Journal of Agriculture and Sustainability
ISSN 2201-4357
Volume 12, Number 2, 2019, 232-249

INFINITY PRESS
www.infinitypress.info

Effects of Tillage Practices and Organic Cropping Systems on the Yield of Sorghum (*sorghum bicolor L.*) and Sweet Potato (*Ipomoea batatas L*) in Yatta Sub-County, Kenya

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ABSTRACT

The study was conducted between October 2012 to February 2013 short rain season (SRS) and April 2013 to August 2013 long rain season (LRS) in semi-arid Yatta sub-county, to evaluate the influence of tillage practices, cropping systems and organic inputs on the yield of sorghum and sweet potato. A Randomized Complete Block Design with a split-split plot arrangement replicated thrice was used. The main plots were tillage practices (TP); Oxen plough (OP), tied ridges (TR) and furrows and ridges (FR). The Split-plots were cropping systems (CS); mono-cropping (MC), intercropping (IC), and crop rotation (CR) while split-split plots were organic inputs; Farm Yard manure (FYM), Minjingu Rock Phosphate (MRP), combined MRP and FYM (MRP+FYM) and the control. Test crops were sorghum and sweet potatoes with Dolichos (*Dolichos lablab*) and chickpea (*Cicer arietinum* L) either as intercrops or in rotation. Plant sampling was done by harvesting the grain and tuber and yield determined by weighing with a precision balance. The yields increased significantly ($P \leq 0.05$) with application of MRP+FYM of 16.37 and 1.38 t ha^{-1} for sweet potatoes and sorghum mono-crop, respectively under TR were observed. There was also significant ($P \leq 0.05$) yield increase of chickpea and dolichos under combined TR, IC of sorghum with chickpea (1.44 t ha$^{-1)}$ and dolichos (1.38 t ha$^{-1)}$ and with application of MRP+FYM during SRS of 2012. Improved yield of srghum and sweet potatoes were attained with the combined TR, MC and with application of MRP + FYM.

Key words: cropping systems; organic inputs; semi-arid; tillage practices, yield.

INTRODUCTION

Sweet potato (*Ipomoea batatas L*) is among the world`s most important and under-exploited crop and is commonly referred to as subsistence, food security, or famine relief crop (Scott and Maldinado, 1999). In addition, sweet potato provides good ground cover, and is usually cultivated with little or no fertilizer additions (Lusweti *et al.*, 1999). In Africa, sorghum (*sorghum bicolor L.*) is a largely subsistence food security crop as it is drought resistant among cereals, can withstand high temperatures and grow in areas with annual rainfall of 500 -700mm per year. Sorghum, an important crop in East Africa (Taylor *et al.*, 2010) is economically rated as the fifth most important cereal after maize, wheat, barley, and rice. It performs well on a wide range of poor soils with low rainfall and often out-yielding most cereals in hot and dry environments. It is particularly adapted to agro-ecological zones of Kenya, which are arid and semi-arid (Kameri-Mbote, 2005). Sorghum and sweet potato are typically valuable hardy crops adapted to the local climate (Chepkemoi, 2014) and are widely grown by the resource poor farmers in the ASALs of Kenya for subsistence and as a source of income (Macharia, 2004).

To the contrary, farmers in the ASALs cultivate a variety of crops of which the main ones are maize, beans, green grams and cowpeas under rain-fed agriculture and horticultural crops such as oranges, mangoes, bananas, tomato, onions, kale, pawpaw and citrus (KARI-NDFRC, 1995). The farmers in Yatta Sub County have abandoned the traditional crops that are drought resistant, can withstand high temperature unlike the introduced crops, and have the potential to contribute to food security, nutrition, health, income generation, and environmental services (Chepkemoi, 2014). Drought-resistant crops reduces the risk of total loss during drought especially where there is overreliance in one crop. Intercropping on the other hand generate beneficial biological interaction between crops, increasing grain yield and stability, more efficient use of available resources and reducing weed pressure (Kadziuliene 2009). Well-managed crop rotations also increase soil organic matter to sufficient levels, help to moderate and retain soil moisture in dry conditions while allowing excess moisture to drain away in wet seasons. Shifting crop types also helps vary water demand within the soil profile. The deep-rooted crops following shallow crops can access moisture reserves as well as capture any nutrients that have leached below the shallower root zones before they reach groundwater (Kadziuliene 2009).

Many techniques have been tried to utilize rain water among them ridges & furrows and tied ridges with mulching being the most effective measures (Li *et al.,* 2000; Karuku *et al*., 2019). In addition Farmyard manure acts as an alternative source of fertility enhancement for inorganic fertilizer as they release nutrients slowly and steadily over long periods and improve soil fertility status by activating the soil microbial biomass (Ayuso *et al.,* 1996; Belay *et al.,* 2001; Karuku *et al*., 2019). The current study investigated the effects of tillage practices, cropping systems and organic inputs on crop yield in Yatta sub-county, Kenya.

MATERIALS AND METHODS

Study Site

The study was carried out in Yatta sub-county, Kenya (longitude -1.4667°S, latitude 37.8333°E, 944m asl). The sub-county falls under agro-ecological zone IV, classified as semi-arid lands (Jaetzold and Schmidt, 2006). The soils are a combination of Acrisols and Luvisols with Ferralsols (WRB, 2015). In most places, the topsoil comprises of loamy sand to sandy loam, sandy clay to clay with low nutrient availability (Kibunja *et al.,* 2010). The mean annual temperature vary from 18°C to 24°C and experiences bimodal rainfall with long rains season commencing early April to May (about 400 mm) and short rains season from early October to December (500 mm). Most farmers in the sub county are small-scale mixed farmers who grow maize, beans, pigeon pea, green grams, sorghum, and cowpea (Macharia, 2004).

Treatments and Experimental design

The treatments included tillage practices (Oxen plough, tied ridges and, furrows and ridges); cropping systems (mono-cropping, intercropping, and crop rotation) and organic inputs (farmyard manure, rock phosphate, and combined Farmyard manure and rock phosphate) plus a control. The design was in a Complete Randomized Block with split-split plot arrangement. The main plots (150m x 60m) were; tillage practices (Oxen plough, tied ridges and furrows, and ridges); Split-plots (10m x 4m) while the split plots comprised cropping systems (mono cropping, intercropping, and crop rotation) and split-split plots (2.5m x 1m) were organic inputs (farmyard manure, rock phosphate and combination of Farmyard manure and rock phosphate). A control with no added inputs applied was included as a split-split plot. The test crops were sweet potatoes (*ipomea batatas* l. lam) and sorghum (*sorghum bicolor l.*) with Dolichos (*Dolichos lablab)* and chickpea Chickpea (*Cicer arietinum* L.) either as intercrops or in rotation.

Field Practices

Land was prepared manually with oxen plough in late September and planted in October short rains and April long rainy seasons of 2012 and 2013, respectively. Tillage practices (tied ridges and furrows & ridges) were constructed during planting according to each crop type spacing. Manure was broadcasted at a rate of 5t ha^{-1} and minjingu rock phosphate (MRP) at 498kg ha^{-1} (equivalent to 60kgP ha^{-1}) and mixed thoroughly with the soil before the vines and the other crop seeds were placed into the holes. Sweet potatoes (wabolinge variety) were propagated through cuttings 30cm long at spacing of 90cm between rows and 30 cm within rows. Weeding was done 5 weeks after planting and harvesting after 6 months when the leaves were yellowish in color and dry. All tubers were harvested using a hoe (Mureithi, 2005). Sorghum crop (serendo variety) on the other hand was sown at spacing of 75cm x 30cm while dolichos and chickpea were planted at a spacing of 30cm within the sorghum and sweet potato rows. Weeding was done as described above. Harvesting of sorghum was after three months after reaching physiological maturity.

Plant sampling

Plant sampling for grain and tuber was done at crop maturity within the middle rows and two rows were left on the sides at harvesting stage for sorghum and for sweet potato and a 1m^2 quadrant used to harvest samples. Grain and sweet potato yields were determined by weighing either grains or tubers in kg m^{-2} and then converting to t ha^{-1} using the formula:

$$\text{Grain/tuber yield (t ha}^{-1}\text{)} = \frac{10000\text{m}^2 * \text{kg ha}^{-1}}{1000\text{kg} * \text{m}^2\text{Area}}$$

Stat*istical analysis*

Data was subjected to analysis of variance using GenStat 18th edition statistical software (Payne *et al.*, 2015) and means separated using least significant difference at 5% confidence level.

RESULTS AND DISCUSSION

Effects of tillage practices, cropping systems and organic inputs on Dolichos (Lablab purpureus) and Chickpea (Cicer arietinum L.) yields

There was a significantly ($P \leq 0.05$) increased yield of chickpea and dolichos for combined tied ridges, intercropping with sorghum and application of MRP+FYM at 1.44 and 1.38 t ha^{-1} for chickpea and dolichos, respectively during SRS of 2012 (Table 1). Both legume yields also increased under intercropping or rotation with sweet potato compared to sorghum under tied ridges and with the application of MRP+FYM. Accordingly, intercropping chickpea and dolichos with sweet potato gave1.54 and 1.48 t ha^{-1} while with sorghum, the yield was 1.38 and 1.44 t ha^{-1}) for Chicpea and Dolichos, respectively in the SRS of 2012 (Table 1).

Table 1: Effects of tillage practice, cropping systems and organic inputs on of dolichos and chickpea yield during SRS of 2012 and LRS of 2013

					SRS 2012				LRS 2013			
	TP	CS	CROPS	CROP	CTRL	MRP	FYM	MRP+ FYM	CTRL	MRP	FYM	MRP+ FYM
SOR PLOTS	FR	Intercropping	SOR/CP	CP	1.23^{f}	1.28^{fg}	1.29^{fg}	1.31^{fgh}	1.34^{e}	1.38^{efg}	1.39^{efg}	1.41^{gh}
		Intercropping	SOR/DOL	DOL	1.21^{defg}	1.23^{gh}	1.25^{gh}	1.31^{ghi}	1.32^{e}	1.33^{e}	1.35^{ef}	1.39^{efg}
		Crop Rotation	CP-SOR	CP	1.13^{def}	1.16^{def}	1.17^{def}	1.23^{gh}	-	-	-	-
		Crop Rotation	DOL-SOR	DOL	1.05^{bc}	1.14^{def}	1.18^{defg}	1.23^{gh}	-	-	-	-
	OP	Intercropping	SOR/CP	CP	1.06^{bc}	1.08^{cd}	1.09^{cd}	1.15^{def}	1.16^{a}	1.18^{a}	1.20^{ab}	1.25^{c}
		Intercropping	SOR/DOL	DOL	1.19^{efg}	1.26^{fg}	1.28^{fg}	1.29^{fg}	1.29^{d}	1.36^{ef}	1.38^{efg}	1.39^{efg}
		Crop Rotation	CP-SOR	CP	1.27^{gh}	1.32^{ghi}	1.33^{ghij}	1.41^{jk}	-	-	-	-
		Crop Rotation	DOL-SOR	DOL	1.04^{abcd}	1.12^{def}	1.16^{def}	1.22^{defg}	-	-	-	-
	TR	Intercropping	SOR/CP	CP	1.34^{ghij}	1.37^{ghij}	1.39^{jk}	1.44^{jk}	1.43^{gh}	1.46^{i}	1.48^{ij}	1.49^{ij}
		Intercropping	SOR/DOL	DOL	1.19^{efg}	1.33^{fgh}	1.36^{fghi}	1.38^{fghi}	1.29^{d}	1.43^{gh}	1.46^{i}	1.48^{ij}
		Crop Rotation	CP-SOR	CP	1.17^{efg}	1.29^{ghi}	1.34^{ghij}	1.39^{jk}	-	-	-	-
		Crop Rotation	DOL-SOR	DOL	1.01^{a}	1.1^{de}	1.13^{def}	1.19^{defg}	-	-	-	-
SP PLOTS	FR	Intercropping	SP /CP	CP	1.33^{f}	1.38^{fg}	1.39^{fg}	1.41^{fgh}	1.44^{e}	1.48^{efg}	1.49^{efg}	1.51^{gh}
		Intercropping	SP /DOL	DOL	1.31^{defg}	1.33^{gh}	1.35^{gh}	1.41^{ghi}	1.42^{e}	1.43^{e}	1.45^{ef}	1.49^{efg}
		Crop Rotation	CP- SP	CP	1.23^{def}	1.36^{def}	1.27^{def}	1.33^{gh}	-	-	-	-

	Crop Rotation	DOL- SP	DOL	1.15^{abcd}	1.24^{def}	1.28^{defg}	1.33^{gh}	-	-	-	-
OP	Intercropping	SP /CP	CP	1.16^{abcd}	1.18^{de}	1.19^{de}	1.25^{def}	1.26^{a}	1.28^{a}	1.30^{ab}	1.35^{c}
	Intercropping	SP /DOL	DOL	1.29^{f}	1.36^{fg}	1.38^{fg}	1.39^{fg}	1.39^{d}	1.46^{ef}	1.48^{efg}	1.49^{efg}
	Crop Rotation	CP- SP	CP	1.37^{gh}	1.42^{ghi}	1.43^{ghij}	1.51^{jk}	-	-	-	-
	Crop Rotation	DOL- SP	DOL	1.14^{abcd}	1.32^{def}	1.26^{def}	1.32^{defg}	-	-	-	-
TR	Intercropping	SP /CP	CP	1.44^{ghij}	1.47^{ghij}	1. 49^{jk}	1.54^{jk}	1.53^{gh}	1.56^{i}	1.58^{ij}	1.59^{ij}
	Intercropping	SP /DOL	DOL	1.29^{a}	1.43^{fgh}	1.46^{fghi}	1.48^{fghi}	1.39^{d}	1.43^{gh}	1.56^{i}	1.58^{ij}
	Crop Rotation	CP- SP	CP	1.27^{def}	1.39^{ghi}	1.44^{ghij}	1.49^{jk}	-	-	-	-
	Crop Rotation	DOL- SP	DOL	1.11^{abc}	1.2^{de}	1.23^{def}	1.29^{defg}	-	-	-	-

Legend: SOR-sorghum, SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard - manure, MRP-minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system. Dash (-) indicates in Rotation SP/SOR were harvested during LRS 2013. Means followed by the same letters in the same season are not significantly different at P ≤ 0.05.

The retained soil cover under intercropping of sweet potato reduces direct evaporative losses, thereby retaining soil moisture longer for crop to use. Increased dolichos and chickpea yield under combined TR and intercropping with sorghum could be attributed to this increased soil moisture and improved soil nutrient status due to application of MRP+FYM, intercropping and tied ridges as compared to oxen plough and furrows and ridges. Tied ridges conserve soil moisture that is then availed for crop consumptive use. Crop roots absorb the available moisture for growth and development, giving the crop under this treatment higher grain yield. Kumar et al. (2000) observed that availability of adequate moisture during various crop growth stages resulted in better crop growth and thus improved yield.

Dolichos and chickpea grain yields were significantly higher ($p \leq 0.05$) in the LRS of 2013 (1.48 t ha^{-1}) across treatments compared to SRS of 2012 (1.38 t ha^{-1}) (Table 1).The higher grain yields in the LRS (of 2013) were as a result of improved nutrient and moisture contents in soil due to residual effect of the of the organic inputs supplied by MRP+FYM and FYM. Rainfall in SRS (of 2012) was also less compared to LRS (of 2013), resulting in the crop depending mainly on the inadequate stored soil moisture in SRS. This in essence affected final economic yield of the crop. Chickpea seed yield was reported by Lopez *et al*. (2004) to strongly depend on rainfall during flowering and seed filling stages, both critical development stages requiring adequate moisture. Karuku et al. (2014) indicated that low moisture content during critical crop growth stages lead to high yield reduction (Ky) leading to poor economic yields.

Sorghum (sorghum bicolor L.) and sweet potato (Ipomoea batatas L) yield

There was a significantly ($P \leq 0.05$) higher yield for combined tied ridges, mono-cropping and MRP+FYM of 1.38 and 16.27 t ha^{-1} for sorghum and sweet potatoes, respectively as compared to furrows and ridges at 1.31 and 15.67 t ha^{-1} and for oxen plough at 1.29 and 16.17 t ha^{-1} during SRS 2012. This was attributed to higher moisture content under tied ridges compared to oxen plough and furrows & ridges (Table 1 and 2).

Table 2: Effects of tillage practice, cropping systems and organic inputs on sorghum yield during SRS 2012 and LRS 2013.

				SRS 2012				LRS 2013			
		CROPS	CROP				MRP+				MRP+
TP	CS			CTRL	MRP	FYM	FYM	CTRL	MRP	FYM	FYM
FR	Intercropping	SOR/CP	SOR	0.92^{ab}	0.97^{abc}	0.94^{abc}	0.98^{abc}	0.91^{a}	0.92^{ab}	0.94^{ab}	0.97^{ab}
	Intercropping	SOR/DOL	SOR	0.95^{abc}	0.98^{abc}	0.99^{abcd}	1.01^{abcd}	0.93^{ab}	0.94^{ab}	0.95^{ab}	1.01^{abc}
	Mono cropping	SOR	SOR	1.23^{f}	1.28^{fg}	1.29^{fg}	1.31^{fgh}	1.21^{defg}	1.23^{gh}	1.25^{gh}	1.31^{ghi}
	Crop Rotation	CP-SOR	SOR	-	-	-	-	1.13^{def}	1.16^{def}	1.17^{def}	1.23^{gh}
	Crop Rotation	DOL-SOR	SOR	-	-	-	-	1.05^{abcd}	1.14^{def}	1.18^{defg}	1.23^{gh}
OP	Intercropping	SOR/CP	SOR	0.81^{a}	0.95^{abc}	0.96^{abc}	1^{abcd}	1.06^{abcd}	1.08^{de}	1.09^{de}	1.15^{def}
	Intercropping	SOR/DOL	SOR	0.87^{a}	1.07^{abcde}	1.17^{f}	1.27^{fg}	0.93^{ab}	1.12^{def}	1.22^{defg}	1.38^{jk}
	Mono cropping	SOR	SOR	1.19^{f}	1.26^{fg}	1.28^{fg}	1.29^{fg}	1.27^{gh}	1.32^{ghi}	1.33^{ghij}	1.41^{jk}
	Crop Rotation	CP-SOR	SOR	-	-	-	-	0.94^{ab}	1.01^{abc}	1.05^{abcd}	1.1^{de}
	Crop Rotation	DOL-SOR	SOR	-	-	-	-	1.04^{abcd}	1.12^{def}	1.16^{def}	1.22^{defg}
TR	Intercropping	SOR/CP	SOR	0.86^{a}	0.87^{a}	0.88^{a}	0.94^{ab}	0.91a^{b}	0.94^{abc}	0.95^{abc}	0.98^{abc}
	Intercropping	SOR/DOL	SOR	1.01^{abcd}	1.03^{abcd}	1.04^{abcd}	1.06^{abcde}	0.99^{abc}	1^{abc}	1.01^{abc}	1.07^{de}
	Mono cropping	SOR	SOR	1.19^{a}	1.33^{fgh}	1.36^{fghi}	1.38^{fghi}	1.17^{def}	1.29^{ghi}	1.34^{ghij}	1.39^{jk}
	Crop Rotation	CP-SOR	SOR	-	-	-	-	1.01^{abc}	1.1^{de}	1.13^{def}	1.19^{defg}
	Crop Rotation	DOL-SOR	SOR	-	-	-	-	1.34^{ghij}	1.37^{ghij}	1.39^{jk}	1.44^{jk}

Legend: SOR-sorghum, SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard - manure, MRP-minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system. Dash (-) indicates in Rotation legumes were harvested during SRS of 2012. Means followed by the same letters in the same season are not significantly different at P ≤ 0.05.

Table 3: Effects of tillage practice, cropping systems and organic inputs on crop yield during SRS 2012 and LRS 2013.

TP	CS	CROPS	SRS 2012 CTRL	MRP	FYM	MRP+ FYM	LRS 2013 CTRL	MRP	FYM	MRP+ FYM
FR	intercropping	SP/CP	8.45^{a}	12.17^{bc}	13.42^{bcd}	13.41^{bcd}	13.61^{abcd}	15.04^{defg}	15.52^{gh}	15.62^{gh}
	Intercropping	SP/DOL	9.25^{a}	12.33^{bc}	13.35^{bcd}	13.35^{bcd}	11.62^{a}	12.84^{abc}	13.25^{abc}	13.24^{abc}
	Mono-cropping	SP	15.2^{bcdef}	15.53^{bcdef}	15.67^{bcdef}	15.77^{bcdef}	16.17^{ghi}	16.53^{ghij}	16.69^{ghij}	16.79^{jk}
	Crop rotation	CP-SP	-	-	-	-	11.87^{a}	13.04^{abc}	13.44^{abcd}	13.43^{abcd}
	Crop rotation	DOL-SP	-	-	-	-	11.97^{a}	13.15^{abc}	13.54^{abcd}	13.54^{abcd}
OP	intercropping	SP/CP	12.56^{bc}	13.89^{bcd}	14.33^{bcde}	14.32^{bcde}	13.61^{abcd}	15.04^{defg}	15.52^{gh}	15.62^{gh}
	Intercropping	SP/DOL	10.72^{b}	11.85b	12.23^{bc}	12.33^{bc}	11.62^{a}	12.84^{abc}	$13.25a^{bc}$	$13.24a^{bc}$
	Mono-cropping	SP	14.7^{bcde}	15.03^{bcde}	15.17^{bcdef}	15.27^{bcdef}	16.17^{ghi}	16.53^{ghij}	16.69^{ghij}	16.79^{jk}
	Crop rotation	CP-SP	-	-	-	-	11.5^{a}	12.68^{abc}	13.07^{abc}	13.17^{abc}
	Crop rotation	DOL-SP	-	-	-	-	11.75a	12.92^{abc}	$13.32a^{bcd}$	13.31^{abcd}
TR	intercropping	SP/CP	11.17^{b}	12.34^{bc}	12.74^{bc}	13.14^{bcd}	12.1^{ab}	13.37^{abcd}	13.8^{abcd}	14.23^{de}
	Intercropping	SP/DOL	12.9^{bc}	13.53^{bcd}	13.67^{bcd}	13.77bcd	13.98^{de}	14.66^{def}	14.81^{def}	14.81^{def}
	Mono-cropping	SP	15.7^{bcdef}	16.03^{bcdef}	16.17^{bcdef}	16.27^{bcdef}	17.27^{jk}	17.63^{jkl}	17.79^{jkl}	17.89^{jklm}
	Crop rotation	CP-SP	-	-	-	-	11.95^{a}	13.12^{abc}	13.51^{abcd}	13.61^{abcd}
	Crop rotation	DOL-SP	-	-	-	-	12.08a	13.26^{abc}	13.65^{abcd}	13.75^{abcd}

Legend: SP-sweet potato, DOL-dolichos, CP-chickpea, TP-tillage practice, TR-tied ridges, FR-furrows and ridges, OP-oxen plough, FYM-farm yard -manure, MRP-minjingu rock phosphate, CTRL-control, LRS-long rain season, SRS-short rain season, CS-cropping system. Dash (-) indicates in rotation legumes were harvested during the SRS 2012 whereas sweet potatoes and sorghum were harvested during the LRS 2013, Means followed by the same letters in the same season are not significantly different at $P \leq 0.05$

The increase in the yield following the application of organic inputs (FYM and FYM+MRP) could be attributed to higher soil nutrient status and availability for crop uptake. Use of organic inputs increases crop yield as they have a positive impact on soil physical and chemical properties such as soil water holding capacity, and enhance nutrient release leading to higher yields (Muhammad and Khattak 2009; Akande *et al.*, 2010). Belay *et al*. (2001) found that the nutrients released from FYM and MRP+FYM upon decomposition activate soil microbial activities thus boosting soil health. Addition of organic manures is attributed to improved nutrient availability of the soil (Boateng *et al*., 2006; Hirzel *et al*., 2007 and Marschner, 2011). This study in addition confirm to the findings of Shirani*et al*. (2002) and Iqbal*et al*. (2005) who concluded that manure application either alone or in combination with different tillage practices and cropping systems improve crop growth and yield.

There was an increase in the yield of sweet potato and sorghum in dolichos rotation (14.81 t ha^{-1} and 1.44 t ha^{-1}) whereas the lowest was noted in the intercrop (13.61 t ha^{-1} and 1.07 t ha^{-1}) during LRS 2013. This was attributed to higher competition between the two crops for light, nutrients and soil moisture leading to a noticeable low yield under the intercrop whereas higher yield under rotation was due the breaking of diseases and pests cycle as a result of change in prevalent crop type (Table 1 and 2). This could also be due to lack of competition of nutrients, water and light with the legume cover crop (Wanderi *et al.*, 2003). In other studies, many justifications have been adduced for yield increase in crop rotation such as due to pests and diseases control when crops are rotated (Rathke *et al.*, 2005), increasing soil biological activity (Larkin, 2008), and rising water use efficiency (Christen and Sieling, 1995) as some of the important reasons. Rotating crops along with increasing SOM increases biodiversity and soil biological community Kamkar and Damghani, (2009).

Combined TR, sole sorghum and MRP+FYM gave higher yields during the long rain season (1.39 and 17.29 t ha^{-1} as compared to short rain season (1.38 and 16.27 t ha^{-1}) as noted in (Table 2 and 3). This was attributed to prolonged rainfall during the long rain season, which translated to a higher yield. This also implies that under such prolonged rainfall the crops utilize both moisture and nutrients more efficiently and effectively during the four growth stages of establishment, development, reproduction and maturity leading less yield reduction (ky) at each stage hence less overall yield reduction factor (Ky) and ultimately better overall yields (Karuku, 201; Karuku et al., 20014). The higher yields in the LRS 2013 were partly as a result of the elevated available NPK and organic carbon content in soil due to residual effect of the amendments FYM, MRP+FYM and MRP (Buresh *et al.,*1997*)* and its subsequent uptake by sorghum and sweet potatoes.

In Northern Ethiopia, Berhane *et al*. (2006) found sorghum (*Sorghum bicolour* L. Moench) yield to be increased by 62% with tied-ridging compared with flat planting. Adoption of tied-ridging for small-scale sorghum production in Africa was found to increase farm income by 12% (Berhane *et al*., 2006).

CONCLUSION

Combined Tied-ridging, rotation of sweet potato and sorghum with dolichos with application of FYM+MRP led to an increase in crop yield. Integrated use of farm yard manure + minjingu rock phosphate with tied ridges and crop rotation would be a better and practical approach to sustain soil fertility and crop productivity.

Acknowledgements

The authors acknowledge the financial support by the McKnight foundation to the first author to undertake the research as part of her postgraduate studies. The farmers who provided their land and other resources for the study are equally appreciated.

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