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Effect of Tillage Methods, Farmyard Manure and Potassium Rates on Some Soil Chemical Properties and Nutrient Contents in Cassava in Kagera, Tanzania

Mgeta Steven Merumba [a*], Johnson Mashambo Semoka [b], Ernest Semu [b], Balthazar Michael Msanya [b] and Jojianas Kokulamka Kibura [a]

[a] *Tanzania Agricultural Research Institute (TARI), Maruku Research Centre, P.O. Box 127, Bukoba, Tanzania.*
[b] *Department of Soil and Geological Sciences, P.O. Box 3008, Sokoine University of Agriculture, Morogoro, Tanzania.*

Authors' contributions

This work was carried out in collaboration among all authors. Author MSM designed the study, 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 JKK managed the experimental field trials and collected data. Moreover, authors MSM, JMS, ES, BMM and JKK read and approved the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted in Bukoba, Missenyi and Biharamulo districts, Tanzania for the objective of determining the effect of tillage methods, farmyard manure (FYM) and potassium rates on soil pH and the concentrations of N, P and K in the soils and cassava leaves. The treatments were

**Corresponding author: E-mail: smerumbason@gmail.com;*

arranged in the Randomized Complete Block Design (RCBD) using the split-plot design with three replications. Tillage methods (flat tillage, open ridging and tied ridging), were the main plots, and the fertilizer rates [farmyard manure (FYM) alone at 4 MT ha^{-1} alone 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 alone at 4 MT ha^{-1} or FYM alone 8 MT ha^{-1} + potassium at 40, 80 or 120 kg K ha^{-1}] and the control, were the sub-plots. The inherent and post-harvest composite soil samples for determining soil pH and the concentration of N, P and K in each site were collected, processed and analysed. Post-harvest soil samples and cassava leaf samples were collected from the control plots and plots that received the combination of FYM at 8 MT ha^{-1} and potassium at 40 or 120 kg K ha^{-1} during the second cropping season. The leaf samples were oven dried at 70^oC, grounded to pass through 0.5 mm sieve and analyzed. The results indicate that there was no a significant (P = .05) difference in the soil pH and the concentrations of N, P and K in the soils and cassava leaves among the tillage methods. There was a significant ($P < .001$) difference in the soil pH and the concentrations of N, P and K in the soils and cassava leaves between the control and the combined use of FYM and potassium rates. However, there was no a significant (P =.05) difference in the concentrations of N, P and K in the soils among the combined use of FYM and potassium rates, but there was a significant ($P < .001$) difference in the concentrations of N and K in cassava leaves among the combined use of FYM and potassium rates. The combined use of FYM at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}, and the combined use of FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} significantly ($P < .01$) increased the soil pH and the concentration of N and K in the soil. However, the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} gave significantly ($P < .001$) higher concentrations of N and K in cassava leaves than the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}. Therefore, combined use of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} is desirable for increasing the concentration of N and K in the soil and in cassava leaves. However, for the resource-poor farmers who cannot afford the high rate of K, the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1} could be used.

Keywords: Farmyard manure; flat tillage; open ridging; tied ridging; potassium fertilizer; soil pH; nutrients concentration; cassava leaves.

ABBREVIATIONS

AGRA	*: Alliance for Green Revolution in Africa*
ANOVA	*: Analysis of variance*
CEC	*: Cation exchange capacity*
CV	*: Coefficient of variation*
^oC	*: Degree Celsius*
DAP	*: Di-ammonium phosphate*
et al.	*: And others*
FYM	*: Farmyard manure*
GENSTAT	*: General statistics*
g	*: Gram*
GPS	*: Global positioning system*
HNO_3	*: Nitric acid*
H_2O_2	*: Hydrogen peroxide*
HSD	*: Honestly Significant Difference*
kg ha^{-1}	*: Kilogram per hectare*
masl	*: Meter above sea level*
m	*: Meter*
mm	*: Millimeter*
MOP	*: Muriate of potash*
MT ha^{-1}	*: Metric tonne per hectare*
OM	*: Organic matter*
N, P, K, Mg, S	*: Nitrogen, phosphorus potassium, magnesium, sulphur*
%	*: Percent*
pH	*: Negative logarithm of hydrogen ion (H^+) concentration*

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	*: Ultra-violent visible spectrophotometer*

1. INTRODUCTION

"The combined use of organic and inorganic fertilizers plays an important role in the improvement of soil physico-chemical properties [1] such as water holding capacity, soil structure, cation exchange capacity (CEC), and lowering bulk density [2], which results in the availability of macro and micro nutrients to plants" [3]. "The soil properties such as pH, organic matter (OM) contents and available forms of macro-nutrients like nitrogen (N) phosphorus (P) and potassium (K) are significantly affected by long-term use of mineral fertilizers and organic manures" [4]. For example, [5] reported "significantly increase in N, P and K concentrations in the soil due to the combined use of organic and inorganic fertilizers". "Incorporation of manures in the soil has beneficial effects on soil health by improving physico-chemical properties and supplying nutrients like nitrogen (N), phosphorus (P), and potassium (K)" [6]. "However, neither use of organic manure nor chemical fertilizers alone can achieve sustainable crop yields under different cropping system where the nutrient depletion and turnover in soil-plant system is high. Although the use of chemical fertilizers improves crop productivity, continuous use of chemical fertilizers alone is associated with decline in some soil properties and crop yields over time [7] due to high solubilization, fast release of nutrients in the soil, and nutrients loss through leaching". "For this reason, therefore, an integrated use of inorganic fertilizers and organic manures is a sustainable approach for efficient nutrient usage, which enhances efficiency of the chemical fertilizers while reducing nutrient losses" [8].

Nutrient uptake by the crops depends on both the ability of the roots to absorb nutrients and nutrients concentration at the surface of the roots. As the plant grow, roots spread out laterally and vertically by taking advantage of areas within the soil that have more water and nutrients depending on the stage of plant growth [9]. Combined use of organic and inorganic fertilizers increases nutrient uptake by the crops. For example, [10] reported increased N uptake by maize crop when compost was mixed with mineral N fertilizer as compared to compost or N mineral fertilizer alone due to improving soil physico-chemical properties and mineralization of the compost. However, in dry soil, nutrient uptake by the plants become low and nutrient levels in plant tissues may be lower than normal [11].

Tillage practices influence soil temperature, moisture and aeration, which eventually affect nutrient uptake by plants [12]. Fertilizer placement also influences nutrient availability and depending upon soil and climate conditions, either enhances or reduces nutrient uptake [9]. Therefore, this study aimed at determining the effects of tillage methods, farmyard and potassium rates, on soil pH and concentrations of N, P and K in the soil and cassava leaves following two consecutive years of planting cassava on tied ridges, open ridges and flat tillage, and the use of different rates of farmyard manure and potassium fertilizers in Bukoba, Missenyi and Biharamulo districts in the Kagera region, Tanzania.

2. MATERIALS 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. 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 [13,14]. 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 altitude 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) [13,14]. Based on rainfall, three agro-ecological zones namely high, medium and low rainfall zones are found in Kagera region [15,16,14], 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 [15,17]. 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 [15,18], scientifically the soils of the study area are named as Haplic Ferralic Acrisols for the Bukoba soil, Fluvic Gleyic Phaeozems for the Missenyi soil and Chromic Ferralic Acrisols for the Biharamulo soil [14]. according to WRB for Soil Resources [19] or Typic Kandiudults for the Bukoba and Biharamulo soils and Typic Endoaquolls for the Missenyi soil [14] according to USDA Soil Taxonomy [20] 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 [18].

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 locations of the experimental trial sites are presented in Fig. 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. Plot size was 6 m x 5 m and the separations between plots and blocks were 1.5 m and 2 m apart, respectively. The treatments were arranged in the split-plot using the Randomized Complete Block Design (RCBD) with three replications; with tillage methods (flat tillage, open ridging and tied ridging) as the main plots and fertilizer rates [FYM at 4 metric tonnes (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}]and the control as the subplots (Table 1). The combinations of N at 40 kg N ha^{-1} + P at 30 kg P ha^{-1} [21] + potassium at 40, 80, or 120 kg K ha^{-1}; were applied as inorganic fertilizer treatments; and FYM at 4 MT ha^{-1} and at 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. The applied farmyard manure in each experimental site was collected from one farmer.

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. The second split of inorganic fertilizer was applied at three months after planting by banding the fertilizers round each cassava plant. Improved cassava variety (*Mkumba*), was the test variety, which was planted at a spacing of 1 m x 1 m in each treatment. The experimental plots were maintained free from weeds, throughout the growing period, and repeated in the following season while maintaining the same plots [22].

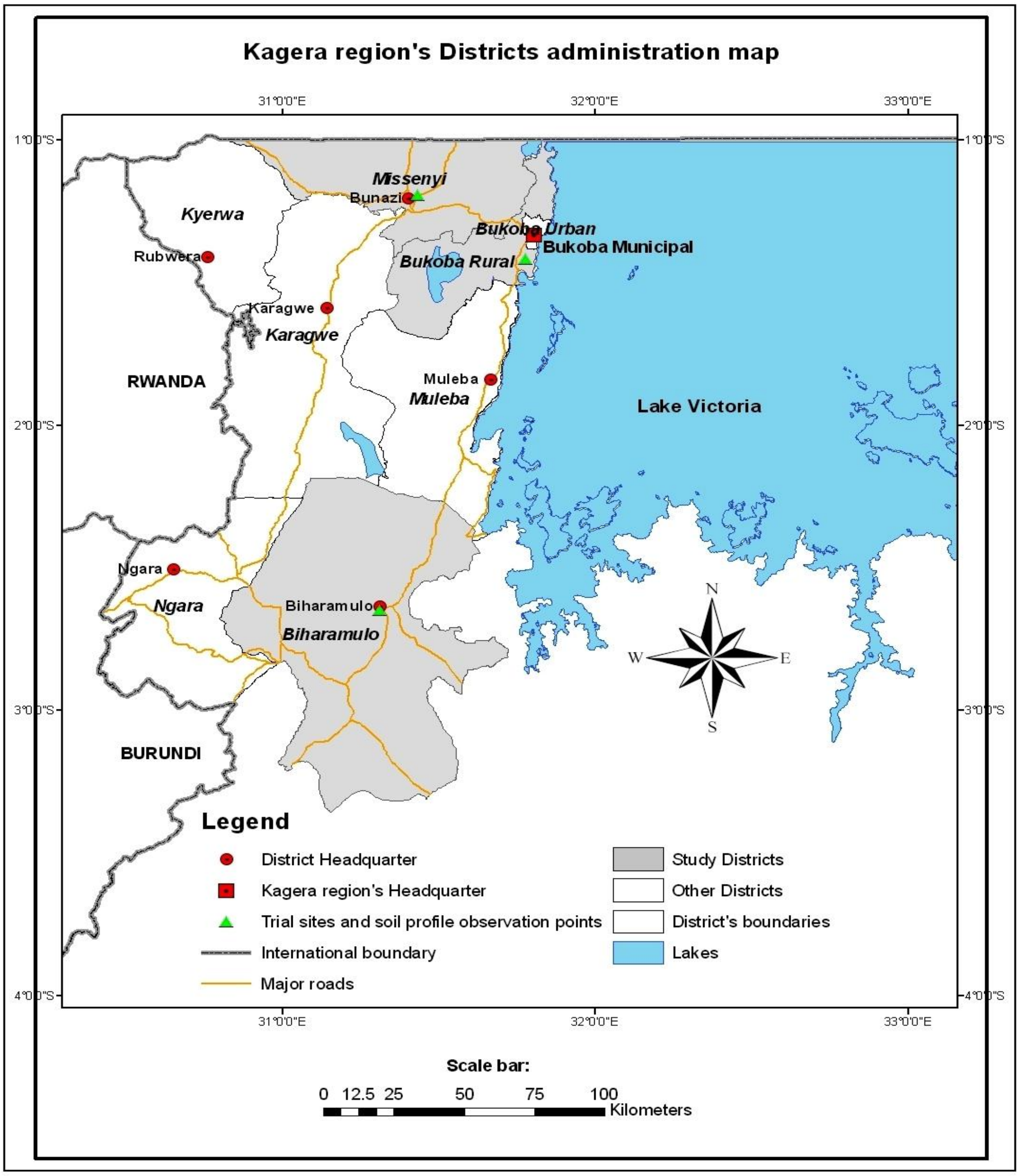

Fig. 1. Location of experimental trial sites in Bukoba, Missenyi and Biharamulo districts
Source: [14]

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

The soil samples for determining soil pH and the concentrations of N, P and K, in the inherent soils were collected before trial establishment during the first season. The post-harvest soil samples for determining the effect of applied treatments on the soil pH and the concentrations of N, P and K in the soils after two-consecutive years of treatments application were collected during the second season. The soil samples were randomly collected at 0-20 cm depth using a zig-zag pattern over the whole field area using a soil auger from at least 20 spots, mixed thoroughly to get one composite soil from each experimental site, air-dried, grounded, sieved through 2 mm sieve, packed, and labelled for laboratory analysis. The soil pH and the concentrations of N, P and K for the inherent soils in each site are presented in Table 2. In addition, the post-harvest composite soil samples from the control plots and the plots that received the combination of FYM at 8 MT ha^{-1} and potassium at 40 and 120 kg K ha^{-1} in each site were collected from each replication using the soil auger by taking the soil at 0-20 cm depth from the planting rows or ridges within the plots of each tillage method, mixed thoroughly to get one composite soil sample, air-dried, grounded, sieved through 2 mm sieve, packed, and labelled for laboratory analysis for soil pH, N, P and K.

Cassava leaf samples were collected at 4 months after planting during the second cropping season to determine the contents of N, P and K in the cassava leaves. At least 20 standard leaves (the fourth young fully-expanded leaves from the top-blades) were collected from the control, the combined use of high rate of FYM (8 MT ha^{-1}) and low rate of K (40 kg K ha^{-1}), and the combined use of high rate of FYM (8 MT ha^{-1}) and high rate of K (120 kg K ha^{-1}) from each replication in each site. The collected leaf samples were oven dried at 70 ^oC, grounded so fine that they can pass through 0.5 mm sieve using Tecator Cyclotec 1093 Sample Mill, packed in paper bags, and well labelled for N, P and K analysis.

It should be noted that the decision to collect and analyze the leaf samples and post-harvest soil samples from the control, the combination of FYM at 8 MT ha^{-1} + K at 40 kg K ha^{-1} and the combination FYM at 8 MT ha^{-1} + K at 120 kg K ha^{-1}, for soil pH, N, P and K was made due to financial constraint, which limited the analysis of the leaf and soil samples from all applied treatments, in all study sites. Thus, the analyzed soil and leaf samples helped to understand the status of the soil pH, and the concentrations of N, P and K in the soils and plant leaves at high rate of FYM, and at low and high rates of K after two-consecutive years of treatments application. This then, enabled to understand the effects of applied treatments on the soil pH and the concentration of N, P and K in the soil and cassava leaves.

In addition, the farmyard manure applied in each site was collected from farmers, processed, packed in paper bags, well labelled and analyzed for N, P and K. The contents of N, P and K in the applied farmyard manure and the amount of N, P and K added added annually in the soils in each cropping season due to farmyard manure application in each experimental site are presented in Table 3.

2.5 Data Analysis

2.5.1 Analysis of soil samples

Laboratory analysis for soil pH and concentrations of N, P and K in the soils was done at Sokoine University of Agriculture (SUA) Soil Science Laboratory following standard soil analysis procedures as described by [24] and [25].

2.5.2 Analysis of leaf samples

Leaf samples sieved through 0.5 mm (20 mesh) sieve were digested using wet digestion method, whereby, leaf samples for extraction of P and K were digested using the nitric acid-hydrogen peroxide (HNO_3 - H_2O_2) wet digestion procedure. The solutions (digests) for determining P were prepared following colour development by the molybdenum blue method [24,25] and the contents of P in the digests (leaf samples) were determined using an ultraviolet-visible (UV/VIS) spectrophotometer [26] Concurrently, the solutions (digests) for determining K were prepared and the contents of K in the digests were determined using flame emission spectrometer. The contents of N in the leaf samples were determined using the macro-Kjeldahl digestion method [27,28]. The contents of N, P and K in cassava plant leaves obtained after laboratory analyses were compared by the required standard levels of those nutrients in cassava leaves based on the ratings by [29].

2.6 Statistical Data Analysis

Data from leaf and soil samples were subjected to analysis of variance (ANOVA) based on the statistical model for the split-plot design [30] (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.

Table 2. Soil pH and N, P and K concentrations in the experimental soils before treatments application in Bukoba, Missenyi and Biharamulo districts

District	Experimental site	Soil pH_w (1:2.5)	TN (%)	Bray – 1 P (mg kg^{-1})	Exch. K (cmol(+) kg^{-1})
Bukoba	TARI- Maruku	5.1	0.41	1.38	0.15
Missenyi	Mabuye Primary School	6.0	0.13	35.32	0.51
Biharamulo	Rukaragata Extension Centre	5.3	0.18	4.96	0.16

Source: [18]

Chemical property: TN = total nitrogen, Bray-1 P = extractable Bray-1 phosphorus, K = exchangeable potassium; Ratings in the table: Soil pH; 5.1-5.3 = strong acid, 6.0 = moderate acid; TN: 0.13-0.18 = low; 0.41 = medium; Bray-1-P: 1.38-4.96 = low, 35.32 = high; Exchangeable K: 0,15-0.16 = low, 0.51 = medium [23]

Table 3. 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

Source: [22]

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

i = 1, 2, 3……, r
j = 1, 2, 3……, a
k = 1, 2, 3…..., 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 Effect of Applied Treatments on Soil Chemical Properties

3.1.1 Effect of tillage methods on soil pH and concentration of nitrogen (N), phosphorus (P) and potassium (K) in the soils in Bukoba, Missenyi and Biharamulo districts

The results on the effects of flat tillage, open ridging and tied ridging on soil pH and the concentration of N, P and K in the post-harvest soil in Bukoba, Missenyi and Biharamulo districts are presented in Table 4. The pH of the soils were strongly acid (Bukoba district), slightly acid (Missenyi district) and very strongly acid (Biharamulo district). The concentration of N in the soils were medium (Bukoba district) and low (Missenyi and Biharamulo districts). Extractable P in the soils were low (Bukoba and Biharamulo districts) and high (Missenyi district). Exchangeable K in the soils ranged from low to medium (Bukoba district), were medium (Missenyi district) and low (Biharamulo district) [23,31,32].

In all the study sites, there was no significant (P =.05) difference in the recorded soil chemical properties among the tested tillage methods, which signified that the use of flat tillage, open ridging or tied ridging had no effects on the soil pH and the concentration of N, P and K in the soils.

3.1.2 Effect of combined use of farmyard manure and potassium fertilizers on soil pH and concentration of N, P and K in the post-harvest soil in Bukoba, Missenyi and Biharamulo districts

The results on the effects of combined use of FYM at 8 MT ha^{-1} and potassium at 40 kg K ha-1 or FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} on soil pH and concentration of N, P and K in the post-harvest soils in Bukoba, Missenyi and Biharamulo districts are presented in Table 5. Soil pH was strongly acid (Bukoba district), slightly acid (Missenyi district) and ranged from very strongly acid to strongly acid (Biharamulo district). Total nitrogen ranged from low to medium (Bukoba district), from very low to low (Missenyi district) and from very low to low (Biharamulo district). Extractable P in the post-harvest soil was low (Bukoba district), ranged from medium to high (Missenyi district) and was low (Biharamulo district). Exchangeable K in the post-harvest soil ranged from low to medium (Bukoba district), from low to high (Missenyi district) and from low to medium (Biharamulo district) [23, 31,32].

In all study sites, there was a significant (P <.001) difference in the recorded soil chemical properties between the control and fertilizer treatments, signifying that combined use of FYM at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1} or FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} had significant effects on the soil pH and on the concentration of N, P and K in the soils. However, there was no a significant (P = .05) difference in the recorded soil chemical properties between combined use of FYM at 8 MT ha^{-1} + potassium at 120 kg K ha^{-1} and FYM at 8 MT ha^{-1} + potassium at 40 kg K ha^{-1}. The low values of soil chemical properties were recorded in the control while the high values were recorded in the combined use of FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}. When comparing the status of the recorded chemical properties in the soil before treatments application (Table 1) and after treatments application (Table 5), the results indicate a slight increase or decrease in the respective soil chemical properties (Table 6).

The results also indicate that in Bukoba district, the control treatment did not cause any change in soil pH while the combined use of FYM at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1} , and the combined use of FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} increased soil pH by 7.27%. In Missenyi and Biharamulo districts, the control treatment decreased soil pH by 3.45% and 10.42%, respectively, whereas, the combined use of FYM at 8 MT ha^{-1} + potassium at 40 kg K ha^{-1} and the combined use of FYM at 8 MT ha^{-1} + potassium at 120 kg K ha^{-1} increased soil pH

Table 4. Soil pH and concentration of N, P and K in the soil with respect to different tillage methods in Bukoba, Missenyi and Biharamulo districts

Treatment	Location											
	1	2	3	1	2	3	1	2	3	1	2	3
	Soil pH_w (1:2.5)			Total N (%)			Bray-1 P ($mg\ kg^{-1}$)			Exchangeable K ($cmol(+)\ kg^{-1}$)		
Flat tillage	5.3[a]	6.1[a]	5.0[a]	0.34[a]	0.10[a]	0.11[a]	1.08[a]	26.56[a]	0.98[a]	0.21[a]	0.40[a]	0.20[a]
Open ridging	5.4[a]	6.2[a]	5.0[a]	0.36[a]	0.10[a]	0.12[a]	1.17[a]	28.43[a]	1.40[a]	0.33[a]	0.55[a]	0.21[a]
Tied ridging	5.4[a]	6.2[a]	5.0[a]	0.37[a]	0.10[a]	0.12[a]	1.19[a]	33.11[a]	1.25[a]	0.34[a]	0.58[a]	0.23[a]
SED	0.08	0.05	0.06	0.02	0.01	0.00	0.11	2.57	0.26	0.04	0.08	0.02
CV (%)	4.50	2.70	3.50	13.60	34.10	12.60	28.70	26.20	30.60	31.10	32.90	28.20

Means within a column (for a particular nutrient) 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; Chemical property: TN = total nitrogen, Bray-1 P = extractable Bray-1 phosphorus, K = exchangeable potassium; Ratings in the table: Soil pH: 5.3-5.4 = strongly acid, 6.1-6.2 slightly acid, 5.0 = very strongly acid; TN: 0.34-0.37 = medium, 0.10-0.12 = low; Bray-1-P: 0.98-1.40 = low, 26.56-33,11 = high; Exchangeable K: 0.20-0.23 = low, 0.40-0.58 = medium [23 21,32]

by 4.76% and 1.85%, respectively. These results conform to the findings by [12] who reported significant increase in soil pH due to combined use of farmyard manure and inorganic N and P fertilizers as compared to the control, inorganic N fertilize alone or inorganic P fertilizer alone. The decrease in soil pH in the control (no fertilizer application) was probably attributed to mineralization of inherent soil organic matter, which releases hydrogen ions in the soil [33]. The increase in soil pH upon use of FYM and potassium fertilizers was attributed to ability of farmyard manure to absorb or bid hydrogen ions in its humic forms [12,34]. Other reason was continued addition of potassium (one of basic cations) from both FYM and muriate of potash (MOP) fertilizer.

In all study sites, there was a decrease in total nitrogen (TN), extractable P and exchangeable K in the control treatment caused by the plant uptake and other soil losses such as leaching, since there was no addition of any fertilizer in the control treatment. However, there was an increase in TN in the fertilizer treatments, with respect to the combined use of FYM at 8 MT ha^{-1} + potassium at 40 kg K ha^{-1} or the combined use of FYM at 8 MT ha^{-1} + potassium at 120 kg K ha^{-1}. This was attributed to the addition of nitrogen in the soil from FYM as compared to the control. Comparable results were reported by [35] and [36] and conform to the findings by [1], [37] and [38] who reported significantly increase in total N due to combined use of farmyard manure and. inorganic N and P or N, P and K fertilizers. The results also indicate that higher values of N were recorded in Bukoba site than in Missenyi and Biharamulo sites. This was because, N was not a limiting nutrient in Bukoba site but was a limiting nutrient in Missenyi and Biharamulo sites [18], as a result; cassava plants took up most of the added nitrogen in the soil from the applied FYM in Missenyi and Biharamulo sites. This was supported by the low levels of N recorded in the post-harvest soils in Missenyi and Biharamulo sites as compared to medium level of N recorded in the post-harvest soil in Bukoba site (Table 5) according to the ratings by [31] and [32].

In Missenyi site, the results indicate an increase in extractable P in the fertilizer treatments while in Bukoba and Biharamulo sites there was a decrease in extractable P in the fertilizer treatments. This was because, P was not a limiting nutrient in Missenyi site but was a limiting nutrient in both Bukoba and Biharamulo sites [18], whereas, the added P from FYM in the soils in Bukoba and Biharamulo sites, were taken up by the cassava plants for growth and development. Thus, the increase in extractable P in Missenyi sites, was attributed to continued addition of P in the soil from FYM due to the combined use of FYM at 8 MT ha^{-1} + potassium at 40 kg K ha^{-1} and the combined use of FYM at 8 MT ha^{-1} + potassium at 120 kg K ha^{-1} as also reported by [1]. Other researchers [39,40], reported significant increase in available P in the soil due to the combined use of FYM and inorganic

Table 5. Soil pH and concentration of N, P and K in the soil with respect to combined use of farmyard manure and potassium rates in Bukoba, Missenyi and Biharamulo districts

Treatment	Location											
	1	2	3	1	2	3	1	2	3	1	2	3
	Soil pH_w (1:2.5)			Total N (%)			Bray-1 P ($mg\ kg^{-1}$)			Exchangeable K ($cmol(+)\ kg^{-1}$)		
Co	5.1^{a}	5.8^{a}	4.8^{a}	0.20^{a}	0.08^{a}	0.09^{a}	0.77^{a}	13.28^{a}	0.90^{a}	0.13^{a}	0.24^{a}	0.11^{a}
$FYM_8 + K_{40}$	5.5^{b}	6.3^{b}	5.4^{b}	0.49^{b}	0.14^{b}	0.20^{b}	1.30^{b}	37.54^{b}	2.14^{b}	0.31^{b}	0.83^{b}	0.31^{b}
$FYM_8 + K_{120}$	5.5^{b}	6.3^{b}	5.4^{b}	0.49^{b}	0.14^{b}	0.20^{b}	1.30^{b}	37.53^{b}	2.14^{b}	0.34^{b}	0.87^{b}	0.33^{b}
SED		0.06	0.06	0.02	0.01	0.00	0.12	2.27	0.26	0.04	0.08	0.02
CV (%)	4.50	2.70	3.50	13.60	34.10	12.60	28.70	26.20	30.60	31.10	32.90	28.20

Means within a column (for a particular nutrient) 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_8K_{40} = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_8K_{120} = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; Chemical property: TN = total nitrogen, Bray-1 P = extractable Bray-1 phosphorus, K = exchangeable potassium; Ratings in the table: Soil pH: 5.1-5.5 = strongly acid, 6.3 slightly acid, 4.8 = very strongly acid; TN: 0.08-0.09 = very low, 0.14-0.20 = low, 0.49 = medium; Bray-1-P: 0.77-2.14 = low, 13.28 = medium, 37.53-.37.54 = high; Exchangeable K: 0.11-0.24 = low, 0.31-0.34 = medium, 0.83-0.87 = medium [23, 31,32]

Table 6. Percentage change in soil pH and the contents of N, P and K in the soil with respect to combined use farmyard manure and potassium rates in Bukoba, Missenyi and Biharamulo districts

Treatment	Location											
	1	2	3	1	2	3	1	2	3	1	2	3
	Soil pH_w (%)			Total N (%)			Bray-1 P (%)			Exchangeable K (%)		
Co	0.0	-3.45	-10.42	-105.0	-62.50	-100.0	-79.22	-165.96	-451.11	-15.38	-112.38	-45.45
$FYM_8 + K_{40}$	7.27	4.76	1.85	16.33	13.33	10.0	-6.15	5.91	-131.78	51.61	38.55	48.39
$FYM_8 + K_{120}$	7.27	4.76	1.85	16.33	13.33	10.0	-6.15	5.89	-131.78	55.88	41.38	51.52

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_8K_{40} = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_8K_{120} = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; Chemical property: TN = total nitrogen, Bray-1 P = extractable Bray-1 phosphorus, K = exchangeable potassium

N, FYM and P and K fertilizers or FYM and inorganic N and P fertilizers. Although the amount of P added from FYM was low in all sites (Table 3), there was high amount of inherent soil P in Missenyi site (Table 2), which was taken up by cassava plants while the unused part remained in the soil. This was supported by the high levels of extractable P recorded in the post-harvest soils in the fertilizer treatments in Missenyi site as compared to the low levels and the decreased extractable P in the post-harvest soils in the fertilizer treatments recorded in Bukoba and Biharamulo sites.

Moreover, the results indicate an increase in exchangeable K in the fertilizer treatments in all study sites, due to continued addition of K into the soil from both FYM and potassium fertilizer. Other researchers [41], reported significant increase in exchangeable K in the soil upon the combined use of farmyard manure and inorganic N, P and K fertilizers due to mineralization of FYM and solubilization of inorganic N, P and K fertilizers. It should be noted that farmyard manure used in this study had high content of K and thus the amount of K added in the soils was also high as compared to N and P. The results also indicate that there were medium levels of exchangeable K in the post-harvest soils in Bukoba and Biharamulo sites, and high level of exchangeable K in the post-harvest soil in Missenyi site, which signified that not all the amount of K added in the soils was taken up by cassava plants, instead, the unused portion remained in the soils. Therefore, the results from this study revealed that the combined use of FYM and potassium fertilizer increased the concentration of K in the soils. This was supported by the high levels and increased exchangeable K in the post-harvest soils in the fertilizer treatments in Missenyi site, and medium levels and increased exchangeable K, in the post-harvest soils in the fertilizer treatments in Bukoba and Biharamulo sites (Tables 5 and 6).

Generally, the increase in N, P and K concentrations in the soils due to the combined use of FYM and inorganic K fertilizer, resulted into increased uptake of N. P and K by the cassava plants, which then improved cassava growth and increased cassava root yields. This was supported by the significantly ($P < .001$) high cassava root yields recorded and reported by [20] working on the same soils by applying the same treatments in the cassava plants.

3.2 Effect of the Applied Treatments on the Contents of Nitrogen (N), Phosphorus (P) and Potassium (K) in Cassava Leaves in Bukoba, Missenyi and Biharamulo Districts

3.2.1 Effects of tillage methods on the contents of N, P and K in the soils in cassava leaves Bukoba, Missenyi and Biharamulo districts

The results on the effects of flat tillage, open ridging and tied ridging on the concentration of N, P and K in cassava leaves soil in Bukoba, Missenyi and Biharamulo districts are presented in Table 7. In all study sites, the results indicate that all the tillage methods used in this study gave very deficient to deficient levels of N, P and K in cassava leaves according to the ratings by [29]. There was no significant ($P = .05$) difference in the concentration of N, P and K in cassava leaves with respect to the tillage methods used in this study. This implied that the tillage methods (flat tillage, open ridging and tied ridging) used in this study had no effects on the concentration of N, P and K in cassava leaves. Thus, whichever the tillage method used in this study can not influences the concentrations of N, P and K in the soils (Table 4) and thus in the cassava leaves.

3.2.2 Effects of combined use of farmyard manure and potassium fertilizers on the concentration of N, P and K in cassava leaves in Bukoba, Missenyi and Biharamulo districts

The results on the concentration of N, P and K in cassava leaves with respect to the control treatment and combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 or 120 kg K ha^{-1} in Bukoba, Missenyi and Biharamulo districts are presented in Table 8. However, according to the ratings by [29], the results indicate that the control treatment and the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 or 120 kg K ha^{-1} gave very deficient to deficient levels of N, P and K in cassava leaves in all studied sites.

The observed very deficient to deficient levels of N, P and K in the cassava leaves in all study sites, was probably, attributed to the slow release of nutrients from FYM in the soils during the decomposition. This was because, at 4 months after planting (leaves sampling time), FYM might have not undergone complete decomposition to release enough nutrients into the soil solution for plant uptake. Other researchers, for example, [42] and [43], reported low use efficiency of farmyard manure due its slow release of nutrients into the soil upon decomposition.

In all study sites, the results indicated a significant (P < .001) difference in the concentration of N, P and K in cassava leaves between the control and the combined use of farmyard manure and potassium rates, with low values of N, P and K recorded in the control. There was a significant (P < .001) difference in the concentration of N and K in cassava leaves between the combined use of FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} and the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}. Whereby, the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} gave significantly (P < .001) higher concentrations of N and K in cassava leaves than the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}. This reflected the significantly (P < .001) higher cassava root yield recorded in the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} than in the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1} as reported by [20] working on the same soils with the same treatments applied in the cassava plants.

However, in all sites, there was no significant (P = .05) difference in the concentration of P in cassava leaves between the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} and the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}. This was probably attributed to the low amount of P added in the soil from the applied farmyard manure as oppose to the amounts of N and K added in the soil from the same farmyard manure [22].

Table 7. The concentration of N, P and K in cassava leaves with respect to tillage methods in Bukoba, Missenyi and Biharamulo districts

Treatment	Location								
	1	2	3	1	2	3	1	2	3
	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
Flat tillage	3.16^a	3.44^a	3.04^a	0.16^a	0.27^a	0.21^a	0.67^a	0.67^a	0.42^a
Open ridging	3.26^a	3.35^a	2.91^a	0.16^a	0.26^a	0.22^a	0.62^a	0.66^a	0.45^a
Tied ridging	3.07^a	3.14^a	2.94^a	0.20^a	0.26^a	0.23^a	0.65^a	0.70^a	0.38^a
SED	0.12	0.18	0.13	0.02	0.02	0.02	0.03	0.05	0.03
CV (%)	11.3	16.50	12.90	25.10	23.60	19.00	11.70	22.10	18.00

Means within a column (for a particular nutrient) 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; Ratings in the table: Nitrogen; 2.91-3.44 = very deficient, Phosphorus: 0.0.16-0.23 = very deficient, 0.26-0.27 = deficient; Potassium: 0.38-0.67 = very deficient [29]

Table 8. The concentration of N, P and K in cassava leaves with respect to combined use of farmyard manure and potassium rates in Bukoba, Missenyi and Biharamulo districts

Treatment	Location								
	1	2	3	1	2	3	1	2	3
	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
Co	1.43^a	1.00^a	1.46^a	0.13^a	0.18^a	0.18^a	0.25^a	0.17^a	0.07^a
FYM_8K_{40}	3.33^b	3.15^b	3.34^b	0.19^b	0.27^b	0.26^b	0.62^b	0.66^b	0.42^b
FYM_8K_{120}	4.53^c	4.77^c	4.09^c	0.20^b	0.29^b	0.29^b	1.07^c	1.20^c	0.75^c
SED	0.12	0.18	0.13	0.02	0.02	0.02	0.03	0.05	0.03
CV (%)	11.3	16.50	12.90	25.10	23.60	19.00	11.70	22.10	18.00

Means within a column (for a particular nutrient) 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_8K_{40} = farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}, FYM_8K_{120} = farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1}; Ratings in the table; Nitrogen; 1.0-3.34 = very deficient, 4.09-4.77 = deficient; Phosphorus: 0.13-0.20 = very deficient, 0.26-0.29 = deficient; Potassium: 0.07-0.75 = very deficient, 1,07-1.20 = deficient [29]

4. CONCLUSION

Planting of cassava on the ridges or on the flat tillage had no effects on the soil pH and the concentrations of N, P and K in the soil and cassava leaves. The combined use of FYM at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} or the combined use of FYM at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1} increased the soil pH and the concentration of N and K in the soil but did not increase the concentration of P in the soil and in cassava leaves following two-consecutive years of applying FYM and potassium fertilizer. In addition, th combined use of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} gave higher concentrations of N and K in cassava leaves than the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1}. Therefore, from the results of this study, planting cassava on the flat tillage or on ridges together with the use of the combination of farmyard manure at 8 MT ha^{-1} and potassium at 120 kg K ha^{-1} is desirable for increasing the concentrations of N and K in the soil and in cassava leaves and thus recommended. However, for the resource-poor farmers who cannot afford the high rate of K, the combined use of farmyard manure at 8 MT ha^{-1} and potassium at 40 kg K ha^{-1} could be used. Since the results indicate low content of P in the applied farmyard manure (especially in Bukoba and Biharamulo districts) where P is a limiting nutrient, we also recommend basal application of inorganic P-containing fertilizer for increasing the concentration of P in the soil and in cassava leaves.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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