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Evaluation of *In-situ* Moisture Conservation Techniques for Maize Production in Moisture Stress Areas of Mirab Abaya Woreda, Southern, Ethiopia

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Abstract

A field experiment was conducted farmers field of Mirab abaya district of Gamo Gofa zone at Fara gosa kebele, southern Ethiopia to determine the effects of different moisture conservation practices on growth, yield and yield components of maize (*Zea mays*) under rain fed condition for consecutive two years (2016 and 2017) cropping calendar. The experiment was undertaken with three different soil moisture conservation techniques and one farmers' practice (Targa, Trus, Tied-ridge, and farmers' practice). The experimental design was a randomized complete block design /RCBD/ with three replications having the plot size of 12 m × 12 m each. Yield and yield components of maize crop as well as soil properties were studied. The results of Analysis of Variance (ANOVA) showed that, there is significant difference between treatments indicating that maize growth performance in the area is significantly affected by moisture conservation practices (p=0.05). According to the result, Targa, as *in-situ* moisture conservation structures has produced significantly higher results in terms of grain yield, plant height, cob length, and biomass than the others. For instance the combined analysis result of grain yield indicated that, maximum was observed by Targa (8843 kg/ha) and followed by Tie ridge (6250.9 kg/ha), Trus (5784 kg/ha) and control (4525.6 kg/ha). The national average yield of maize was 3675 kg/ha which is low by half the yield obtained by practicing *in-situ* moisture conservation structures specially Targa. Targa also overweighed producing high biomass as well as other plant growth parameters. The finding showed that Targa is the best solution to solve the soil moisture stress to enhance the maize productivity in dry land agriculture. Hence, use of Targa is advisable and could be appropriate for maize production in dry land areas though further fine-tuning work is required to come up with strong recommendation.

Keywords: Moisture conservation techniques; Maize; Yield; Yield components; Moisture stress

Introduction

In the semi-arid and dry sub humid tropics of rain fed agricultural systems water scarcity is a series problem, however *in situ* moisture conservation has able to solve this important bottleneck of agricultural productivity [1]. *In situ* moisture harvesting focuses on the principle of properly using the harvested rainfall or runoff when the rainfall is scarce. This is especially true in arid and semi-arid areas where water is a limiting factor for agricultural activities or where the rainfall is erratic in its occurrence. The most common technology for this purpose is conservation tillage, which aims at maximizing the amount of soil moisture within the root zone. A number of agronomic practices such as mulching, ridging, manuring, and other small farm structures such as field ridges/bunds, contour bunds, bench terraces within cropped area and others, could fall under *in situ* moisture conservation category [2]. Soil and water conservation practices are important to improve crop yields by enhancing soil moisture, conserving rain water and controlling erosion [3,4].

Addressing the problem of moisture stress requires means of supplying additional water for crops to meet their Evapo-transpiration demand with the help of either irrigation or on-farm water harvesting techniques. *In-situ* soil 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 [5]. *In-situ* rainwater harvesting practice is recommended for low land areas, with small and variable volume of rainfall [6]. Slope of the land less than 5%, impermeable soils and low topographic relief are the main requirements for its better performance [6]. *In situ* soil water conservation technologies are suitable for increasing soil moisture for increased land productivity in Arid and Semi-Arid Lands (ASALs) of eastern Kenya. Zai pits, tumbukiza and deep tillage can increase crop yields by 4 to10 times when compared with other similar conventional cultivated fields [7].

In field, water harvesting technology is a solution to the problems of arid area that can enhance soil water storage, and this will enable crops to survive during mid-season droughts [8]. Unabated climate change will have adverse effects on crop yields in many regions, but on farm water management can minimize such effects to a significant degree by alleviating soil evaporation and enhancing infiltration [9]. To improve dry land agricultural production adopting *in situ* rainwater harvesting has greater potential to effectively conserve adequate soil moisture [10]. *In situ* moisture conservation is an important strategy to increase infiltration and storage of water in soil and reduce the effects of drought stress on maize grain yield [11].

Description of the *in-situ* moisture conservation structures used in this study

Targa: A traditional water harvesting technique indigenous to Southern Ethiopia by the Dreashe peoples is a rectangular basin built from soil and plant residue (sorghum and maize straw), constructed along contour lines spaced 2 m apart, which are tied at 3 m interval by ridges made in staggered position across the contour. The bunds and ridges of Targa rise about 30 cm above the ground.

Figure 1: The structure of Targa (Own photo source).

Trus: Trus is a U shaped wide micro basin capable of concentrating water from rainfall and run-off to support plant growth during dry spells following erratic rainfalls. In central Darfur region of western Sudan, where the amount of rainfall is much less than PET demand, significantly higher yield of sorghum was obtained from lands treated with Trus than from untreated plots.

Figure 2: the structure of Trus (photo is own source).

Tie ridge: Tie-ridging involves creating ridges that are 20-30 cm high and commonly spaced 75 cm apart before, during or after planting. Row-crops, such as sorghum or corn, may be sown on the ridge or in the furrow. The furrows are tied at intervals of 2 m or more, depending on field conditions, to prevent runoff in the furrow [12].

Figure 3: Structure of Tied-ridge (photo is own source).

In areas with erratic and short duration rainfall, either use of runoff collection or *in situ* water harvesting is very crucial. There are farmers who traditionally use the aforementioned different types of *in situ* moisture conservation for crop production however the effectiveness of either of these methods is not known for wider application. Therefore the objective of this experiment was to identify the effectiveness of different types of *in situ* moisture conservation methods for maize production in moisture stress area of Gamo Gofa zone, Ethiopia.

Materials and Methods

Description of study area

The experiment was conducted at Mirab Abaya district which is one of the 15 districts of Gamo Gofa zone and it is located 50 km from the capital of zone Arba minch Town. The area lies within 6°11'-6°51'N Latitude and 37°58'-37°98'E Longitude with mean annual rain fall ranging from 750 to 930 mm and mean annual temperature ranging from 14 °C-32 °C. The vegetation is dominantly occupied by Woody Grass Land (WGL) especially along the sides of grazing area and drainage lines and there is a height gallery of forest along the rivers like Acacia species [13]. Its altitude ranges from 1100 to 2300 masl. The total area of the district is 121,150 ha which is divided in 23 rural and 1urban kebles. Fara gossa keble was selected to conduct the experiment. Mixed crop-livestock farming is the major livelihood activity at the study site. *Zea mays* L (maize) were the dominantly cultivated crop in the area.

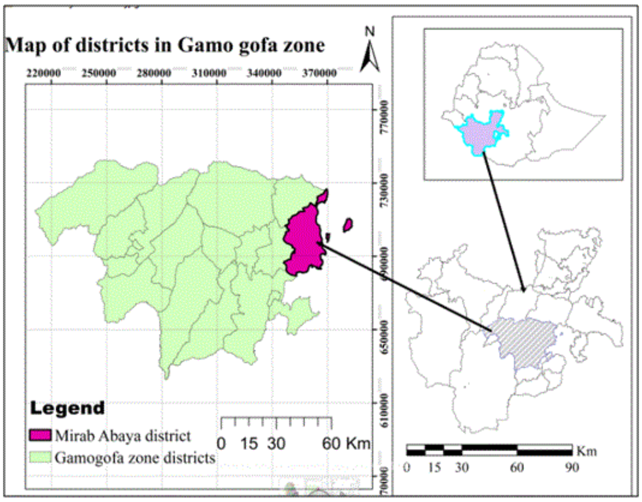

Figure 4: Map of study location.

Experiment setup

A field experiment was conducted on the effect of different *in-situ* soil moisture conservation structures for maize production under rain fed farming situations during cropping season of 2016 and 2017 at Fara gossa and Kola barana. The experiment consisted of four different *in-situ* soil moisture conservation methods (Targa, Trus, Tied-ridge and control) with maize planting at spacing of 40 cm × 80 cm between plant and between rows respectively.

Targa: soil bunds constructed along the contour lines spaced 2 m apart; each bund tied to its precede and following by ridges made, at 3 m interval, in staggered rows along the slope.

Trus: soil bunds of length 5.5 m constructed along contour lines leaving 1 m space between bunds and 2 m between contour lines; then a 1.5 m long arm will be fitted to the ends of each bund to form a U shaped Micro basin, facing upslope.

Tied ridge: Tie spacing for tied-ridge will be 6 m interval therefore; one plot of tie-ridge will have four ties in 12 m × 12 m.

Control: farmers practice in Mirab Abaya area that means simply plowing the fields without any *in situ* moisture conservation methods. For implementation of experiment, randomized complete block design was used as experimental design with plot size 12 m × 12 m.

Method of data collection

Moisture content: Measuring of moisture in the structure was done after 5 days of rainfall to evaluate the role of structures to save moisture. To perform this, an auger was used for soil sampling to measure the soil moisture content for the average depth 0 cm and 40 cm. The weight of the wet soil samples was measured and put in an oven at 105 °C for 24 hours and then the weight of dry samples were measured. The following formula was used for calculating the soil moisture content.

$SMC=Ww-Wd/Wd^{*}100$

Where:

SMC=Soil Moisture Content dry base (%)

Ww=Weight of the wet soil (gm)

Wd=Weight of the dry soil (gm)

If the density of the soil water is assumed as 1 g/cm³, then volumetric soil water content (cm^3/cm^3) is determined as:

$\theta = w^{*}\rho d$

Where:

w=gravimetric water content

ρd=bulk density (g/cm^3)

Grain yield and yield components: Three central rows were harvested for determination of grain yield. Grain yield was adjusted to 12.5% moisture content. Five plants were randomly selected from the three central rows to determine yield and yield components, which consisted of thousand seeds weight. Seed weight was determined by taking a random sample of hundred seeds and adjusted them to 12.5% moisture content. Total biomass yield was measured from the three middle rows when the plant reached harvest maturity.

Laboratory analysis of soil samples: The soil samples were air dried under the shade, ground using pestle and mortar and sieved to pass through 2 mm sieve. Soil bulk density was determined using undisturbed core sampling method following the procedures described in Black [14]. Particle size distribution (soil texture) was determined by the hydrometer method [15]. Soil pH was determined in a 1:2.5 soil to water suspension procedure [16]. The organic carbon content was analyzed by wet digestion method using the Walkley and Black oxidation method [17]. Soil organic matter (OM) content was calculated by multiplying soil organic carbon content by a factor of 1.724. The Total Nitrogen (TN) content was determined using the Kjeldahl method; while the Available Phosphorus (AP) was determined following the Olsen procedure [18,19]. The Cation Exchange Capacity (CEC) was determined after extraction of the samples with 1 N ammonium acetate [20].

Statistical analysis of data: All the agronomic data were recorded and being subjected to analysis. Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1 [21]. Effects were tested under (P=0.05). Means were separated using Fisher's Least Significant Difference (LSD) test.

Results and Discussions

Soil analysis result

Soil properties of the experimental treatments of second year experiment sampled after the harvesting of the maize were shown in Table 1 below.

Treatment	pH	%OM	%OC	%TN	AvP (ppm)	CEC (meq/Cmol)	Textural class
Trus	7.6	1.293	0.75	0.06	1.92	41.6	Sandy loam
Tie-ridge	8	1.508	0.875	0.07	1.94	37.2	
Targa	8.1	1.882	1.092	0.095	3.18	40.2	
Control	8.1	1.848	1.072	0.092	2.38	39.2	

Table 1: Soil analysis result for structures at study area.

From the Table 1, the PH of the soil on different treatments ranged between 7.6-8.1which shows alkalinity in all treatments. The textural class of the soils was obtained to be sandy loam. The table indicated that there is shortage of available P and it is in the range of very low (less than 5 ppm). The OM content in all structure ranges between 1.293-1.882% and it is low in all four treatments according to rating of Tsidale et al. [22]. The result of nitrogen content has low value (less than 0.1%) for all treatments. However CEC values are at optimum level which shows the capacity of soil to be productive provided that required fertilizers are applied using area recommendation rate. Overall, it can be observed that, there are no significant differences on structures regarding all soil properties.

Yield and yield components of maize

In both years, there was significant (P=0.05) difference between treatments. Regarding parameters, there was significant (P=0.05) difference between treatments on plant height, cob length, biomass weight as well as the yield but there was no significant (P=0.05) difference between all treatments with seed weight. In all parameters except 100seed weight, Targa significantly overweigh to other structures by more than 30% in both years. In-field water harvesting is one of the many climate change adaptation strategies in the semi- arid regions and that can be improved crop yields, food security and livelihood among households [8]. As shown in Table 4 the combined results of agronomic parameters (grain yield, plant height, cob length and biomass), Targa has shown a significant difference than other structures. For instance in terms of grain yield the combined result of Targa is 8843 kg/ha , Tie ridge 6250.9 kg/ha, Trus 5784 kg/ha and finally control has 4525.6 kg/ha. The average Production and yield of maize at Meher season of 2016 was 3675 kg/ha and 3152 kg/ha at the country and zonal level [23]. According to agriculture and natural resource office of Mirab Abya woreda (study area), the average grain yield production of maize in the area on irrigated and without irrigation was reported to be 3670 kg/ha and 2025 kg/ha respectively which indicates that, practicing of *in situ* moisture conservation structures particularly Targa can produce more than double than conventional farming practice. According to (Anonymus, Unpublished), in dry seasons yields can increase by as much as 300% compared to yields without runoff harvesting [24].

Treat	Pl ht	Cob L (cm)	BM (kg/ha)	GY (kg/ha)	100 swt (gm)
Trus	184.9^{b}	22.93^{b}	12223.4^{ab}	3877.37^{ab}	33.57^{a}
Targa	204.0^{a}	26.33^{a}	12752.5^{a}	4727.10^{a}	35.92^{a}
Tie	195.7^{ab}	23.2^{b}	10243.1^{ab}	3549.7^{b}	36.97^{a}
Control	188.0^{ab}	24.3^{ab}	9804.9^{b}	3497.57^{b}	34.65^{a}
LSD (0.05)	16.79	2.76	2878.5	902.84	ns
CV (%)	4.35	5.72	12.8	11.54	7.54

Note: Pl ht (plant height), Cob L (cob length), BM (biomass), 100 swt (100 seed weight), treatments with the same letters have no significant difference

Table 2: Means of yield and yield components of maize at first year.

Treat	Pl ht	Cob L (cm)	BM (kg/ha)	GY (kg/ha)	100 swt (gm)
Trus	172.3^{b}	24.33^{b}	2550.0^{b}	7690.63^{bc}	32.50^{a}
Targa	212.5^{a}	32.47^{a}	7091.7^{a}	12958.8^{a}	34.64^{a}
Tie-ridge	205.2^{a}	25.8^{b}	3674.5^{b}	8952.1^{b}	33.05^{a}
Control	182.0^{ab}	24.8^{b}	2918.2^{b}	5553.63^{c}	35.14^{a}
LSD (0.05)	32.83	5.29	3658	968.75	Ns
CV (%)	8.52	9.86	20.81	11.94	5.94

Note: Pl ht (plant height), Cob L (cob length), BM (biomass), 100 swt (100 seed weight), treatments with the same letters have no significant difference

Table 3: Means of yield and yield components of maize at second year.

As shown in the Table 5 below, *in-situ* water harvesting treatment (Targa) recorded the highest SMC values at harvest period in both years. In contrast, tie-ridge and Trus recorded relatively less than Targa. Next to conventional, tie-ridge and Trus recorded better moisture.

Treatment	Mean yield (kg/ha)	Pl ht (cm)	Cob L (cm)	BM (kg/ha)	100swt (gm)
Trus	5784.0^{bc}	178.650^{c}	23.63^{b}	7386.7^{b}	33.03^{a}
Targa	8843.0^{a}	208.283^{a}	29.40^{a}	9922.1^{a}	35.38^{a}
Tie-ridge	6250.9^{b}	200.45^{ab}	24.53^{b}	6958.8^{b}	35.01^{a}
Control	4525.6^{c}	184.667^{bc}	24.53^{b}	6361.6^{b}	34.89^{a}
LSD (0.05)	1468.5	15.97	4.2	1407.3	Ns
CV (%)	18.89	6.76	13.44	15.02	8.28

Note: Pl ht (plant height), Cob L (cob length), BM (biomass), 100 swt (100 seed weight), treatments with the same letters have no significant difference.

Table 4: Combined analysis of yield and yield components for two years.

Treatment	Moisture content at harvest (%)
Control	11.11^{b}
Targa	13.50^{a}
Tie-ridge	12.08^{ab}
Trus	11.65^{ab}
LSD (0.05)	2.19
CV (%)	14.84

Table 5: Combined analysis of soil moisture content (%) at harvest for two years.

Conclusion and Recommendation

Structure of Targa has shown better results in moisture content, grain yield, soil moisture holding capacity, biomass and the other agronomic parameter in two consecutive years of study. Generally, in Mirab Abaya area of southern Ethiopia, the rainfall distribution is characterized as low in amount, erratic and unevenly distributed during the cropping season which is one of the most limiting factors for crop production and driver force to conduct this experiment. Therefore, it is critical to use and apply rainwater harvesting structures in the area so as to improve grain and biomass yields of maize in a sustainable manner. Hence, there is need to disseminate the results of the present study to the end users even though, further research should be carried out to put the recommendation on strong basis and also to come up with increased yield and improved maize production in other similar areas where moisture is the most limiting factor. In this regard, Targa structure is recommended as a better solution to solve the problem in water stress and drought prone area to produce maize. It is better to test and scale up this indigenous knowledge of Derashe peoples, found in southern Ethiopia to the areas with a similar agro-ecology.

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