Mulching and Tied Ridges as A Moisture Conservation Strategy to Improve the Yield of Sorghum (*Sorghum Bicolor*) in Semi-Arid Parts of Swaziland

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***Abstract*—** *An experiment was conducted to determine the effectiveness of soil moisture conservation techniques on improving sorghum yield in a semi-arid rural area of Swaziland. The four treatments were; planting sorghum on flat soil (F), planting on tied ridges (T), planting on mulched soil (M) and planting on a combination of tied ridges and mulch (TM). Sorghum planted on flat soil was used as control in the experiment. The sorghum variety 8625 was planted. The experiment was complete randomized design and each treatment was replicated three times. The parameters measured were; grain yield, total biomass yield, soil moisture suction and grain moisture content at harvest. The grain yields from all the other treatments (mulching, tied ridges, tied ridges with mulching) were higher than those of the control (flat planting). The grain yield from TM was the highest at an average of 10.002 tons/ha. It was significantly different from that of T and F ($p<0.05$). The grain yields for M, T and F were 8.790 tons/ha, 8.202 tons/ha and 6.785 tons/ha respectively. Total dry matter yield was the highest for TM, at 36.980 tons/ha. Soil moisture suction for TM was the lowest at 11.6 centibars, indicating that moisture was readily available to the crop for a longer period than all the other treatments. Grain moisture content for all the treatments was below 20%, and the mean grain moisture content for all the treatments were not significantly different ($p>0.05$). The results showed that a combination of tied ridges and mulching provided superior results in terms of grain yield, dry matter yield and soil moisture suction. Mulching and tied ridges also yielded results that were better than the control (F).*

***Keywords*— Mulching, semi-arid, sorghum, tied ridges.**

I. INTRODUCTION

Sorghum (*Sorghum bicolor*) is one of the widely grown cereal crops in Africa, and it is grown in marginal areas of the southern Africa where other crops such as maize would normally fail. It is known for thriving under soils generally classified as poor (Chisi, 2004). It is the fourth most important food crop globally in terms of sources of energy and protein in human nutrition and fifth on global production (Basavaraja *et al*., 2005). It is the second major food after maize that has C4 photosynthesis (Taylor, 2004). Industrially, the grain is used to manufacture wax, starch, syrup, alcohol, dextrose agar, edible oils and gluten feed (Gwari *et al*., 2006). As food, the grain is used in making fermented and non-fermented porridge and traditional dishes where it can be mixed with legumes (Muui *et al.*, 2013). Sorghum is one of the drought tolerant crops that may be adopted for areas with adverse climate conditions (Ottman and Oslen, 2009). The optimum temperature for the growth of sorghum is 27-32 °C. Sorghum production can be sustained under fluctuating rainfall conditions of approximately 400 mm to about 800 mm but can survive even in drought conditions of less than 300 mm annual rainfall (Du Plessis, 2008).

Mulch is any material placed on the soil surface to conserve moisture, lower soil temperatures around plant roots, prevent erosion and reduce weed growth. It can be derived from either organic or inorganic materials (Sinkeviciene et al, 2009). It is through the water that is retained under the mulches that this technique is able to achieve improved yields. However improper mulching materials and practices may have little, or negative impact on the crops planted (ISA, 2011). The practice of mulching has been proven to significantly improve the growing conditions of horticultural crops (Testahunegn et al., 2012). A good layer of mulch will help to preserve moisture and suppress weed germination (Cregg and Schutzki, 2009). A layer of about 7 to 10cm is appropriate for most organic mulches (Kwambe et al., 2005; Jauron, 2013).

Tie-ridges are a soil and moisture conservation structures that involve the construction of small rectangular basins formed within the furrow of cultivated fields mainly to increase storage and to allow more time for rainfall to infiltrate the soil (Wiyo *et al.*, 1999). The stored water can be usable to the plants for a longer period of time better than it can be used in a situation of runoff (Gichangi *et al*., 2012; Belenchew and Abera, 2010). Adoption of soil moisture conservation techniques such as tie-ridges and mulching has shown improved soil moisture retention in a wide range of environments (Balenchew and Abera, 2010).

The effectiveness of the moisture conservation techniques has not been widely investigated in Swaziland. This experiment intends to establish the most effective soil moisture conservation technique that may be suitable for sorghum production at a semi-arid region of Swaziland.

II. MATERIAL AND METHODOLOGY

The experiment was conducted at Dvokolwako a rural area in the semi-arid region of Swaziland (Fig 1). The long-term annual rainfall for the area ranges between 350 mm and 500 mm. The average temperature ranges from 28°C to 31°C. The area has been experiencing drastic climate variation over the years in terms of reduced and late onset of rainfall, which are not evenly distributed over the crop growing season. The predominant soils in the area are sandy loams with low water holding capacity.

Prior to conducting the experiment, soil samples were taken, and soils were analysed to determine soil pH and available nutrients. The soil pH was found to be 6.3, and the exchange acidity was 0.15 meq/100 g. The experiment was conducted between October 2014 and March 2015. A sorghum variety, PAN 8625 was used for the experiment. It is a high yielding and drought tolerant variety that is suitable to the semi-arid conditions of Swaziland. It contains tannin with a bitter taste that deters consumption by birds. It takes between 130 and 140 days to mature, with an average yield of 6.1 tons/ha (PANAGRI, 2013).

The Complete Randomized Design was used in the experiment with four treatments: planting on flat soil (F) and used as control, tied ridges (T), mulch (M) and tied ridges with mulch (TM). The ridges were made to be of 0.25m in height and the ties were at a height of 0.20m. A total of 12 (4m by 2m) plots were prepared and planted according to the described treatments. There were four rows of sorghum in each plot planted at a 0.90 m row spacing and 15cm plant spacing. The sorghum seed was planted at a 50 mm soil depth. The grass mulch was evenly applied at thickness of 10 cm for mulched treatments.

The fertilizer added during planting, based on soil analysis contained Nitrogen, Phosphorus and Potassium at the rate of 16 kg/ha, 24 kg/ha and 16 kg/ha respectively. Nitrogen was applied as topdressing some six weeks after planting, at a rate of 14 kg/ha. Weed was controlled by hand weeding and using a hoe.

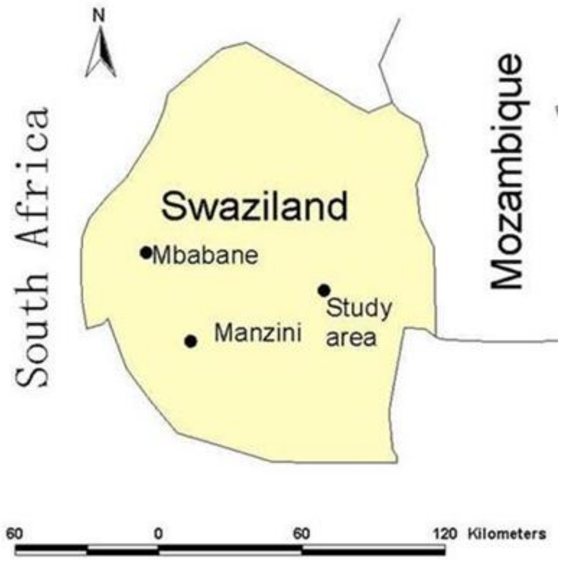

FIGURE 1: LOCATION OF STUDY AREA

The parameters collected during the experiment were total grain yield, total above ground dry matter, soil moisture suction and grain moisture content. Harvesting was done at 130 days after planting, by cutting the panicle from the plants and threshing to remove seeds from the panicle. The dry matter for each plot included the stem, panicle and seeds. The soil moisture retention was measured for seven days after each rainstorm using soil moisture probe (Soil Moisture Equipment Corp, 2011) that was inserted at 30 cm depth in the middle row for each plot. An MD7822 digital grain moisture meter (Ebay, 2013) was used to determine the moisture of grain at harvesting.

Data was analyzed using the IBM SPSS statistics version 20 analysis software (IBM, 2014). Variation among treatments was determined using the Wild Chi-square test and the means were separated using the least significant difference (LSD).

III. RESULTS AND DISCUSSIONS

The tied ridges + mulch (TM) treatment yielded the highest (10.022 tons/ha) grain. The mulch (M) and the tied ridges (T) treatments yielded 8.790 tons/ha and 8.203 tons/ha, respectively. Planting on flat soil (F) yielded the lowest (6.788 tons/ha) of grain (Table 1). Grain yield for the TM was significantly different from that of T and F ($p < 0.05$). The significant difference between these treatments is understood to be as a result of the moisture retention which was achieved as an effect of the mulching. Sorghum plants required moisture for development and production especially at the critical stages of growth such as flowering and seed formation.

The TM treatment also recorded the highest dry matter yield of 36.980 tons/ha. Average dry matter yields for M, T and F treatments were 32.081 tons/ha, 26.906 tons/ha and 22.212 tons/ha respectively. The dry matter yield for TM was significantly different from that of T and F ($p<0.05$). It was not significantly different to that of M ($p>0.05$). Sorghum stover is an important feed resource in smallholder crop/livestock production systems (Syomiti et al., 2011).

TABLE 1
AVERAGE GRAIN YIELD, DRY MATTER YIELD, SOIL MOISTURE SUCTION AND GRAIN MOISTURE CONTENT FOR DIFFERENT TREATMENTS

Treatment	Parameter*			
	Grain yield (tons/ha)	Dry matter yield (tons/ha)	Soil moisture suction (centibars)	Grain moisture content (%)
Mulching (M)	8.790^{a}	32.081^{a}	13	14.5
Tied ridge	8.202^{b}	26.906^{b}	12.1^{a}	13.9
Tied ridge + mulching (TM)	10.002^{bc}	36.980^{bc}	11.6^{b}	13.9
Flat bed	6.785^{ac}	22.212^{ac}	13.9^{ab}	14.1

***Parameters on same column with same symbol indicate that their means were significant different.**

The TM treatment recorded the lowest average soil moisture suction value of 11.6 centibars. This was an indication that moisture was retained in the soil for a longer period in the TM treatment, compared to the other treatments. The value was significantly different from that of treatment T, but not significantly different from that of treatments M and T. Treatment F recorded the lowest soil moisture retention, with an average moisture suction value of 13.9 centibars. The average soil moisture suction value for F was significantly different for treatments T and TM, but not with M.

The grain moisture content for the treatments varied from 13.9% to 14.5% (Table 1). The different between average grain moisture content for all the treatments was not significant ($p>0.05$). The moisture content was below the critical value of 20% for storage of grain (Paderes et al., 1996).

IV. CONCLUSION

Based on the results of this study, it can be concluded that the combination of tied ridges and mulch (TM) was effective in retaining soil moisture. The tied ridges and mulch treatment (TM) recorded the highest (11.6 centibars) average moisture content when compared to the other treatments. The effect of the moisture retention was significant on the sorghum yield as well. The tied ridges + mulch treatment (TM) also recorded the highest grain (10.022 tons/ha), and dry matter yield (36.768 tons/ha). The conservation of moisture using tied ridges and mulch in the semi-arid region of the country which receives comparatively less rainfall could have a positive effect on sorghum yield.

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