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Response of Sorghum Yield to Mulching and Planting Methods on Dry Land Areas of Tigray, Ethiopia

BY
Berhanu Arbissie Asmamaw[1] and Kidane Georgis[2]

1. Tigray Agricultural Research Institute, P.O.Box 492, Mekelle, Tigray, Ethiopia
E-mail: b_arbissie@yahoo.com

2. Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia
E-mail: kidanegeorgis@yahoo.com

ABSTRACT

The response of sorghum yield to mulching and planting methods was studied during 2006 main growing season of Alamata district, Tigray region. Treatments consisted of factorial combinations of five planting methods and three levels of sorghum stover mulch. The treatments were replicated three times in a randomized complete block design. Regardless of planting methods, there were77.1% and 99.6% advantage of grain and stover yield respectively due to tied-ridging over the control. Furthermore, sorghum planted in furrows and on top of ridges increased grain yield in the order of 98.3% and 41.6% and stover yield by 114.2% and 57.8% respectively over flat planting method. A grain yield increase in order of 14.5% and 25.9% and stover yield increase in order of 31.8% and 33.9% was obtained by applying 3 and 6 t/ha of mulch over the bare plot treatment respectively. In case of soil water content dynamics, the highest volumetric soil water content (VSWC) was obtained from the tied-ridges followed by open ridges over the flat tillage. VSWC was significantly greater under furrow planting and the lowest was observed in flat planting method. Like wise, soil surface covered with 3 and 6 t/ha mulch levels gave higher VSWC respectively over the no-mulch treatment.

Keywords: Mulching, Planting method, tied-ridges, Sorghum

INTRODUCTION

Sorghum was grown on more than 1.13 million hectares of land and gave a yield of around 15.5 million quintals of grain in Ethiopia. This makes the crop to be the third important cereal crop after tef and maize in total area as well as total production (CACC, 2002).

The arid and semi arid zone accounts about 61% of the total land area and 46% of the total arable land of Ethiopia. Substantial portion of the most important part of the country fall within the arid and semi-arid regions. Crop production is mainly practiced under rainfed conditions. In these areas, the average annual rain fall may be sufficient for successful growth of one or in some cases two crops in a year. However, the distribution of rainfall is highly variable and erratic with occasional runoff losses of water associated with heavy rainfall events contribute to the soil water deficits. As the result of this, prevalent dry spell is occurred at any time of the crop growth stage. The severities of these constraints are also amplified by high evapotranspiration, low organic matter content and low water holding capacity (Mitiku and Kidane, 1994). This problem leads to crop production instability and uncertainty with recurrent low crop production and occasional total crop failure to prevail in Alamata district. Therefore, the primary solution in such areas would be adoption of suitable technologies of soil and water conservation for effective crop production that can fit to the rainfall condition and edaphic characteristics of the area.

The most efficient and cheapest way of conserving rainfall is to hold it in in-situ. Evaporation loss can also be reduced greatly if rainfall is stored in the soil rather than in structure with a free water surface. Moreover, the water in the soil is readily available to plants (Reddy and Kidane, 1993). Among the different in-situ water harvesting technologies available, tied-ridges and mulch were found to be very effective in soil and water conservation and yield increase in many dry land areas of Ethiopia and also in other parts of the world (Huluf, 2003; Lal, 1977; Li *et al*., 2001).

Although some studies have been conducted on the effect of in-situ water harvesting especially using tied-ridging on the yield and yield attributes of sorghum, their interactive advantages, along with the other in-situ water harvesting methods such as mulching has not been intensively studied in the country in general and in the study area in particular. Therefore this study was designed to determine the effect of sorghum stover as mulch on different land formation and planting method that could maximize the productivity of sorghum.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted on farmers' training center located in Alamata district, during July-November main growing season of 2006. Alamata is located 600 km north of Addis Ababa on the main road to Mekelle and 182 km south of Mekelle (Tigray regional capital). The experimental site has an elevation of 1600 meter above sea level (m.a.s.l.) and lies at $12^{0}\,15'$ N latitude and $39^{0}\,35'$ E longitude. The site receives 663 mm mean annual rainfall that ranges from 400 mm to 700 mm. The rainfall in the area is very erratic and has a bimodal pattern. The short rains (belg) come from March to May and the main rains (Kremt) occurs from July to September. The mean annual minimum and maximum temperatures are 14.6 ^{O}C and 29 ^{O}C, respectively. In the study area, the lowest temperature occurs during January to February and the highest from June to September (Mullugeta, 2003). Eutric Vertisols, Lithic Leptosol (Cambic) and Lithic Leptosols (Orthic) are the soil types covering nearly 100% of the land in the woreda (RVDP, 1998).

Experimental design and treatments

The treatments consisted of a factorial combinations of five planting methods (flat planting, ridge planting on untied ridges, furrow planting between untied ridges, ridge planting on tied-ridges and furrow planting between tied ridges) and three rates of mulch (0 , 3 and 6 t/ha). Sorghum stover was chopped and spread manually as per treatments to the respective plots just after thinning of seedlings. Treatment combinations were laid out in a randomized complete block design (RCBD) with three replications. Each experimental plot was 5.25 X 5 m of seven rows of 0.75 m separated by alleyways of 1.5 m between blocks and 0.75 m between plots. A plant spacing of nearly 0.20 m was achieved by hand thinning 15 days after emergence.

Crop management

The land was properly ploughed with an ox and a ridge of 0.30 m height and a furrow width of 0.45 m were constructed manually using hand hoes 10 days prior to planting and cross tied as per the treatments with soil bunds across the ridges of 0.25 m height at 2.5 m intervals. Sorghum variety Gobiye, a striga resistant and early maturing type was planted on July 28, 2006. Planting was late due to less amount and poor distribution of rainfall received in July. All plots were fertilized uniformly with 46 kg N/ha and 20 kg P/ha using urea and diammonium phosphate respectively. Full dose of P and half of N were applied at the time of planting and the remaining half dose of nitrogen was side dressed 4 weeks after emergence. All other cultural practices were as per recommendations for the crop.

Measurment

Monthly total rainfall, minimum and maximum monthly temperatures of 2006 cropping season and also long term climatic data were collected from weather station located about 3 km away from the experimental site. Yield and yield component parameters including stover yield, grain yield and harvest index parameters were determined as the average weight at maturity only from sampling areas of each net plot.

Soil water content data were recorded at planting time, 50% flowering and physiological maturity stages. Soil water in 30 cm increments within the soil profile up to 90 cm was measured using gravimetric method from each plot in the central rows in two replications using a core sampler. This method was used to determine the soil water by subtracting oven dry weight of each sampled soils from the fresh weight sample of soils from each plot at depth of 0-30 cm, 31-60 cm and 61-90 cm in the respective plots (Hillel, 1980). Oven drying of soils was done at 105 ^{0}C for 24 hrs and the water content was determined as follows:

$$\theta m(\%) = \left[\frac{SWf - SWd}{SWd}\right] * 100 \quad \text{-------------------------------- (1)}$$

Where: $\theta m(\%) =$ Percent gravimetric soil water content

$SWf =$ Fresh soil water weight

$SWd =$ Oven dry soil weight

The gravimetric soil water content was converted to the volumetric basis and calculated by multiplying the gravimetric water content with the average bulk density of soil cores taken from each depth (Hillel, 1980). Bulk density was determined as a ratio of mass to volume of soil cores (0-30, 31-60 and 61-90 cm) (Hillel, 1980) from undisturbed soil collected by core samplers of specific length and diameter from each depth of soil.

$$\theta v(\%) = \theta m(\%) * \frac{\rho b}{\rho w} \quad \text{--- (2)}$$

$$\rho b = \frac{SWd}{Vc} \quad \text{--- (3)}$$

Where: $\theta v(\%) =$ Percent volumetric soil moisture content

$\theta m(\%) =$ Percent gravimetric soil moisture content

ρb = Bulk density (g/cm^3)

ρw = Density of water (g/cm^3)

SWd = Oven dry soil weight (g)

Vc = Volume of core sampler (cm^3)

A total of fifteen sub-samples (three soil samples from each sampling point) were collected with auger from the entire experimental field up to 30 cm depth to analyze some selected physio-chemical properties of the soil before planting. The analysis was made at Tigray regional soil laboratory. Particle size distribution or soil texture was determined by hydrometer method following the standard procedures using sodium hexa metaphasphate as dispersing agent (Day, 1965). The composite soil sample were analyzed for soil pH by means of pH meter in a suspension of a 1:2.5 soil to water ratio as described by Jackson (1958), Soil N using Kjeeldahl method (Bremner and Mulvaney, 1982) and available Phosphorus using Spectrophotometer from extracts obtained following the Olsen extraction method (Olsen *et al*., 1954). Organic carbon was also determined following the wet digestion methods as described by Walkley and Black (1934).

All data were subjected to analysis of variance (ANOVA) following a procedure appropriate to a factorial experiment in randomized complete block design (Gomez and Gomez, 1984) using MSTAT-C statistical software. Duncan's Multiple Range Test (DMRT) was used for mean separation.

RESULTS AND DISCUSSION

Pre-sowing surface soil properties

The pre-plant composite surface soil sample (0-30 cm) collected from the experimental site was analyzed for some selected physcio-chemical properties of the soil. The soil analysis indicated the textural class of the soil as clay loam (34% sand, 32% silt and 34% clay) with the soil pH value of 7.82 (Table 1). In other studies, the pH of the soil was reported as 7.5 (RVDP, 1998) and 7.7 (Mulugeta, 2003) in a 1:1 soil water suspension. From the soil pH values, it is apparently clear that the level of alkalinity is increasing gradually within the last ten years. Total N content of the study area was 0.032, which is very low. The available P was 3.89 ppm which is below the limit of the low to normal P-status of the soil. The low organic Carbon content (1.9%) in surface soils of the study area obtained might be due to low biomass incorporation to the soil because of its use as a fuel and animal feed.

Table 1. Salient physical and chemical properties of the experimental soil

Soil pH	Total N (%)	Available P (ppm)	Organic carbon (%)	Particle size distribution (%)			Textural class
				Sand	Silt	Clay	
7.82	0.032	3.89	1.9	34	32	34	Clay loam

Climatic condition

The rain fall record during the year 1993-2005 of the cropping season from June-November of the study area was 515 mm while the rainfall record for the year 2006 was 440 mm and rain started late and had no uniform distribution and also ceased early (Figure 1 and Appendix Table 1 and 2). The rainfall distribution was good in the month of August, but terminated in third week (21 August). Rainfall distribution was however poor and less in amount at late growing stages of the crop (September- November). Generally, the rain in small amount during crop growing stage and further exaserpated by early cessation of rainfall before the crop maturity that leads to drought stress at reproductive stage.

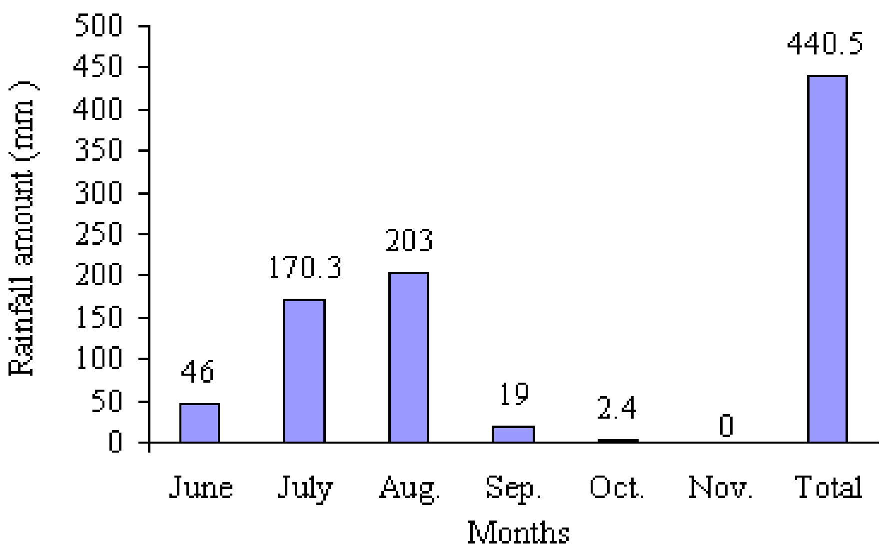


Figure 1: Monthly and total rainfall data of the year 2006 of Alamata meteorological station

The maximum and minimum annual mean temperatures were 29.6 ^{0}C and 16.5 ^{0}C respectively. The lowest temperature occurred during November to March and the highest temperature of the year coincided with the crop growing season from April to October (Figure 2). In addition to soil moisture deficit of the area, the subsequent high solar radiation during the crop growing sea-son (July-November) which brings high evapotranspiration loss, contributed for the depletion of soil water content and subsequent reduction in crop yield per hectare.

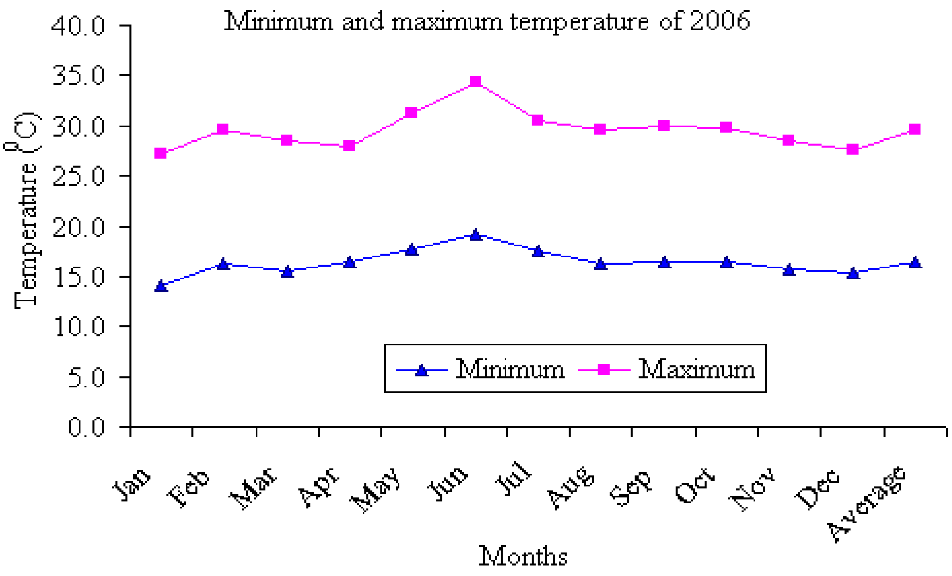
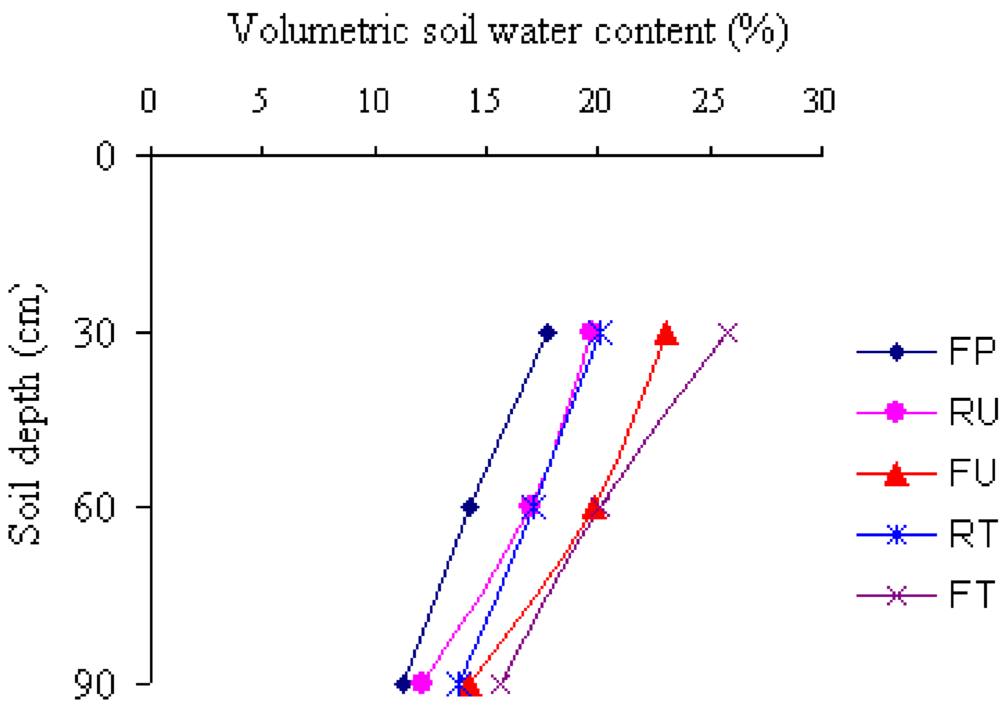


Figure 2. Monthly minimum and maximum temperatures the year 2006 main growing season of Alamata meteorological station

Soil Water Dynamics

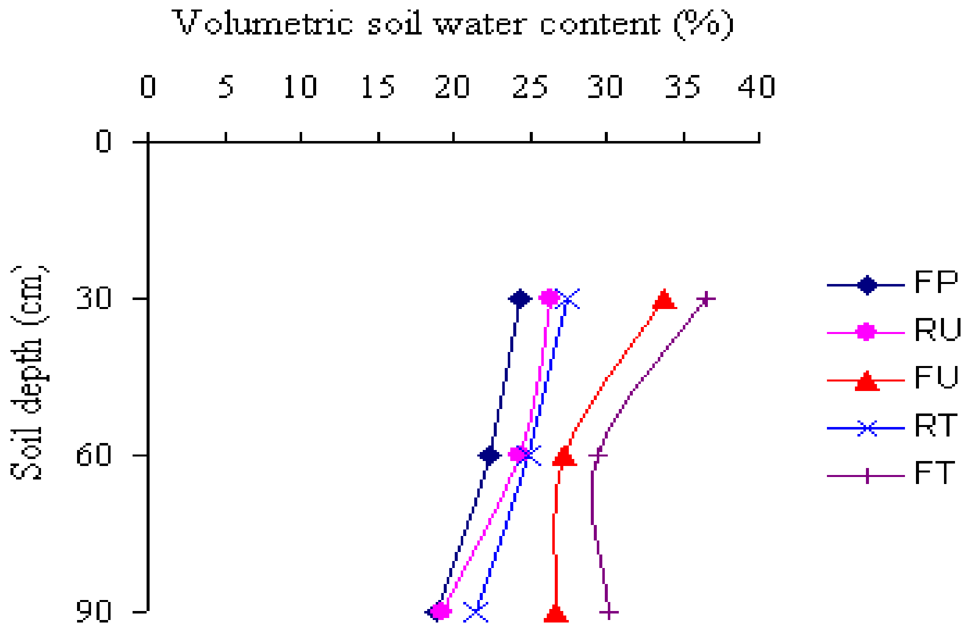
Soil profile water content was measured during the growing season at planting, flowering and physiological maturity for comparison of treatment effects on water harvesting. Volumetric soil water content (%) at time of planting ranged from 17-27.9, 14.2-22.5 and 11.3-17.4% in 0-30, 31-60 and 61-90 cm soil depths respectively (Figure 3 and Appendix table 4). The amount of soil water harvested due to in-situ water harvesting techniques and planting methods were highest in the upper layer (0-30 cm) followed by the middle (31-60cm) and the lower (61-90 cm) soil layers. Soil water content decreased as the soil depth increased.



Flat planting (FP), Ridge planting on untied ridges (RU), Furrow planting between untied ridges (FU), Ridge planting on tied ridges (RT) and Furrow planting between tied ridges (FT)

Figure 3. Changes in volumetric soil water content (%) with depth at planting as influenced by planting methods

Similar pattern of soil moisture content difference was observed at flowering stage of the crop, among treatments as of planting time. The highest was measured in the upper soil layer, followed by the mid-layer and the lowest in the deeper soil layer (Figure 4 and Appendix table 4). Among the planting method treatments, in each depth of the soil, tied and untied furrow planting method showed greater soil water content over flat bed planting and followed by tied and untied on ridge planting respectively.

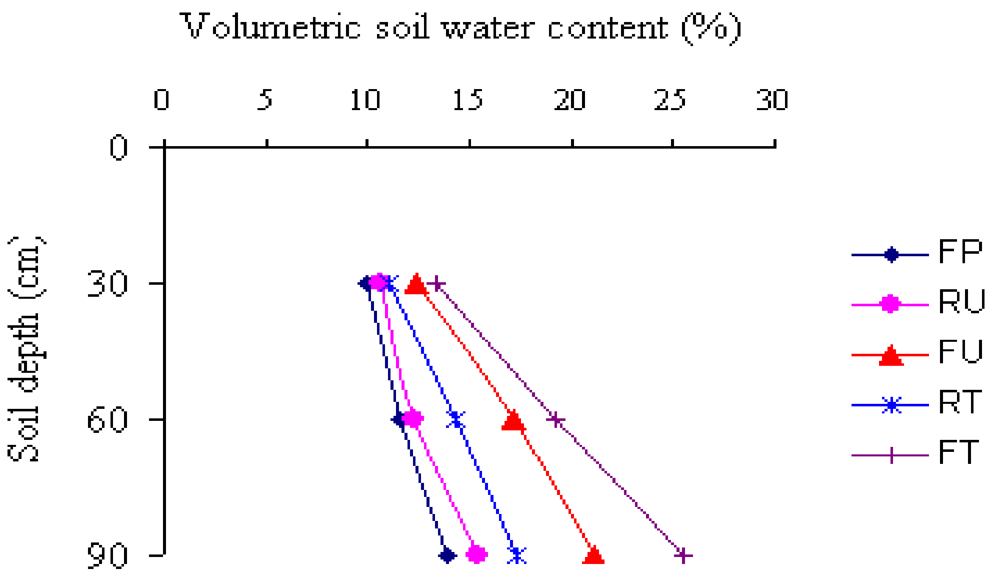


Flat planting (FP), Ridge planting on untied ridges (RU), Furrow planting between untied ridges (FU), Ridge planting on tied ridges (RT) and Furrow planting between tied ridges (FT)

Figure 4. Changes in volumetric soil water content (%) with depth at flowering as influenced by planting methods.

Further, due to soil drying at physiological maturity, most of the moisture content had depleted in the upper soil surface as compared to that at planting and flowering stages of the crop. Accordingly, the lowest soil water in each depth of soil layer (Figure 5) was recorded at this stage of the crop growth. Of all types of planting methods used, lowest changes in soil moisture trend in each depth of soil were observed when sorghum was planted in flat bed. Whereas higher soil water was found in each soil depths when planting was performed in furrow followed by on ridge planting methods.

Soil moisture content determined at physiological maturity of the crop was extremely low at each depths of soil layer because of the prevailing dry period. But the extent of depletion was higher in the upper soil layer, intermediate in middle soil depth layer (Figure 5 and Appendix Table 4).

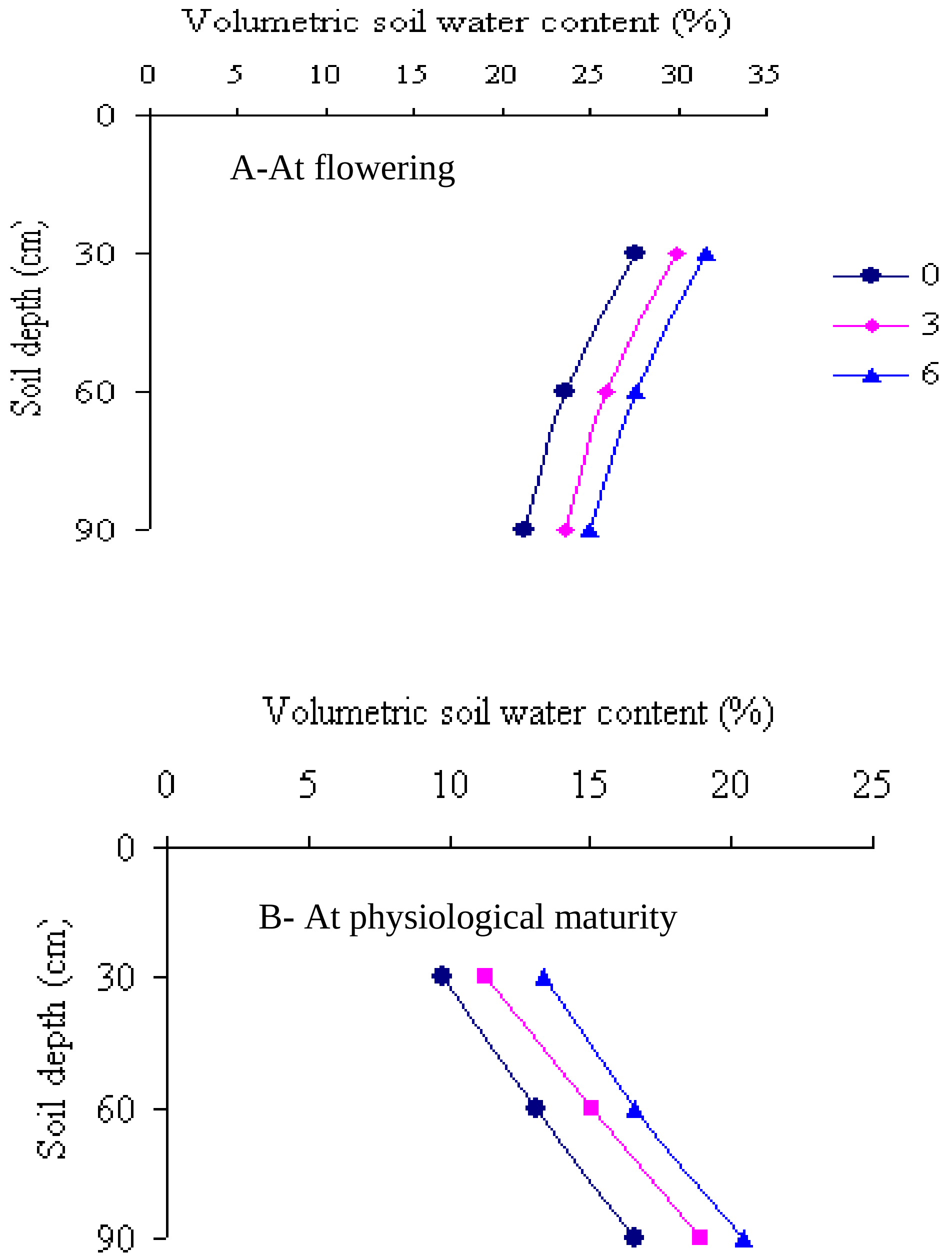


Flat planting (FP), Ridge planting on untied ridges (RU), Furrow planting between untied ridges (FU), Ridge planting on tied ridges (RT) and Furrow planting between tied ridges (FT)

Figure 5. Changes in volumetric soil water content (%) with depth at physiological maturity as influenced by planting methods

The effect of sorghum stover mulch on volumetric soil water content was illustrated in Figure 6. Irrespective of sampling time, the highest mean soil water content was recorded in plots received 6 t/ha followed by 3 t/ha sorghum stover mulch. The lower soil water content was obtained in plots when mulch application was nil.

Regardless of mulching rate, the lowest soil water content was recorded at the time of planting as compared to sampling taken at flowering stage. This was due to absence of early application of mulches. The significant role of mulching associated with in-situ water harvesting methods was clearly observed during the long dry spell period of the crop growth which occurred at physiological maturity. Due to absence of rainfall at this stage of the crop growth lower water content was recorded for the upper soil layers as compared to lower soil depth. Relative to the upper two soil depth layers, the last layer had significantly higher soil water content. This was due to mulching which facilitates the retention capacity of the soil and reduces evaporation losses.



No mulch (0), 3 t/ha mulch (3) and 6 t/ha mulch (6)

Figure 6: Changes in volumetric soil water content (%) at flowering (A) and physiological maturity (B) as influenced by mulching rates

Yield and Yield Components

Grain yield per hectare

Significant difference in grain yield of sorghum was obtained among different treatments (Table 2). It was significantly influenced by in-situ water harvesting techniques with planting methods. The lowest mean average sorghum grain yield in the study was obtained on the flat bed (1128 kg) as compared to the highest mean averaged sorghum grain yield recorded in the furrow planting between tied-ridges (2312 kg/ha), followed by untied furrow planting type (2162 kg/ha). The percentage increment in grain yield of sorghum against the flat plot for FT, RT, FU and RU were 104.99%, 49.16%, 91.64% and 33.95% respectively. Within the same planting methods, tied-ridges gave higher yield of sorghum over open ridges and flat beds. Similarly, regardless of the in-situ water conservation methods used, furrow planting method (2237 kg/ha) showed higher grain yield of sorghum than on ridge (1597 kg/ha) and flat bed (1128 kg/ha) planting methods.

This result agrees with those of Asfaw et *al*. (1998) and Huluf (2003). They attributed the higher grain yield obtained to soil and moisture conservation schemes that reduced run off and allow prolonged time of rain water on the plots to penetrate into the soil which will likely improve grain yield. Birru (1982) also reported a similar finding that, planting in tied-ridges with furrow planting provides 3.4 t/ha crop yield over the other planting methods. Similarly, during below average rainfall season in Zimbabwe, a sorghum yield increment from 118 to 388 kg/ha because of tie-ridging was reported by Nyakatawa (1996).

In case of mulch treatments with planting methods, significantly highest grain yield of sorghum was observed in plots that as compared to flat planting received 6 t/ha and had an increase of 25.87%. The next higher grain yield record was also obtained in plots that received 3 t/ha sorghum stover mulch and showed an increase of about 14.47% over the plots with nil mulch application. Such increase in grain yield due to mulching was attributed to reduction in evaporation, improvement in permeability (which increase infiltration rate), reduce run off and reduction in soil losses and consequently results an increase in soil water content (Poesen *et al*., 1990; Valentin and Casenave, 1992).

Stover yield per hectare

The analysis of variance (Appendix Table 1) indicated that the main effect of planting methods and mulching rates influenced stover yield per ha significantly ($P \leq 0.01$) but their interaction was not significant. The highest mean stover yield was recorded in the tied-ridge with furrow (4565 kg/ha) planting and the lowest under traditional (flat bed) planting method (1987 kg/ha). The increase in stover yield per hectare obtained due to FT, FU, RT and RU planting methods showed significantly greater stover yield advantage over the yield recorded on the flat bed by 129.7%, 99.7%, 69.4% and 46.3% respectively.

Stover yield was also significantly ($P \leq 0.01$) influenced by different application of mulch rates. Though, no significant mean result was observed between 3 and 6 t/ha rates of mulch with average stover yield of 3689 kg/ha on 6 t/ha mulch plot as compared to plots received 3 t/ha mulch with stover yield of 3632 kg/ha.

Stover is also an important product highly needed by farmers in the dry land areas such as Alamata due to its alternative use as animal feed, house construction and fuel wood purposes. Any significant increase in this matter has a great value nearly equal as the grain yield.

Harvest index (HI)

From the analysis of variance (Appendix table 1.), HI was significantly ($P < 0.01$) influenced by planting methods. Among the five planting methods considered significantly lower harvest index was observed under flat bed planting methods. The contribution of FT, FU, RT and RU planting methods were 18.1%, 19.5%, 6.6% and 5% over FP respectively. However, variation in mulch application rates showed a non significant ($P > 0.05$) influence on HI. HI reflects the rate of dry matter partioning to the grain yield. Few grains and proportionally more vegetative plant part reduce HI (Ong and Monteith, 1982).

Table 2. Stover and grain yield as influenced by the main effect of planting methods and mulching rates

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index
Plating methods			
FP	1128	1987	0.26
RU	1511	2907	0.28
FU	2162	3969	0.31
RT	1683	3366	0.28
FT	2312	5365	0.31
SEM$\pm$	91	158	0.11
LSD ($P < 0.05$)	264	458	0.32
Mulching Rate (t/ha)			
0	1551	2755	0.29
3	1775	3632	0.28
6	1952	3689	0.29
SEM$\pm$	71	122	0.01
LSD ($P < 0.05$)	205	355	Ns
CV%	16	14	11.5

Flat planting (FP), Ridge planting on untied ridges (RU), Furrow planting between untied ridges (FU), Ridge planting on tied ridges (RT) and Furrow planting between tied ridges (FT)

CONCLUSIONS

In this study, tied ridge with furrow planting and application of 6 t/ha mulch generally gave better grain yields of sorghum. This advantage of tied ridges with furrow planting and 6 t/ha mulches might be due to more water accumulation in furrows, most probably by reducing soil water losses and evaporation which later allows to infiltrate down to the deeper soil profile and easily accessed by sorghum roots. Economic analysis should be considered to recommend the feasible treatment by justifying appropriate rate of cereal mulch which is a valuable product for the farmers in for various purposes.

Constructing of tied ridges manually may take nearly 26-30 work days per ha which was the likely reason for the low adoption rate of this technique by farmers. Therefore, it is important to provide farmers with simple tied ridge attached oxen plough implement with affordable price or on credit. In order to boost sorghum production in the semi-arid areas, in line with the implementation of better soil water conservation practices, selection of appropriate soil fertility enhancing practices to address soil fertility problem is of paramount importance.

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