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Effect of Tied Ridging and Fertilizer on the Productivity of Sorghum [*Sorghum bicolor* (L.)Moench] at Raya Valley, Northern Ethiopia

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Abstract

Water deficit and poor fertility of soil are among the main constraints to sustain production of sorghum in the semi-arid regions of northern Ethiopia. Thus, one experiment was conducted to determine the appropriate tied-ridging practice and planting method that maximizes sorghum productivity under rainfed conditions. It was carried out in 2015 and 2016 cropping seasons. Treatments comprised flatbed planting as control; open tied ridge, furrow planting; open tied ridge, planting on ridges; closed tied ridge, furrow planting; and closed tied ridge, planting on ridges were tested separately under fertilized and unfertilized conditions. These treatments were laid out in Randomized Complete Block Design with three replications. According to the current result, days to heading, plant height and panicle length were not significantly ($P>0.05$) influenced while grain and biomass yields were significantly influenced in both fertilized and unfertilized conditions. Accordingly, the maximum grain yield (3226.70 - 4621.00 kg ha^{-1}) under fertilized and (2678.00 - 4318.80 kg ha^{-1}) unfertilized conditions was obtained from closed tied ridge with planting in furrow. Moreover, the highest biomass yield (6844.40 - 11471.00 kg ha^{-1}) was produced from closed tied ridge integrated with fertilizer in furrow planting. On the other hand, the minimum average yields were obtained from flat planting (farmers' practice) with and without fertilizer. It is concluded that closed tied ridge with planting in furrow can be recommended for sorghum growers in Raya Valley areas and other places with similar agro-ecologies to enhance sorghum yield.

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Introduction

Sorghum is produced in almost all regions of Ethiopia occupying an estimated total land area of 1.68 million ha with its national average productivity of 2369 kg ha^{-1}[1]. It is grown mainly as a rainfed crop in the semi-arid areas[1]. In these areas, where this crop has its most significant role as a cereal food crop, water deficit and poor soil fertility are the major biophysical constraints to sustain crop production[2]. The productivity of rainfed agriculture in the semi-arid regions of northern Ethiopia is limited by moisture stress[3]. Similarly, it was reported that low grain yield in this region is commonly associated with occurrence of intra-seasonal dry spells or droughts and rapid land degradation which adversely affect crop yields[4]. In semi-arid areas, rainfall is scarce, irregularly distributed and each season is different from one another. Moreover, the prevailing of high diurnal temperatures and high evaporations aggravate the effects of soil moisture deficit. In these areas, soil evaporation can reach 30-50% of the total rainfall leaving only 10-30% for crop due to the presence of high temperature[5]. Soil moisture conservation technologies are important for increasing crop production and productivity in the semi-arid areas. Water productivity in rainfed agriculture of the semi-arid environments can be improved by maximize plant water availability (maximize infiltration of rainfall, minimize unproductive water losses (evaporation), increase soil water holding capacity, maximize root depth and maximize water-uptake capacity of plants[6].

Previous experiences have shown that tied-ridge, which is a proven in-situ soil moisture conservation practice in semi-arid areas, increases grain yield by 50% have been reported in both Kobo and Melkassa by using this practice[7,8]. Response to fertilizer applications in the semi-aridareas was related to increasing rainfall and soil moisture availability[7]. Experimental evidences showed that combined use of tied ridges and fertilizer application resulted in sustainable increase in crop production as compared to using them alone in semi-arid areas of Ethiopia[9]. It has also been reported that in countries where agriculture is rainfed and subsistence, moisture conservation and increase water productivity through the application of conservation tillage is paramount[10].

Therefore, an experiment on sustainable and integrated use of tied ridging and fertilizer with other agronomic management practices was conducted to determine the appropriate tied ridging practices, thereby enhance productivity of sorghum in low moisture areas under fertilized and unfertilized conditions.

Materials and Methods

Site Description

The trial was conducted under rainfed conditions at Fachagama, which is a testing site of Mehoni Agricultural Research Center. It is situated at latitude of 12^{0}41’50” N and longitudes of 39^{0}42’08” E. It is found at 678 km to the north direction of Addis Ababa (capital city of Ethiopia) and is placed at an altitude of 1578 m above sea level (m.a.s.l)[11]. The experimental area has a long term average rainfall of 539.32 mm, and its average minimum and maximum annual temperature is 18 ^{0}C and 25 ^{0}C, respectively. The soil, which has a proportion of 15% sand, 27% silt, and 58% clay, is texturally classified as clay soil with a pH value of 6.89, which is neutral[12]. The soil also comprised total N of 0.1008%, which was low[13] and low available P (6.60 mg kg^{-1})[14]. The electrical conductivity of the soil (0.12 ds m^{-1}) showed non-saline soil15. The experimental site had a bulk density of 1.10g cm^{-3} and field capacity of 45.47% with permanent wilting point of 28.47%. Rainfall during the growing season of seven months was 406.20 and 350.00 mm in 2015 and 2016 cropping seasons, respectively, which is less than the long term average rainfall. Similarly, the mean minimum and maximum temperature during the growing season of seven months was 11.6 - 23.1^{0}C in the year 2015 and 12.2 - 23.6^{0}C in 2016 cropping seasons, respectively[16].

Treatments and Experimental Procedures

The treatments were arranged in a randomized complete block design with three replications. Improved sorghum variety (Meko-I) adapted to the area was used. Two separate trials, the first trial under tied-ridging with fertilizer andthe second one was under tied-ridging without fertilizer, were conducted for the same treatments. The treatments were flat bed planting as control; open tied ridge and furrow planting; open tied ridge and planting on ridges; closed tied ridge and furrow planting; and closed tied ridge and planting on ridges. Meko-I sorghum was planted in a plot size of 3.75m x 4m (15 m^2) with five rows at spacing of 75 cm between rows and 20 cm between plants within a row. Urea and Diammonium phosphate (DAP) were used as sources of nitrogen and phosphorus, respectively. Nitrogen at 41kg N ha^{-1} and phosphorus at 46 kg P_2O_5 ha^{-1} were applied to each treatments of the first trial (tied-ridging with fertilizer) where DAP was applied at planting time while 50% of the recommended urea during planting and the remained 50% urea was applied 35 days after planting at 7-10 cm away from the plant as two side dressing at about 5 cm below the surface. The ridges were made to be of 0.35m in height and the ties for closed end tied ridge treatments were at a height of 0.30m. Weeding, thinning, and hoeing practices were applied uniformly to the experimental field.

Data Collection and Analysis

Agronomic data such as days to 50% heading, 90% physiological maturity, plant height (cm), panicle length (cm), grain yield (kg ha^{-1}), and dry biomass yield (kg ha^{-1}) were collected and analyzed. The data were taken from central rows of a net plot area, where the two outer most rows of each plot were left as border effects. Similarly, 0.20 m length in both ends for intra row spacing of each harvestable row was left as border effects. Data of plant height and panicle length were collected from five pre tagged plants of net plot area. Dry matter yield was measured using an electronic balance (Mark: Sartorius; TUV product service; Schutzart IP65SARTORIUS AGGOTTIIUGEN, Germany) after the net plot area plants had been harvested and oven dried at 70^{0}C until constant dry weight was attained. Furthermore, grain yield was calculated using electronic sensitive balance (Mark: Sartorius; TUV product service; Schutzart IP65SARTORIUS AGGOTTIIUGEN, Germany) from the harvested plants of net plot area. These agronomic data were deployed to the analysis of variance (ANOVA) using the SAS software computer package version 9.0[17]. According to the standard procedure of Gomez and Gomez[18], significant mean difference among the treatments was computed with least significant difference (LSD) at 5% probability level.

Results and Discussion

Days to Heading

The results pertaining to days to 50% heading of sorghum did not differ due to tied ridging in both fertilized and unfertilized plots. This could be most likely due to equal contribution for optimum moisture

Table 1: Influence of Tied Ridging on Days to 90% Physiological Maturity of Sorghum under Fertilized and Non-Fertilized Conditions

Treatments	Days to maturity					
	With fertilizer			Without fertilizer		
	2015	2016	Pooled Mean	2015	2016	Pooled Mean
Flat planting	111.33	109.67c	110.5	109.33	101.67b	105.5
OET, P in F	111.33	113.00ab	112.67	110.33	104.00a	107.17
OET, P on R	111.67	110.33bc	111	110	101.33b	105.67
CET, P in F	112.33	114.33a	113.33	109.67	104.67a	107.17
CET, P on R	112	111.33ab	111.67	110.33	101.00b	105.67
CV (%)	1.03	1.51		1.14	1.08	
F-test	0.78	0.04		0.83	0.01	
LSD (5%)	NS	3.19		NS	2.09	

= statistically significant at 0.05 probability level; NS= non significant; Means with the same letter (s) in the same column are not significantly different at P<0.05; OET= Open tied ridge; P in F= furrow planting; P on R= planting on ridge; CET= closed tied ridge; LSD= least significant difference; CV= coefficient of variance.

supply by the treatments to the crop untilits heading date. Generally, its days to heading ranged from 63.00– 66.00 days starting from its planting time in the case of fertilized plots while under unfertilized plots, it took 60.00– 64.33 days. The a fore mentioned non-significance of results was due to moisture conservation practices in southern Ethiopia[19], showing that heading date of sorghum was not significantly varied by circular pitting, open ridge, tied ridge, half moon as well as farmers' practice (flatbed).

Physiological Maturity

This parameter was not significantly affected (P>0.05) by tied-ridging in 2015 cropping season while it was significantly influenced by tied ridging in 2016 cropping season regardless of fertilizer (Table 1). Sorghum planted in furrow under closed tied ridge took more time to mature in comparison of the other treatments as it conserved and sustained more moisture while flat planting of sorghum contributed for early maturity of the crop under fertilized condition. In the case of unfertilized plots, sorghum planted in furrow under open and closed tied ridging treatments matured late while the other treatments were significantly at par to mature sorghum earlier. This significant variation might be due to the effect of tied-ridge on retaining more water at plant root zone. These results are inconformity with the findings of another study in which noted that moisture conservation practices significantly affected days to maturity[19] and found that tied ridge is the best in situ moisture conservation practice that increased crop yield by enhancing soil moisture retention during the crop growing period.

Plant Height

Tied ridging practices did not give significant response (P>0.05) on plant height of sorghum in both cropping seasons under fertilized and unfertilized conditions. This could be because of the role of the treatments to supply optimum moisture needed for increment of plant height of sorghum. Plant height of sorghum ranged from 119.10 – 166.33 cm in the case of fertilized plots while under unfertilized plots, it ranged from 117.07– 162.00 cm. Numerically, the highest plant height was obtained from closed tied ridge and when sorghum was planted in furrow in both fertilized and un fertilized conditions. In contrast, research work done on different soil moisture practices at Southern Ethiopia; showed a high significant plant height (180 cm) was recorded due to the effect of tied ridge as compared to circular pitting, open ridge, half moon and farmers' practice (flatbed) practices[19].

Table 2: Mean grain yield of sorghum as influenced by tied ridging under fertilized and non-fertilized conditions

Treatments	Grain yield (kg ha^{-1})					
	With fertilizer			Without fertilizer		
	2015	2016	Pooled Mean	2015	2016	Pooled Mean
Flat planting	3870.40bc	2319.50c	3094.95	3307.80c	2107.70b	2707.75
OET, P in F	4292.90ab	3080.00ab	3686.45	3950.10ab	2629.10a	3289.6
OET, P on R	3706.50c	3074.60ab	3390.55	3570.00bc	2379.30ab	2974.65
CET, P in F	4621.00a	3226.70a	3923.85	4318.80a	2678.00a	3498.4
CET, P on R	4269.10ab	2515.10bc	3392.1	3771.30bc	2330.40ab	3050.85
CV (%)	5.47	12.11		7.45	7.97	
F-test	0.007	0.04		0.02	0.04	
LSD (5%)	427.36	648.37		530.62	363.8	

= statistically significant at 0.05, and 0.01 probability level, respectively; Means with the same letter (s) in the same column are not significantly different at P<0.05; OET= Open tied ridge; P in F=furrow planting; P on R= planting on ridge; CET= closed tied ridge; LSD= least significant difference; CV= coefficient of variance

Panicle Length

Tied ridging practices did not give significant response on panicle length of sorghum in both cropping seasons under fertilized and unfertilized conditions. Like to plant height, the reason could be due to the contribution of tied ridging practices to supply optimum moisture needed for increment of panicle length of sorghum. Sorghum produced a panicle length ranged from 21.67– 25.27 cm in the case of fertilized plots and under unfertilized plots, it ranged from 22.00– 24.13 cm. Even though statistically non-significant, the highest numerical value of panicle length was achieved from closed tied ridge integrated with furrow planting in both fertilized and unfertilized conditions. However, it was reported that significantly high panicle length (19.25 cm) of sorghum was obtained as a result of tied ridge19.

Grain Yield

Closed tied ridging integrated with planting in furrow gave significantly high grain yield in both cropping seasons under fertilized and non-fertilized plots (Table 2). Closed tied ridging integrated with furrow planting of sorghum over yield farmers practice (flat planting) under fertilized condition by 19.39 % in 2015 and 39.11% in 2016 cropping seasons. It was also analyzed that closed tied ridging integrated with furrow planting over yield farmers practice (flat planting) under unfertilized condition by 27.06% in 2015 and 30.56% in 2016 cropping seasons. This significant variation attributed to the effect of tied ridging on optimum moisture retention, which required for development and production especially at the critical stages of growth such as flowering and seed formation. This also created favorable condition to absorb water by sorghum plants planted in furrow. Other research works indicated that conservation tillage resulted in optimum moisture availability, improved soil fertility and better root growth which in turn increases yield[20]. Moreover, from the findings of study, which was conducted in the semi-arid areas of northern Ethiopia[21], the yield of sorghum showed increment by 7 to 48% due to the effect of conservation tillage integrated with fertilizers compared to the traditional tillage. According to the results of the fore said study, tied-ridging and fertilizer interaction significantly influenced the yield of sorghum and resulted in up to 48% increment[21]. In another study found that tied ridging gave yield increment of 15 to 50% in maize and 15 to 38% in sorghum on different soil types of eastern Ethiopia[22]. These findings are in line of the study in which found that moisture conservation practices significantly affected for the grain yield

Table 3: Mean biomass yield of sorghum as influenced by tied ridging under fertilized and non-fertilized conditions

Treatments	Dry biomass yield (kg ha^{-1})					
	With fertilizer			Without fertilizer		
	2015	2016	Pooled Mean	2015	2016	Pooled Mean
Flat planting	9856.50b	4981.20c	7418.85	8981.90bc	4112.40b	6547.15
OET, P in F	10962.50a	5741.70bc	8352.1	9170.10abc	5270.20a	7220.15
OET, P on R	9559.20b	5627.70bc	7593.45	8004.70c	4791.10ab	6397.9
CET, P in F	11471.00a	6844.40a	9157.7	10672.70a	5669.50a	8171.1
CET, P on R	11290.30a	6045.90ab	8668.1	9865.60ab	5110.50a	7488.05
CV (%)	5.22	8.36		8.61	9.71	
F-test	0.009	0.02		0.03	0.04	
LSD (5%)	1045.1	920.9		1513.8	912.84	

= statistically significant at 0.05, and 0.01 probability level respectively; Means with the same letter (s) in the same column are not significantly different at P<0.05; OET= Open tied ridge; P in F=furrow planting; P on R= planting on ridge; CET= closed tied ridge; LSD= least significant difference; CV= coefficient of variance of maize varieties matured early[22]. Furthermore, it was also pointed out that tied-ridge during planting time produced significantly higher grain yield (2806 kg ha^{-1}) than other in situ moisture conservation techniques such as tied ridging after a month of planting, shilshalo and farmers' practice at Ethiopia Somalia Region[2].

Dry Biomass Yield

Tied ridging practices were significantly influenced biomass yield of sorghum (Table 3). Closed tied ridging integrated with planting in furrow gave significantly high dry biomass yield in both cropping seasons under fertilized and non-fertilized plots. As compared to closed tied ridging practice planting in furrow, conventional practice (flat planting) reduced sorghum biomass yield by 14.07 to 27.22% under fertilized condition and also showed 15.84 to 27.46% yield reduction under unfertilized conditions. This could be ascribed to less efficiency of flat planting to conserve and hold moisture in relative to the other moisture conservation techniques. These results are similar with the findings of another study, which showed that biomass yield of sorghum was significantly influenced by moisture conservation practices at which the highest (15.50 t ha^{-1}) and the lowest total biomass weight (9.53 t ha^{-1}) were recorded from tied ridge and farmers' practice, respectively in southern Ethiopia[19]. Other research work in Ethiopia Somalia Region showed that biomass yield of sorghum was increased due to tied ridging at planting and after one month under fertilized and non-fertilized conditions as compared to farmers' practice[2]. They also noted that in-situ rainwater harvesting tillage techniques with tied-ridge during planting time has better performance to minimize the loss of fertilizer applied on the farm land. In general, the substantial biomass yield response of the crop to tied ridging on both the fertilized and unfertilized experiments revealed that in areas having poor rainfall distributions such as the Raya valley lowlands, moisture conservation technique is a necessary agricultural operation.

Conclusion

In areas with low and erratic rainfall, use of effective moisture conservation practices is indispensable for increasing crop yield. From the findings of this study, closed tied ridging integrated with planting in furrow gave remarkably high grain and dry biomass yields as compared to the other tied ridging practices with planting methods in general and farmers' practice in particular in both fertilized and unfertilized conditions. Tied ridging practices are crucial for sorghum yield improvement under moisture stress areas. It was observed that furrow planting, regardless of the type of the tied ridge, proved to be more effective in preserving water and enhancing sorghum yield with relatively consistent effects in both seasons than planting on ridge and flat bed methods on both soil fertility levels. Generally, integrated soil and crop management practices should be addressed simultaneously to increase water infiltration and nutrient availability and thereby increase crop productivity in moisture stress areas like Raya valley. Accordingly, efforts have to be made to disseminate tied ridging practice with planting in furrow integrated with the recommended fertilizer to the beneficiaries and additional research works on agro-ecologically based in situ moisture conservation techniques and different fertilizer levels is imperative to improve sorghum production in areas where moisture and nutrient deficiency are the major constraints for sustainable crop production.

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