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EFFECT OF WATER HARVESTING TECHNIQUES ON GRAIN YIELD AND ABOVE GROUND BIOMASS OF COWPEA

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Abstract

Purpose: The purpose of this study was to determine the effect of water harvesting techniques on grain yield and above ground biomass of cowpea.

Methodology:A randomized complete block design was used.Field experiments were conducted.The study was conducted at Agriculture demonstration farm (Dakabaricha) and Yayo's farm(Nagayo) and a private farm Demo farm.There were 18 treatment combinations consisting of three water harvesting techniques and two intra-row spacing.

Results: Results indicate that the use of proper water conservation practice is imperative on areas like the Dakabaricha and Nagayo division of marsabit district.In line with the above ground biomass, tied ridges with a spacing of 60 x 20cm planting could be safely recommended as the first and effective type of water harvesting techniques for use as a means of soil and water conservation for rain-fed cowpea under the prevailing conditions.The results of the study also showed that water harvesting techniques had a significant effect on the growth and yield of cowpea (Katumani K80). A pronounced effect was observed for leaf production, plant heights, number of pods per plant, number of seeds per pod and overall shoot yield.

Unique Contribution to Theory, Practice and Policy: Farmers are encourage to give more emphasis to water harvesting techniques in situ and drought tolerant crops (DTC) which are high yielding in order to boost the economic of the resource poor residence in the area through capacity building.

Keywords:*Water harvesting techniques, grain yield, above ground biomass.*

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INTRODUCTION

The greater Marsabit District is situated in Northern Kenya, Eastern Province. It borders the Federal Republic of Ethiopia to the North, Moyale District to the North East, Turkana District to the West, Samburu District to the South and Isiolo and Wajir Districts to the East respectively. The district lies between latitude 01^{o} 15' and 04^{o} 27'North and longitude 36° 03'and 38° 59' East.The district is approximately 61,590km^2 in size and has a population of 187,367 people in 40,333 households. Marsabit district is home to approximately 1.1 million shoats, 200,000 cattle, 160,000 camels and 40,000 donkeys. Marsabit Central has a population of 46,502 people (KNBS, 2009).

Agricultural activities are concentrated around Marsabit Central District where between 20-30% of the land is under farming. The main crops grown are maize, beans, wheat, sorghum, millet, teff and cowpeas. Thirty five percent of the land area is considered to have high agricultural potential (GOK 2002, LRMP 2010). However, agricultural development has been slow and is not being fully encouraged because areas with a high agricultural potential also serve as important water catchment areas, national parks and forest reserves. The small fraction used to grow crops is competing with *khat* (miraa) growing which is an economically important stimulant in the region. Miraa is an immediate cash earner especially to the resource poor farmers in the region. A kilogram of miraa costs about 300 kenya shilings (4$). According to a miraa business dealer interviewed, approximately ten people can buy from her every day at cost of 300 kenya shilings (4$) translating into 3,000 shilings (40$) per day. Water harvesting techniques have not been practiced in the region due to lack of technical knowhow on the role drought tolerant crops and water harvesting techniques play. Cowpea is grown at small scale usually intercrop with maize in the district.

The soils in Marsabit Central are generally red loam clay soils which are slightly acidic with moderate levels of the major macronutrients (Muya et al, 2010). The area receive low and erratic annual rainfall which ranges from 400mm to 600mm with maximum and minimum temperaures of 27^{0}c and 20^{0}c respectively (Muya *et al*, 2010). The rainfall distribution is bimodal where short rains are normally during the November-December while long rains in April-May (Borghesio 2004). The climate of the area is arid and semi-arid zone.

Most of the communities practicing crop production in Marsabit central were either previously pastoralist who have limited farming skills or moved in from the Ethiopian highlands where the climatic conditions are humid. Therefore they do not grow the most appropriate crops nor do they practice water harvesting technologies suitable for semi-arid areas (Muya et al., 2010). In most of the region within the proposed study area, farmers are practicing mixed farming where farmers integrate livestock rearing with small scale farming involving the use of highbrid maize and beans. This study therefore seeks to evaluate the performance of a known drought tolerant crop i.e. cowpea under different water harvesting technologies so as to generate information for assisting the communities and policy makers to improve the agricultural production within the District. The idea of the use of drought tolerant crop has been necessitated by global warming. Climate change has interfered with the rainfall pattern in the region. The long and short rains are no longer predictable which has motivated the use of drought tolerant crop coupled with water harvesting techniques. The water harvesting techniques are simple to construct by the peasant farmer and are cost effective as well.

Problem Statement

Marsabit central district faces persistent food insecurity despite the relatively good agro climatic conditions found in the area. One of the most limiting factors to optimal crop production is water scarcity occasioned by poor and unreliable rainfall. On-farm water harvesting has been shown to increase the yields of maize in parts of Machakos District where rainfall is also low. However the effect of such water harvesting techniques on the performance of cowpeas in Marsabit Central District is not well understood.

Pastoralism and communal small scale farming is the chief source of livelihood in the Marsabit Central but the rain fed agriculture is highly vulnerable to the vagaries of climate change which calls for water conservation techniques and drought tolerant crops to meet the demands of the residence of Marsabit Central (Warui, 2000). This is worsened by the fact that the area is an agricultural marginal area and has a fragile ecosystem. Physical presence of relief agencies almost yearly to provide food handouts is now a common phenomenon which provides evidence that agricultural production has drastically fallen as farmers cannot produce enough to meet their daily subsistence food requirements.

The mountain region within the central division receives higher rainfall of between 400 – 800mm as compared to the riverine with 180 – 200mm (Lost Crops of Africa, 2006). Conservation of soil moisture within this range of rainfall can give good yield. The use of highbrid varieties of maize have been tested in the region but was not adopted by farmers due to lack of water in the soil. Limited literature is available on the use of water harvesting techniques in Marsabit Central for crop production. It is therefore envisaged that water harvesting techniques are not well understood by farmers in the County. It is for this reason that this study is conducted to determine the effect of water harvesting techniques on cowpea production in Marsabit Central.

Objective of the Study

The objective of the study was to determine the effect of water harvesting techniques on grain yield and above ground biomass of cowpea.

LITERATURE REVIEW

Rainwater harvesting is broadly defined as the collection and concentration of runoff for productive purposes such as crop, fodder, pasture or trees production, livestock and domestic water supply in arid and semi-arid regions (Macartney et al.,1971). Its ability to withstand drought, short growing period and multi-purpose use make cowpea a very attractive alternative for farmers in marginal, drought-prone areas with low rainfall and less developed irrigation systems (Dutt*et al*., 1981).

Recent studies (Reij and Waters-Bayer 2001; Bittar 2001; Abbay et al. 2000, Critchley et al. 1999; Hatibu and Mahoo 2000) have shown the emergence of success cases of rain-fed agriculture in East Africa, which are transforming the lives of many poor farmers. Innovative and indigenous technologies have been applied to achieve improved yields. These have involved a wide diversity of interventions, ranging from integrated soil fertility management (Ndakidemi et al. 1999), soil and water conservation, rainwater and runoff harvesting systems, integrated pest management, tillage and soil management systems, improved seeds, and innovative agronomic practices.

Africa is the only continent where food production per capita is less than the rate of population growth. Factors contributing to food insecurity have included delayed and erratic rains, and high costs of commercial fertilisers. Attempts to address the problems of delayed and erratic rains have included the construction of huge dams, which invariably ended up being used mainly for the production of non-food crops such as sugarcane. One possible means of mitigating the adverse effects of drought on food insecurity is on-farm rainwater harvesting. The concept and the practice of on-farm rainwater harvesting, which is the method of inducing, collecting, storing and conserving water is not new. It has been used traditionally for several years (Boers and Ben-Asher, 1982). Some of the earliest agricultural civilizations were based on rainwater harvesting.

Rainwater harvesting techniques such as tied-ridges, also known as cross bars, micro-basin tillage, boxed ridges, furrow diking, damming, infiltration pits or *fanya juus* and other techniques including rainwater from roof tops, have been used successfully is the Sahel and other regions (Mutekwa and Kusangaya, 2006; Semu-Banda, 2008). Higher water infiltration rates, less soil loss and higher crop yields have been reported for sorghum, maize and other crops with tied-ridges (Edje, 2006).

However, information on the use of tied-ridges for on-farm rainwater harvesting for crop production is scarce, hence the rationale for this study. Rainwater harvesting is broadly defined as the collection and concentration of runoff for productive purposes such as crop, fodder, pasture or trees production, livestock and domestic water supply in arid and semi-arid regions (Fentaw et al., 2002; Gould, 1999; Stott, 2001). Soil moisture is the foremost factor that limits the productivity of rainfed pulses where rainfall is the only source of water. To maintain required soil moisture in rainfed lands, every action must be focused to conserve as much quantity of rainfall in the soil as possible.

Conservation of rainwater through land configuration techniques like compartmental bunding, ridges and furrows, tied ridging and broad bed furrow will considerably scope for improve the soil moisture availability, which in turn can increase the crop growth and yield and finally sustain the food security of dry land farmers. The in situ soil moisture conservation techniques are location-specific and depend on the rainfall intensity, slope and texture of soil (Acharya and Hati, 2002). In alfisols, tied ridging has not only helped to reduce the runoff and soil loss but also increased crop yields (Selvaraju et al., 1999). Similarly, ridges and furrows were beneficial for pigeonpea growth and yield in alfisols (Okada et al., 1991)

Interest in water harvesting is growing in East Africa, as more people are beginning to realize that surface runoff is a resource as important as the rain, and that it can be used for sustainable crop production and/or livestock watering. Consequently, there has been a major development in a diverse range of technologies in water harvesting and conservation. This has been attributed, in part, to the transition from the imposed top-down rural development approaches to the more progressive adoption of community-based participatory approaches (Lundgren 1993). These have probably favored the development of the diversified set of runoff farming techniques. Today, one can see these techniques being used in various farming systems in the region.

RWH systems are also applicable over a wide range of conditions in areas where average annual rainfall is insufficient to meet the crop water requirement, with seasonal rainfall being as low as 100 to 350 mm (Oweis et al. 2001; Critchley and Siegert 1991; SIWI 2000). Innovations by progressive farmers seem common in the field of runoff farming (Mburu 2000; Kibwana 2001). Farmers observe the flow of surface water through their own watersheds, and based on experimentation on trial and error basis, sophisticated runoff farming systems are developed (SIWI 2001). This can, for example, be the tapping of sheet flow from roads, diversion of sheet flow from rocky areas adjacent to the farmland, or diversion of surface runoff from footpaths. Runoff farming systems play an important role in small-scale farming practices, which is explained by the fact that: (i) the techniques are easy to design, (ii) runoff volume is reasonably limited (sheet and rill runoff), which means that the farmer can control the inflow of water with little effort, and (iii) relatively simple methods and a significant volume of water can be added to crops during rainfall periods.

Lower amounts of rainfall are being received in most parts of the District, a phenomenon that could lead to great hardships for the population in this region. It thus becomes imperative to produce food with less water than was previously available. Use of ridges, a strategy that attempts to use less water but conserve economic returns could be adopted in the face of the present situation in Marsabit Central. Increased rainwater conservation coupled with reduced loss of soil moisture by ridges and furrows or tied ridges along with mulching resulted in favourable crop growth and increased total biomass (Cogle et al. (1997).

In-situ rain water harvesting, also called soil and water conservation, involves the use of methods that increase the amount of water stored in the soil profile by trapping or holding the rain where it falls (Hatibu & Mahoo, 1999; Stott et al., 2001). In this application there is no separation between the collection area and the storage area, the water is collected and stored where it is going to be utilized (UNEP, 1997).

In-situ rainwater harvesting involves small movements of rainwater as surface runoff, in order to concentrate the water where it is wanted most. It is basically a prevention of net runoff from a given cropped area by holding rain water and prolonging the time for infiltration. This system works better where the soil water holding capacity is large enough and the rainfall is equal or more than the crop water requirement, but moisture amount in the soil is restricted by the amount of infiltration and or deep percolation (Hatibu & Mahoo, 1999).

In-situ rainwater harvesting has been extensively used in western Africa, north-eastern Brazil, in the Chaco region of Paraguay and in Argentina. It can be used to augment the water supply for crops, livestock, and domestic use. Its practice is recommended for low topography areas, with small and variable volume of rainfall.

The technology has the following advantages: Minimal additional labor, flexibility of implementation, rainwater harvesting is compatible with agricultural best management practices, additional flexibility in soil utilization and as a way of recharging groundwater aquifers artificially. Slope of the land less than 5 %, impermeable soils and low topographic relief are the main requirements for its better performance (UNEP, 1997). The in-situ rainwater harvesting for crop production purposes is better achieved by the following means: Conservation tillage, conservation farming and conventional tillage. Where these biological soil conservation measures cannot be done to full effect, particularly in areas of high intensity storms, or where there are periods of poor crop cover, earth works (physical control measures) can provide surface protection by holding water to give it time to soak through the surface. Such physical conservation measures involve land shaping, the construction of contour bunds, terraces and ridges (FAO, 1993).

The practice of planting or seeding crops on ridge tops, along ridge sides, or in the furrow is ridge tillage. The ridges may have short cross ties to create a series of basins called tied-ridges for the purpose of storing water. Tied ridging system is therefore a special type of surface configuration whereby the ridges are "tied" to each other at regular intervals by cross-dams, thus blocking the furrow. The system can be used when surface run-off has to be prevented. The basic concept is a shovel dragged over the bottom of the furrow, collecting soil; a cross-dam is formed by lifting the shovel. Simpler units (also suitable for animal traction) operate a shovel attached to a frame which jumps at regular intervals as a result of the action of a triangular or off-center support wheel. Construction of tied ridges has been found to result in striking yield increases for cotton, maize, cowpeas, millet and sorghum in the semi-arid tropical areas of Africa. They have been used in Niger, Mali, Burkina Faso and other parts of West Africa where rainfall is scarce (Persaud, et al. 1985).

Tied ridging is also a useful technique for farming areas with poor soil physical properties, low fertility, and probable drought. The bunds increase water infiltration, improve soil physical properties, and decrease runoff and erosion. Consequently, fields with tied ridges have greater water storage capacity than either flat or open ridged fields. CIMMYT/ECAMAW initiated studies on soil moisture conservation in ECA in 1998 with the following broad objectives:

1) To evaluate and verify the response of different drought tolerant varieties to tie-ridging.

2) To demonstrate and promote large-scale soil moisture conservation for increased maize production and

3) To assess farmers' response and evaluate the economic return of tie ridging.

In Kenya and Tanzania, ridging is normally done for crops such as potatoes, tobacco, cowpea, groundnuts and even for maize (Assmo and Eriksson 1999). Ridging systems are mostly suited for areas with an annual rainfall ranging from 350 to 750 mm (Critchley and Siegert 1991). Among farmer innovators of East Africa, ridging has emerged as one innovation that has made a big difference in crop production (Kibwana 2000; Thomas and Mati 2000). In the semi-arid areas, tied ridges are made by modifying normal ridges. The technique involves digging major ridges that run across the predominant slope, and then creating smaller sub-ridges (or cross-ties) within the main furrows. The final effect is a series of small micro-basins that store rainwater in-situ, enhancing infiltration. Depending on the system, the crop is planted at the side of the main ridge, to be as close as possible to the harvested water while also avoiding waterlogging in case of prolonged rains. Tied ridges have been found to be very efficient in storing the rain water, which has resulted in substantial grain yield increase in some of the major dryland crops such as sorghum, maize, wheat, and mung beans in Ethiopia (Georgis and Takele 2000). The average grain yield increase (under tied ridges) ranged from 50 to over 100 percent when compared with the traditional practice.

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A study was done on the effect of tied ridges on soil water content, evapotranspiration, root growth and yield of cowpeas in the Sudan Savanna of Burkina Faso. The experimental treatments were ridges without (simple ridges) and with (tied ridges) earthen bunds constructed at right angles to the ridges at intervals of 1 m. Soil water content was measured gravimetrically at 0.15 m depth increments to a depth of 0.75 m. Root growth was measured with the core-break method. Tied ridges increased profile water content by an average of 30.5 and 24.6 mm per week in 1985 and 1986, respectively. Root growth was increased by tied ridging, although in 1986 when rainfall was above average there was a greater concentration of roots in the surface regions. Tied ridging increased grain yield by 51% in 1985 but had no significant effect in 1986 (Hulugalle 1987).

METHODOLOGY OF THE STUDY

The field experiments were conducted on short rain season of October to December 2012 under rain fed.The experiment was laid out in a randomized complete block design with three replications. The treatments consisted of two intra-row spacing of 60 and 45cm designated as S1 and S2 respectively and three water harvesting techniques namely: flat seed beds as a control, open ridges and tied ridges with cross bars at 2.5m interval, designated as W1, W2 and W3 respectively. Seeds were sown on rows of 20 cm apart; in intra-row spacing of 60 and 45cm.

RESULTS AND DISCUSSION

Yield parameters

Yield in cowpea is the result of many interacting yield components such as number of pods per plant, number of seeds per pod and mean seed weight. Yield and its components are affected by various factors including phonological development, planting date, genotypic differences and the environment (Gardener *et al*., 1985). The growth parameters under review included emergence, budding, flowering, podding and ripening.

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Table 1: Number of days to emergence, number of days to budding, number of days to 50% flowering, number of days to pod formation, number of days to physiological maturity of cowpea (k80)

Treatments.	Days to emergence.	Days to budding.	Days to flowering.	Days to podding.	Days to ripening.
W1/S1	4.50a	39.17c	62.00c	75.33c	97.50b
W1/S2	4.83a	39.33c	62.83c	76.00c	96.33b
W2/S1	4.43a	38.17b	57.33b	71.83b	95.83b
W2/S2	4.67a	38.50b	58.00b	73.50b	96.67b
W3/S1	4.40a	36.32a	55.81a	70.76a	94.03a
W3/S2	4.44a	36.68a	53.52a	70.07a	92.30a

Days to emergence

Field data from all the plots were observed from the date of sowing to the date when 50% of the plots have germinated and their averages were calculated and taken as the number of days to germination. This was a result of enough rain which was evenly distributed in all the plots despite the construction of water harvesting techniques. There was enough water available for the crop at all time during the season and therefore it was not easy to see the differences between the treatments.

From the ANOVA table the results indicates that there was no significant difference in number of days the crop took to germinate as a result of the different treatments ($P \leq 0.660$,) (table 2). There was enough water available for crops in all the treatments despite water harvesting techniques constructed in the farms. Both Flat seed beds and tied ridges equally received enough water since there was enough rain during this season. This was probably due to higher rainfall and lower temperature conditions during the growing season. These could have been the results of high rainfall and low temperature. The results are in accordance with that of Ahmad *et al.* (2001), who reported that high temperatures experienced during the growing season resulted in low yields and poor pod set.

Table 2: ANOVA for days to emergence

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Water harvesting techniques	0.389	2	0.194	0.422	0.660
Error	13.833	30	0.461		

a. R Squared = 0.076 (Adjusted R Squared = -0.078)

Data was observed and recorded from the date of emergence to the date when 50% of the plots have shown appearance of first flower buds. Their averages were computed and taken as the number of days it took for bud formation. The analysis from the summary table (Table 1) indicates that the tied ridges (W3/S1) took the shortest time to bud, with a mean of 36.32 days while flat seed beds (W1/S2) took long days to bud (39.33 days).

It was also evidence from the analysis of LSD table (Table 3) that there was asignificance difference between all the three water harvesting techniques ie Flat seed beds, Open ridges and Tied ridges ($P \leq 0.05$). it was observed that Tied ridges took less days to bud as compared to both Open ridges and Flat seed beds. According to the ANOVAwater harvesting techniques had a significant effect on the days to budding ($P \leq 0.000$).

Table 3: LSD for days to budding

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		0.917*	2.750*
Open ridges			1.833*
Tied ridges			

***The mean difference is significant at the 0.05 level**

Days to 50% flowering

Plots were observed and data recorded for the number of days taken from sowing to days when 50 per cent of the plants have showed anthesis (when the first flower opens) and their averages taken as the days to flower formation. From the summary table (Table 1), tied ridges (W3/S2) relatively took less number of days to flowering (53.52 days) compared to open ridges (W2/S2) (58.00 days) and flat seed beds (W1/S2) (62.83 days) which took longer days to attain 50% flowering. Ntare (1992) has shown that significant differences exist among cowpea cultivars in their ability to flower and set pods under high temperature regimes. The patterns of flowering and pod set showed that flowers formed in the first 10 days after initial flowering resulted in the highest percentage pod set. Potential pod set per plant ranged from 5 to 81%. Ntare (1992) found that there was considerable variation among cultivars in the duration of the reproductive period, crop growth rate and partitioning. Crop growth rate was largely responsible for differences in grain yield among cultivars.

When LSD was run, it was observed that all the water harvesting techniques were statistically different. However, Tied ridges took less days to flower.This might be ascribed to higher temperatures during planting in December and January, which was the onset of flowering.

Table 4: LSD for days to flowering

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		4.250*	7.750*
Open ridges			3.500*
Tied ridges			

*The mean difference is significant at the 0.05 level

Days to podding

Data was recorded for the number of days to pod formation from the date of sowing to the date when flowers fall off and pods formed from 50% of the plots. Their averages were calculated and taken as the days to pod formation. The analysis from the table 1 indicates that tied ridges relatively took less days to pod formation (70.42 days) while open ridges and flat seed beds took comparatively longer days respectively (72.67 and 75.67 days). The analysis of LSD shows that there was significance difference between all the water harvesting techniques under review.

Table 5: LSD for days to poding

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		3.000*	5.250*
Open ridges			2.250*
Tied ridges			

*The mean difference is significant at the 0.05 level

Days to 50% ripening

Field data were observed and recorderd for the number of days to ripening from date of emergence to the date when pods have matured (wilts) and become yellow and dry in 50% of the plots. Their averages were computed and taken as the number of days the crop took to mature. The average time taken to reach for 50% physiological maturity among different treatments varied from 92.30-97.50 days (Table 1). Tied ridges took less time to mature W3/S1,(92.30 days) compared to open ridges W2/S2,(96.67 days) and flat seed beds W1/S1,(97.50 days)

There was no statistical difference between Flat seed beds and open ridges and that Open ridges performed better than Flat seed beds. The treaments had a significance between Open ridges and

Tied ridges and LSD analysis indicates that Tied ridges performed better overall which will lead one to conclude that Tied ridges to be the best option among the treatments under review.

Table 6: LSD for days to ripening

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		0.667	3.750*
Open ridges			3.083*
Tied ridges			

*The mean difference is significant at the 0.05 level

Growth components

Table 7 summarizes the effect of varietal difference on plant height, number of leaves per plant, number of branches per plant, number of days to flowering, number of pods per plant and number of seeds per pod. The results indicates that Tied ridges perfomed genearlly better than other water harvesting techniques under review.

Table 7: Plant height, number of leaves per plant, number of branches per plant, number of pods per plant, number of seeds per pod of cowpea (Katumani K80)

Treatments.	Plant heights (cm)	Number of leaves per plant	Number of branches per plant	Number of pods per plant	Number of seeds per pod
WI/S1	152.61b	126.50b	10.08b	32.79c	13.60b
WI/S2	158.10b	126.81b	10.10b	32.88c	13.98b
W2/S1	155.36b	126.75b	10.34b	34.15b	14.01b
W2/S2	156.60b	127.28b	10.60b	43.45b	14.65b
W3/S1	161.78a	137.58a	12.42a	37.00a	16.30a
W3/S2	161.27a	135.28a	12.30a	36.42a	15.30a

Plant heights

The height of five plants in the net plot area was measured in centimeter using a tape measure from the base of the plant to the base of the fully opened youngest leaf of the twine and the average height of the plant was calculated and taken as the height of plants. Tied ridges had the highest plant heights with a mean average of 162.03cm and flat seed beds with the lowest plant heights (155.36cm) (Table 7). The analysis of LSD indicates that there were no statistical difference between Flat seed beds and Open ridges but there was a significance difference between Open and Tied ridges (Table 8). It was observed that Tied ridges performed better than open ridges and Flat seed beds.

Table 8: LSD for plant heights

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-1.333	-7.583*
Open ridges			-6.250*
Tied ridges			

*The mean difference is significant at the 0.05 level.

Number of leaves

The total number of fully opened green trifoliate leaves on the main stem and lateral branches of five plants was counted in each plot and their average was taken as the number of leaves per plant. Higher number of leaves were observed for Tied ridges as compared to Flat seed beds and open ridges. It can be deduced from table 7 that tied ridges had the highest number of leaves with mean average of 136.43cm followed by open ridges with mean of 127.01cm and finally flat seed beds with lowest means of 126.66cm.

There was no significance difference in the number of leaves between Flat seed beds and open ridges from different treatments as illustrated LSD tables. There was a significance difference between Tied ridges and Open ridges at the 0.05 level.

Table 9: LSD for number of leaves per plant

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-0.392	-9.725*
Open ridges			-9.333*
Tied ridges			

*The mean difference is significant at the 0.05 level.

Number of branches

Number of branches borne on the main stem of five plants was counted and their average was taken as the number of branches per plant. Tied ridges had comparatively a higher number of branches with a mean of 12.36 as compared to open ridges with a mean of 10.47 and flat seed beds with a mean of 10.09 (table 4.8). When LSD was run, it was found that there were no significant difference between open ridges and flat seed beds (0.333). it was also observed that there was significance difference between open ridges and tied ridges (Table 10). The higher

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water harvesting and retaining capacity of the furrows than the ridges and flat beds, as to supply the plants with enough available water throughout the growing period, might be responsible for the higher number of branches produced when the crop was planted in the tied ridges. The analysis indicates that water harvesting techniques had a significant influence on the number of branches.

Table 10: LSD for number of branches per plant

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-0.333	-2.267*
Open ridges			-1.933*
Tied ridges			

*The mean difference is significant at the 0.05 level.

Number of pods per plants

The pods from the randomly selected five plants from the net plots were counted and their average was taken as the number of pods per plant. The analysis from table 7, indicates that significantly higher number of pods per plant were noted on tied ridges (36.71plant^{-1}). Flat seed bed produced comparatively less number of pods per plant (32.83plant^{-1}). Results shows that tied ridges had the highest number of pods per plant as compared to the other water harvesting techniques under review. When LSD was run the results indicates that tied ridges performed overall better than both open ridges and Flat seed bed. It was also noted that there were significant difference between the three treatments under review (1.433*, 3.892*, 2.458*) as illustrated in table 11. The major reason being more water was colleted at the tied ridges which was available for crops use during water scarcity period. The traditional Flat seed beds perfomed poorly as compared to water harvesting techniques of tied and open ridges. The conserved water in the furrows improved soil structure and plant nutrition thereby leading to high number of pods per plants and high productivity.It is clear that increase in drought increased the days to flowering and thus fewer flowers were produced by cowpea. As a result the number of pods plant^{-1} was also decreased.

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Table 11: LSD for number of pods per plant

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-1.433*	-3.892*
Open ridges			-2.458*
Tied ridges			

*The mean difference is significant at the 0.05 level.

Number of seeds per pod

The seeds from five representative matured pods were separated and counted and their average was taken as the number of seeds per pod. Significantly higher number of seeds per pod was recorded in tied ridges with a mean average of 15.80 plants^{-1}. Less number of seeds per pod was collected from flat seed beds (13.79 plants^{-1}). Table 7 illustrates that Tied ridges had the highest number of seeds per pod as compared to both open ridges and flat seed beds.

When LSD was run, it showed that there are no statistical difference between Flat seed beds and open ridges (Table 12) . The analysis shows that open ridges performed better than Flat seed beds since the furrows constructed stored some water during the rainy season which was available for the plant use during the dry spell. It can also be deduced from the table of LSD that Tied ridges performed better than open ridges and that there was significance difference between the two. The tied ridges collected and stored more water for a while than open ridges where water was allowed to flow. This could be the reason why tied ridges performed better than both Flat seed beds and Open ridges.

Table 12: LSD for number of seeds per pod

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-0.500	-2.075*
Open ridges			-1.575*
Tied ridges			

*The mean difference is significant at the 0.05 level

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Effects of Water Harvesting Techniques on above Ground Biomass and Grain Yield.

Above ground biomass

Table 13 summarizes the effects of water harvesting techniques on above ground biomass yield and dry grain yield and their yield in hactare. It was evidence from the table that water harvesting techniques had a profound effects on the yields of cowpea. Tied ridges responded well to water harvesting techniques and gave the highest yield of 18732 kg/ha (above ground biomass).

Table 13: above ground biomass and dry grain yield of cowpea (k80)

Treatments	Above ground biomass Yield (kg)	Above ground yield (kg/ha)	Dry grain yield (kg)	Dry grain yield (kg/ha)
W1/S1	30.06b	12024	2.89b	1156
W1/S2	26.50b	10600	2.20b	880
W2/S1	35.39b	14156	2.85b	1140
W2/S2	26.62b	10648	2.78b	1112
W3/S1	46.83a	18732	3.52a	1408
W3/S2	36.06a	14424	3.24a	1296

The total fresh weight of five plants used for biometrical observations was collected and recorded and their average was taken as the fresh weight per plant (g). Oven dry weight (at 70 ^{0}C to a constant weight) after partitioning of whole plant into leaf, stem and reproductive parts of five plants was recorded. The sum of mean dry weight of all the plant parts represents total dry matter per plant (g). The respective mean dry weight of plant parts represents dry matter accumulation in leaf, stem and reproductive parts per plant (g). After harvesting the plants from the net plot area they were dried for three days under a shade and their weight was recorded and computed to kg per ha. The highest (46.83kgs) and lowest (26.50kgs) biomass yields of cowpea were obtained when the crops were planted in tied ridge (W3/S2) and the flat bed (W1/S2) planting treatments.

However, the above ground biomass yield recorded for open ridges was not significantly different when compared with the yield obtained from flat seed bed (3.52 kgs). The lowest yield of cowpea produced on the flat bed (traditional) planting method was highly significantly lower than the mean yields produced on other treatments, except on open ridges. There was a significant difference for Open ridges and Tied ridges as illustrated in the LSD table (Table 14).it can be deduce that Tied ridge performed better campared to both Flat seed bed and Open ridges.

The higher water harvesting and retaining capacity of the furrows than the open ridges and flat beds, as to supply the plants with enough available water throughout the growing period, might be responsible for the higher cowpea grain yields produced when the crop was planted in the tied ridges. Moreover, the higher cowpea yield production on tied ridges than in the open ridges suggests the optimum water retention capacity in the furrows. This was to be expected for the fact that the water conservation relaxes the soil moisture stress occurring as a result of the sparsely distributed and low total rainfall during the cropping season, which is often a typical characteristic of the region, and the drainage removes the excessive water (water lodging stress) retained by the soil. Furthermore, it should be expected that the benefits obtained from water harvesting will be much higher in regions and crop seasons with erratic and low total rainfall and with crops/varieties that are more sensitive to soil moisture deficit.

The reasons that have been advanced to explain similar yield conditions in the same experiment can also be applied to explain the higher above ground biomass yield records observed in furrow planting compared with ridge planting method and in closed end compared with open end tied ridges.

Table 14: LSD for above ground biomass

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-3.052	-13.508*
Open ridges			-10.457*
Tied ridges			

*The mean difference is significant at the 0.05 level

Grain yield

The pods harvested from each net plot area were dried thoroughly and separately. By beating with wooden sticks manually, seeds were separated, cleaned and sun dried thoroughly. The seed weight was recorded after attaining 8 to 9 per cent moisture and then computed to kg per ha. Table 12 summarizes the effects of water harvesting techniques on grain yield which indicates that among the treatments considered in the study, tide ridge (W3/S2) produced the highest cowpea grain yield (3.52 kgs) followed by open ridge (3.24 kgs) and flat seed bed (W1/S2) produced the lowest grain yield (2.54 kgs).

The analysis of LSD indicates that there were significance difference between Flat seed beds and Open ridges but there were significance difference between Open ridges and Tied ridges (Table 15) .The higher grain yields of cowpea recorded for tied ridges over open ridges and flat seed bed, respectively, are attributed to the higher water harvesting and retaining capacities of the former as compared to the latter treatments and the flat bed planting. Tied ridges gave more time to penetrate and infiltrate rain water than open ridges and flat beds and therefore allow crop plants to use the water that could have been lost as runoff. The impacts of tied ridges in improving crop growth and yield were significantly higher during crop seasons with low total rainfall and/or with poorly distributed rains. The different water harvesting techniques under review influence grain yield of cowpea significantly.

Table 15: LSD for dry grain yield

Water harvesting techniques	Flat seed beds	Open ridges	Tied ridges
Flat seed bed		-0.251	-0.808*
Open ridges			-0.558*
Tied ridges			

*The mean difference is significant at the 0.05 level

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Generally, the results indicate that the use of proper water conservation practice is imperative on areas like the Dakabaricha and Nagayo division of marsabit district, which is characterized by erratic and generally low total rainfall.

In line with the above ground biomass, tied ridges could be safely recommended as the first and effective type of water harvesting techniques for use as a means of soil and water conservation for rain-fed cowpea under the prevailing conditions.

The results of the study also showed that water harvesting techniques had a significant effect on the growth and yield of cowpea (Katumani K80). A pronounced effect was observed for leaf production, plant heights, number of pods per plant, number of seeds per pod and overall shoot yield. Thus in the production of cowpea as a source of leafy vegetable and animal fodder in dry lands would require that among other factors, the tied ridges for water conservation is given attention.

Recommendations

Farmers are encourage to give more emphasis to water harvesting techniques in situ and drought tolerant crops (DTC) which are high yielding in order to boost the economic of the resource poor residence in the area through capacity building.

Cowpea responded significantly to Tied ridges and produced a highest yield and therefore more research be done on testing of alternative crops in rain fed areas of Marsabit central e.g. cotton, root crops like cassava, sweet potatoes, and other cereals like wheat and barley which does well in a similar climatic conditions to diversify production base.

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