods, fertilizer rates and their interaction in Missenyi district

2018/19 SEASON					**2019/20 Season**			
Tillage Methods								
Multiple R	0. 99				0.96			
R-square	0.99				0.91			
Standard error	0.33				0.93			
	Coefficients	**Std error**	**t-statics**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	7.929730	2.48	3.19	0.13	-1.92	10.56	-0.18	0.89
X-variable (Moisture)	1.134982	20.12	9.47	0.07	1.03	0.32	3.24	0.19
Farmyard manure and potassium rates								
Multiple R	0.84				0.80			
R-square	0.71				0.64			
Standard error	2.04				2.87			
	Coefficients	**Std error**	**t-statics**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	20.82	2.65	7.85	0.001	12.32	5.33	2.31	0.001
X-variable (Moisture)	0.56	0.12	4.70	0.001	0.62	0.16	4.40	0.001
Interaction of tillage methods and farmyard manure and potassium rates								
Multiple R	0.91				0.90			
R-square	0.82				0.80			
Standard error	1.86				2.30			
	Coefficients	**Std error**	**t-statics**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	17.09	1.36	12.59	0.001	6.53	2.41	2.71	0.001
X-variable (Moisture)	0.74	0.06	12.03	0.001	0.79	0.07	11.33	0.001

Table 9. Regression analyses between soil moisture and cassava root yields with respect to tillage methods, fertilizer rates and their interaction in Biharamulo district

2018/19 Cropping Season					**2019/20 Cropping Season**			
Tillage methods								
Multiple R	0.75				0.99			
R-square	0.56				0.99			
Standard error	0.19				0.25			
	Coefficients	**Std error**	**t-stat**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	8.40	1.62	5.18	0.12	0.18	1.55	0.12	0.93
X-variable (Moisture)	0.08	0.08	1.12	0.47	1.09	0.13	8.70	0.07
Farmyard manure and potassium rates								
Multiple R	0.96				0.87			
R-square	0.92				0.76			
Standard error	0.40				1.21			
	Coefficients	**Std error**	**t-stat**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	0.99	0.95	1.05	0.001	4.17	1.86	2.25	0.01
X-variable (Moisture)	0.45	0.04	10.48	0.001	0.77	0.14	5.35	0.001
Interaction of tillage methods and farmyard manure and potassium rates								
Multiple R	0.98				0.96			
R-square	0.95				0.92			
Standard error	0.38				1.21			
	Coefficients	**Std error**	**t-stat**	**P-value**	**Coefficients**	**Std error**	**t-stat**	**P-value**
Constant	-0.27	0.45	0.60	0.01	3.82	0.57	6.67	0.001
X-variable (Moisture)	0.50	0.02	25.06	0.001	0.81	0.044	18.44	0.001

However, during the 2019/20 cropping season, Bukoba site conserved high soil moisture followed by Missenyi site and the least was Biharamulo site, contrary to the trend recorded during the 2018/19 cropping season. This may be due to the reason that during the 2019/20 cropping season, Biharamulo site experienced a long dry spell of four months (Fig. 4), which might had affected the content of water in the soil, caused by increased evaporation and evapotranspiration. The results also indicated that in both cropping seasons, Missenyi site gave significant high cassava root yields followed by Bukoba site and the least root yield was recorded in Biharamulo site. This may be due to the differences in annual rainfalls and soil conditions among the sites. Bukoba is a high rainfall zone while Missenyi is a medium rainfall zone and Biharamulo is a low rainfall zone. The high rainfall in Bukoba site might had caused leaching of plant nutrients from root zones [30], which affected plant uptake as compared to Missenyi site, which is a medium rainfall area. In addition, the soil texture of Missenyi site is sandy loam [16], which might had favoured water infiltration, good drainage, and root proliferation [33] hence, increased cassava root yield. The low cassava root yield in Biharamulo site was attributed to the low rainfall accompanied by dry spells, just 1 - 2 months after planting for about 2 - 4 months consecutively (Fig. 4), which affected the growth and development of cassava plants. Other researchers [6,10], reported that cassava requires significant water supply during root and shoot initiation mostly, at 1 - 5 months after planting, and water deficit during this period, severely affects growth, root development, and lowering root yield [10]. In addition, presence of high soil penetration resistant, ranging from 3.4 - 3.5 MPa between 20 - 90 cm depth [16], might had caused poor cassava root growth, hence affected the performance of cassava. Other researchers, for example, Kebeney et al [38] and Hazelton and Murphy [39] reported that soil penetration resistance of > 3.0 MPa signifies compaction that can impair growth and development of crops [40].

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

From this study, results indicated that the use of ridges conserved more soil moisture than flat tillage in each experimental site. However, the use of tie ridges conserved more soil moisture than open ridges in areas with medium and high rainfall as opposed to the areas with low rainfall as recorded in in Biharamulo site, which is a low rainfall area. The results also indicated that soil texture is an important factor for management of soil moisture. This is supported by the observed fast decrease in soil moisture just at 1 week after the last rain event in Missenyi site, which has sandy loam soil texture as compared to Bukoba and Biharamulo sites, which have sandy clay loam and sandy clay, respectively.

The use of FYM lone at 8 MT ha^{-1} or the combined use of FYM at 8 MT ha^{-1} and inorganic K fertilizer at 40, 80 or 120 kg ha^{-1} increases soil moistures as opposed to the use of inorganic fertilizers alone ($N_{40}P_{30}$ and K at 40, 80 or 120 kg ha^{-1}). Moreover, the use of FYM alone at 8 MT ha^{-1} or, presumably higher, conserved more soil moisture than the use of FYM alone at 4 MT ha^{-1} or presumably lower.

The use of FYM alone at 8 MT ha^{-1}, interaction of tillage methods and FYM at 8 MT ha^{-1} or interaction of tillage methods and the combined use of FYM at 8 MT ha^{-1} with K at 40, 80 or 120 kg ha^{-1} conserved high soil moisture, which was associated with the changes in cassava root yields in all sites. These results imply that, the changes in soil moisture are associated with the changes in cassava root yields. However, apart from the soil moisture, there are other factors such plant nutrients which are associated with the changes in cassava root yields.

Moreover, the results indicated that high cassava root yields were recorded from the Missenyi site, which is a medium rainfall area and has sandy loam soil texture followed by Bukoba site, which is high rainfall area and has sandy clay loam soil texture whereas, the low cassava root yields were recorded from the Biharamulo site, which is a low rainfall area and has sandy clay soil texture. Therefore, based on rainfall regimes and soil types of Kagera region, and the results from this study, it shows that cassava can perform better in areas experiencing medium annual rainfall, with sandy loam soil texture as compared to the areas experiencing high and low annual rainfalls, with sandy clay loam and sandy clay soil textures, respectively.

4.2 Recommendations

This study has revealed that for conserving adequate soil moisture and increasing cassava root yields, it is recommended to plant cassava on ridges concurrently with the application of farmyard manure at 8 MT ha^{-1}. Therefore, the use of farmyard manure at 8 MT ha^{-1} or presumably higher, is desirable for improving soil moisture which, from this study has shown a positive correlation (association) with the increased (changes) cassava root yields.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative artificial intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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