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Efficiency of Combined Tillage Practices, Cropping Systems and Organic Inputs on Soil Moisture Retention in Yatta Sub-County, Kenya

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Abstract

The study evaluated the efficiency of combined tillage practices, cropping systems and organic inputs on soil moisture retention. It was carried out between October 2012 to February 2013 short rain season (SRS) and March to August 2013 long rain season (LRS). Randomized Complete Block Design with a split-split plot arrangement was used. Main plots tillage practices (TP); Oxen plough (OP), tied ridges (TR) and furrows and ridges (FR). Split-plots cropping systems (CS); mono cropping (MC), intercropping (IC) and crop rotation (CR) while split-split plots organic inputs; Farmyard manure (FYM), Minjingu Rock Phosphate (MRP), combined MRP and FYM (MRP+FYM) and control. Test crops sorghum and sweet potatoes with Dolichos (*Dolichos lablab*) and chickpea (*Cicer arietinum* L.) as intercrops or in rotation. Soil samples taken at 0-30 cm depth at the start of the experiment and maturity of test crops for soil moisture content and efficiency determination expressed as percentage. Significant ($p \leq 0.05$) increased in soil moisture content was recorded in TR under IC of dolichos with application of FYM (7.53% and 7.88%) for sorghum and sweet potato plots respectively. Intercropping of sweet potato/dolichos under TR with the application of FYM are efficient soil moisture conservation techniques.

Keywords: cropping systems; tillage practices; organic inputs; Semi-arid; soil moisture

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1. Introduction

Agricultural production in Sub-Saharan Africa (SSA) primarily relies on rain-fed production that is climate sensitive (IITA, 1993). The most limiting factor to crop production in the arid and semi arid lands of Kenya especially Yatta Sub County is availability of soil moisture. The low rainfall together with its unreliability and poor distribution severely limits crop production (KARI, 1996). Additionally, the low quality of soil resource base which on one hand has been due to inherent and induced deficiencies of major nutrients N, P and K or low nutrient holding capacity and low organic matter (Okalebo *et al.,* 1992; Kaolo R. 2003) negatively affect crop production.

To ensure increased crop production and food security, farmers in the semi-arid tropics intercrop cereals with grain legumes, such as pigeon pea (*Cajanus cajan*), as a strategy for diversifying food production and household income since legumes are both cash and food crops (Mafongoya *et al.,*2006). The legume improves soil fertility and yields of associated cereals, as well, through atmospheric di-nitrogen fixation in association with rhizobia bacteria, nutrient pumping and incorporation of green manure (Chikowo *et al.,* 2004).

In addition to intercropping, farmers practice well-managed crop rotations with the aim of increasing soil organic matter to sufficient levels that help to moderate and retain soil moisture under dry conditions, and allow excess moisture to drain away in wet seasons thus recharging the ground water aquifers. The deep rooted crops following shallow rooted crops can access moisture reserves as well as capture any nutrients that have leached below the shallower root zones before they reach groundwater (Adam *et al.,* 2011).

Further, the application of manures to soil provide benefits such as fertility, structure, increased soil organic matter, better water holding capacity (Phan *et al.,*2002, Blay *et al.,*2001) and transmission properties. Besides use of organic inputs to enhance and conserve soil moisture, various tillage practices; furrows and ridges and tied ridges, have been found to conserve soil moisture (Gebrekidan and Yohannes 2002) in semi-arid areas.

Tillage modifies soil surface structure by breaking the pan layer, total porosity and macro-porosity, pore continuity and pore size distribution and therefore has great influence on the hydrology of an agricultural catchment (Mwendera, 2002).

These have shown positive response in terms of yield increase in maize and other crops. These moisture conservation methods contribute to increased infiltration, reduction of run-off hence reduced erosion episodes and increasing rooting volume in shallow soils (Vogel *et al .,* 2001).

These methods mentioned have not been tested in the ASALs as combined the farmers have practiced such techniques solely not as combined. Therefore, this research has provided a chance for testing their effectiveness in soil moisture conservation as combined techniques.

The current study therefore evaluated the efficiency of soil moisture conservation techniques (tillage practices organic based cropping systems and organic inputs- in Yatta sub-county, Kenya.

2. Materials and Methods

2.1 Study Site

The study site is located on -1.4667 S and 37.8333°E at Yatta Sub-county, Kenya. It lies at an altitude of 944m above sea level. The sub-county falls under agro-cological zones IV, which is, classified as semi-arid lands (Jaetzold and Schmidt, 2006). The soils in Yatta Sub County are a combination of Acrisols and Luvisols with Ferralsols (WRB, 2006). In most places, they have topsoil that is loamy sand to sandy loam, sandy clay to clay with low nutrient availability (Kibunja *et al.,* 2010).

It has a semi-arid climate with mean annual temperature varying 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 commencing from early October to December (500 mm). Most of the farmers in the sub county are small-scale mixed farmers. Crops grown in the area include maize, beans, pigeon pea, green grams, sorghum, and cowpea (Macharia, 2004).

2.2 Treatments and Experimental Design

The treatments were 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) and control.

The experiment was in a Randomized Complete Block Design with split-split plot arrangement. The main plots (150 by 60 metres) were; tillage practices (Oxen plough, tied ridges and furrows, and ridges). Split plots (10 by 4 metres) were cropping systems (mono cropping, intercropping, and crop rotation) and split-split plots (2.5 by 1 metres) were organic inputs (farmyard manure, rock phosphate and combined Farmyard manure and rock phosphate). A control (no organic input applied) was also included as a split-split plot. The test crops were sweet potatoes (*i pomea batatas* l.lam) and sorghum (*sorghum bicolor l.*) with Dolichos (*Dolichos lablab)* and chickpea Chickpea (*Cicer arietinum* L.) either as intercrops or in rotation.

2.3 Field Practices

Land was prepared manually using oxen plough in late September and planted in October short rain season 2012 and April long rain season 2013.

Manure was broadcasted at a rate of 5t/ha and minjingu rock phosphate (MRP) at 498 Kg/ha equivalent to 60 Kg P/ ha and mixed thoroughly with the soil before the vines and seeds were placed in the holes. Sweet potatoes (wabolinge variety) were propagated through cuttings of 30 cm long at spacing of 90 cm between rows and 30 cm within rows. Weeding was done 5 weeks after planting and harvesting was done after 6 months when the leaves were yellow and dry. Harvesting was done using a sharp hoe by removal of all tubers (Mureithi, 2005).

Sorghum (serendo variety) was sown at spacing of 75 cm by 30 cm and weeding done after 5 weeks of planting. Harvesting was done after three months when it had reached physiological maturity.

The spacing for chickpea was 60 cm by 30 cm (Singh and Diwakar, 1995). The spacing for Dolichos 60 cm by 30 cm was according to (Edwards, 2007). Weeding was done after every 5 weeks and harvesting was done after three months when it had reached physiological maturity.

2.4 Soil Sampling and Analysis

Soil samples were taken in a randomized manner at 0-30 cm depth at the start of the experiment three samples were taken from the whole farm and at maturity of the test crops and thoroughly mixed to form one composite sample per treatment for soil moisture content % volume and efficiency of soil moisture conservation techniques determination expressed as percentage.

Soil moisture determination: soil moisture content % volume was determined using gravimetric method. The soil moisture percent (percentage volume) was calculated using the following formula as described by (RNAM, 1995).

$$MC = \frac{(Ww - Wd)}{Wd} * 100$$

where,

MC = Moisture content (%)
Ww = Weight of wet soil (g)
Wd = Weight of dry soil (g)

Efficiency of soil moisture conservation techniques: Performance of moisture conservation techniques was quantified by their efficiency in percentage. The efficiency of the techniques on moisture conservation was calculated from initial and final soil moisture content, and total rainfall received as follows:

$$E = \frac{M_2}{(M_1 + R)} * 100$$

Where;

E - Efficiency of moisture conservation
M_1 – moisture content at the beginning of cropping period;
M_2 – moisture content at the end of cropping period;
R - Rainfall received during cropping period

2.5 Statistical Analysis

Data was subjected to general analysis of variance using Genstat statistical software (Payne *et al.,* 2006). Means were separated using least significant difference and Duncan Multiple Range Test (where interactions occurred) at a probability level of 5%.

3.0 Results and Discussion

3.1 Effects of Tillage Practices and Organic Based Cropping Systems on Soil Moisture Content

An increased soil moisture content was recorded in all the tillage practices and cropping systems with application of FYM and MRP+FYM (Table 1).

Significantly, ($p \leq 0.05$) tied ridges recorded an increased soil moisture content under the intercrop of sorghum chickpea with the application of MRP+FYM with a value of 8.37% and 8.44% followed by the crop rotation of chickpea –sorghum with a value of 7.89% and 7.95% for short rain season 2012 and long rain season 2013, respectively.

Table 1: Effects of Soil Moisture Conservation Techniques on Soil Moisture Content in % in Sorghum Based Plots During Short Rain Season 2012 and Long Rain Season 2013

			Organic inputs SRS 2012				Organic inputs LRS 2013			
TP	CS		CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SOR	3.5^{fg}	5.26^{o}	4.38^{k}	4.73^{lm}	3.89^{jk}	5.3^{pqrs}	3.93^{jk}	4.91^{p}
	crop rotation	DOL-SOR	3.32^{f}	4.98^{n}	4.15^{ij}	4.48^{k}	3.58^{hi}	5.02^{pq}	3.72^{ij}	4.65^{o}
	inter cropping	SOR/DOL	3.01^{e}	4.51^{k}	3.76^{h}	4.06^{hi}	3.23^{eg}	4.55^{n}	3.37^{gh}	4.21^{m}
	inter cropping	SOR/CP	3.72^{h}	5.58^{p}	4.65^{kl}	5.02^{n}	4^{kl}	5.63^{t}	4.17^{m}	5.21^{pqr}
	mono cropping	SOR	3.05^{e}	4.58^{kl}	3.8^{1h}	4.12^{ij}	3.24^{eg}	4.62^{o}	3.42^{gh}	4.27^{m}
OP	crop rotation	CP-SOR	2.63^{b}	3.94^{h}	3.29^{f}	3.55^{fg}	2.92^{bc}	3.98^{kl}	2.95^{bd}	3.68^{ij}
	crop rotation	DOL-SOR	2.49^{b}	3.74^{h}	3.11^{e}	3.36^{f}	2.68^{ab}	3.77^{ij}	2.79^{bc}	3.49^{gh}
	inter cropping	SOR/DOL	2.26^{a}	3.38^{f}	2.82^{bc}	3.04^{e}	2.42^{a}	3.41^{gh}	2.53^{a}	3.16^{de}
	inter cropping	SOR/CP	2.79^{bc}	4.18^{ij}	3.49^{fg}	3.77^{h}	3^{cd}	4.22^{m}	3.13^{de}	3.91^{jk}
	mono cropping	SOR	2.29^{a}	3.43^{f}	2.56^{b}	3.09^{e}	2.43^{a}	3.46^{gh}	2.86^{bc}	3.21^{eg}
TR	crop rotation	CP-SOR	5.26^{o}	7.89^{x}	6.57^{s}	7.1^{uv}	5.83^{u}	7.95^{z}	5.89^{u}	7.36^{x}
	crop rotation	DOL-SOR	4.98^{n}	7.47^{w}	6.23^{r}	6.72^{s}	5.37^{pqrs}	7.54^{y}	5.58^{t}	6.98^{w}
	inter cropping	SOR/DOL	4.51^{k}	6.77st	5.64^{p}	6.09^{q}	4.85^{p}	6.82^{w}	5.06^{pq}	6.32^{v}
	inter cropping	SOR/CP	5.58^{p}	8.37^{y}	6.97^{tu}	7.53^{w}	5.99^{u}	8.44^{z}	6.25^{v}	7.81^{z}
	mono cropping	SOR	4.58^{kl}	6.86st	5.72^{p}	6.18^{r}	4.86^{p}	6.92^{w}	5.13^{pq}	6.41^{v}

Legend: SOR-sorghum, DOL-dolichos, CP-chickpea, MRP-minjingu rock phosphate, FYM-farm yard manure, TR-tied ridges, FR-furrows and ridges, SRS-Short Rain Season, LRS-Long Rain Season. Means per season followed by the same letter are not significantly different at $P \leq 0.05$

The increased in soil moisture content with the application of MRP+FYM was attributed to addition of organic manure, which contributed to the maintenance of soil physical structure, and results in better soil moisture retention. Addition of organic inputs conserves rainwater, reduce runoff and improve the soil moisture content.

These conformed to the study by (Sugeet et al., 2011) and Lemlem (2012), who found that addition of Organic fertilizers improved soil water holding capacity. (Boateng et al., 2006) and Adeleye et al., 2010) also found out that higher levels of FYM increased the soil water content.

Control had significantly ($p \leq 0.05$) lowest soil moisture and this was attributed to the soils of the study site being naturally low in organic matter. Due to low residue returns and high temperature causing fast decomposition as well as reduced rainfall hence the low water holding capacity.

This conform with research by (Cornelis, 2006) who found out that soils of arid and semiarid zones are very susceptible of water erosion mostly due to the scarce vegetation cover, low organic matter content and the small resistance to the erosion forces.

Soil moisture reduced in the mono crop of sorghum in all tillage practices (Table 3) due to high evapotranspiration potential; on the contrary, soil moisture increased in the mono crop of sweet potato (Table 4) in all tillage practices due to low evapotranspiration potential. The sweet potato covers the ground adequately thus reducing direct losses from soil surface unlike in sorghum. Sweet potato provides good ground cover as reported by (Lusweti *et al.,* 1999).

There were significant ($p \leq 0.05$) increase in the soil moisture content under intercropping of sweet potato-Dolichos (8.44%), and sweet potatoes mono cropping (7.67%) therefore the water evaporation at soil surface was low and soil moisture retention high compared to intercrop of chickpea (6.44%) with the application FYM under tied ridges (Table 2).

Table 2: Effects of Soil Moisture Conservation Techniques on Soil Moisture Content (% Volume) in Sweet Potato Based Plots During Short Rain Season 2012 and Long Rain Season 2013

			Organic inputs SRS 2012				Organic inputs LRS 2013			
TP	CS		CTRL	FYM	MRP	MRP+FYM	CTRL	FYM	MRP	MRP+FYM
FR	crop rotation	CP-SP	3.5^{fg}	5.26^{o}	4.38^{k}	4.73^{lm}	3.89^{jk}	5.3^{pqrs}	3.93^{jk}	4.91^{p}
	crop rotation	DOL-SP	3.32^{f}	4.98^{n}	4.15^{ij}	4.48^{k}	3.58^{hi}	5.02^{pq}	3.72^{ij}	4.65^{o}
	inter cropping	SP/DOL	3.01^{e}	4.5^{1k}	3.76^{h}	4.06^{hi}	3.23^{eg}	4.55^{n}	3.37^{gh}	4.21^{m}
	inter cropping	SPCP	3.72^{h}	5.58^{p}	4.65^{kl}	5.02^{n}	4^{kl}	5.63^{t}	4.17^{m}	5.21^{pqr}
	mono cropping	SP	3.05^{e}	4.58^{kl}	3.81^{h}	4.12^{ij}	3.24^{eg}	4.62^{o}	3.42^{gh}	4.27^{m}
OP	crop rotation	CP-SP	2.63^{b}	3.94^{h}	3.29^{f}	3.55^{fg}	2.92^{bc}	3.98^{kl}	2.95^{bd}	3.68^{ij}
	crop rotation	DOL-SP	2.49^{b}	3.74^{h}	3.11^{e}	3.36^{f}	2.68^{ab}	3.77^{ij}	2.79^{bc}	3.49^{gh}
	inter cropping	SP/DOL	2.26^{a}	3.38^{f}	2.82^{bc}	3.04^{e}	2.42^{a}	3.41^{gh}	2.53^{a}	3.16^{de}
	inter cropping	SPCP	2.79^{bc}	4.18^{ij}	3.49^{fg}	3.77^{h}	3^{cd}	4.22^{m}	$3.13d^{e}$	3.91^{jk}
	mono cropping	SP	2.29^{a}	3.43^{f}	2.56^{b}	3.09^{e}	2.43^{a}	3.46^{gh}	2.86^{bc}	3.21^{eg}
TR	crop rotation	CP-SP	5.26^{o}	7.89^{x}	6.57^{s}	7.1^{uv}	5.83^{u}	7.95^{z}	5.89^{u}	7.36^{x}
	crop rotation	DOL-SP	4.98^{n}	7.47^{w}	6.23^{r}	6.72^{s}	5.37^{pqrs}	7.54^{y}	5.58^{t}	6.98^{w}
	inter cropping	SP/DOL	4.51^{k}	6.77^{st}	5.64^{p}	6.09^{q}	4.85^{p}	6.82^{w}	5.06^{pq}	6.32^{v}
	inter cropping	SPCP	5.58^{p}	8.37^{y}	6.97^{tu}	7.53^{w}	5.99^{u}	8.44^{z}	6.25^{v}	7.81^{z}
	mono cropping	SP	4.58^{kl}	6.86^{st}	5.72^{p}	6.18^{r}	4.86^{p}	6.92^{w}	$5.13p^{q}$	6.41^{v}

This was due to adequate ground cover provided In addition, distribution of root systems among species and cropping system influenced the soil moisture content in that when crops are intercropped the distribution of the roots in the soil is more intense as opposed to mono cropping.

Ogindo and Walker (2005) also observed that under intercropping, water conservation was largely due to early high leaf area index and higher leaf area.

Intercropping has also been reported Ghanbari *et al. (*2010) to reduce water evaporation, and improve soil moisture conservation compared with sole cropping

This conformed to the results by KARI (2005) who stated that there is a positive effect of the tied ridges and furrows and ridges in conservation of soil moisture and prolonged moisture availability in arid and semi-arid regions due to reduced soil loss through erosion and runoff.

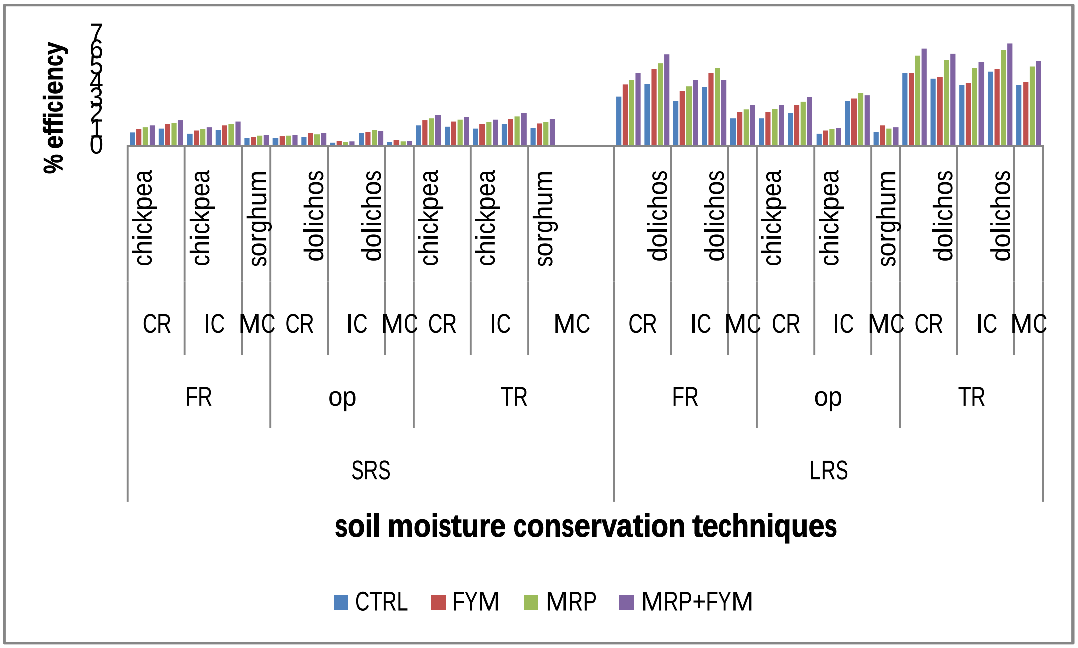
The results also conformed to study by Vogel *et al. (*1994) who found out that moisture conservation method such as tied ridges and furrows and ridges contribute to increased infiltration, reduction of run-off and increasing rooting volume in shallow soils.

3 Efficiency of Moisture Conservation Techniques

Tied ridges under intercrop dolichos and sorghum with the application of FYM were found to be the most efficient techniques for moisture conservation with a (6.73%) a during the long rain season whereas oxen plough showed very poor efficiency (3.2%) (Fig.1).

Figure 1: Efficiency of Combined Tillage Practices, Cropping Systems and Organic Inputs on Soil Moisture Retention Under Sorghum Based Plots

Legend: CR-crop rotation, IC-intercroppin



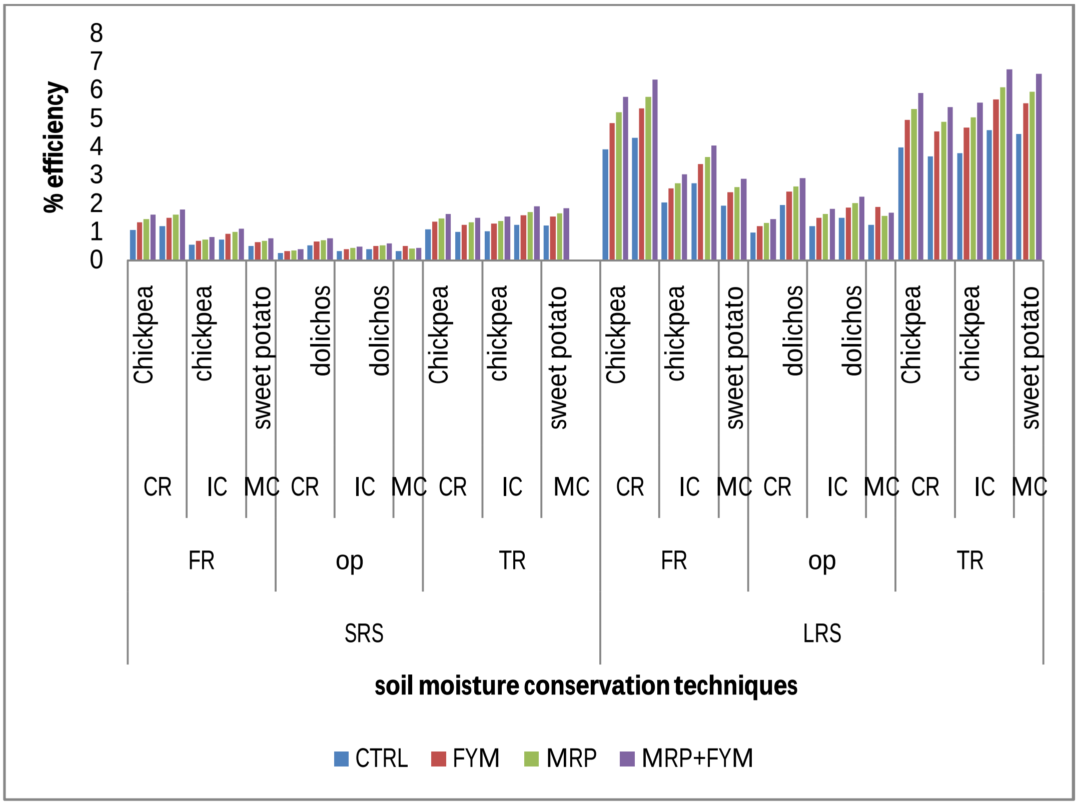
g, Mc-Mono cropping, CTRL-control, FR-furrows and Ridges, FYM-farm yard, MRP-minjingu rock phosphate OP-oxen plough, LRS-long rain season, SRS-short rain season

The improved efficiency recorded was attributed to tied ridges allowed rainwater to be retained on the furrows for longer duration and reduced evapotranspiration under intercropping and moisture conservation by the application of FYM thus proving to be more effective in conserving the soil moisture.

Itabari *et al*., (2003) made similar observation that furrows and ridges and tied ridges favored prolonged rainwater infiltration and retention, thus raising the overall soil moisture retention and soil water holding capacity.

Sweet potato intercropping with dolichos under tied ridges with the application of FYM +MRP was efficient techniques for moisture conservation (Fig. 2) the same trend was observed during the long rain season.

Figure 2: Efficiency of Combined Tillage Practices, Cropping Systems and Organic Inputs on Soil Moisture Retention Under Sweet Potato Based Plots



This was attributed to the improved ground cover and increased amount of organic matter in the soil ensuring reduced loss of soil moisture through evapotranspiration. In addition improved ground cover results into improved soil structure and reduced water losses through soil erosion.

This conformed to the observation by Crusciol *et al.* (2005) who reported that rotation and intercropping of crops with species that increase plant residues on the soil surface is fundamental to avoid erosion.

The soil moisture conservation techniques were more efficient in the long rain season as compared to the short rain season but the same trend was observed with more efficiency under tied ridges; Intercrop of dolichos with the application of MRP+FYM as the most efficient techniques for moisture conservation.

This was due to prolonged rainfall during the second season as opposed to the first season, which led to increased soil moisture content. This resulted into an increased biomass, which further increased the moisture content by reducing the evapotranspiration and erosion, hence increased percolation.

Conclusion

A combination of tied ridges with intercrop of Dolichos with sorghum and sweet potato and the application of MRP+FYM are viable methods for soil moisture conservation in the semi-arid areas of Yatta Sub County.

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