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Enhancing Maize (*Zea mays* L.) Yields through Tied-Ridge Moisture Conservation in Semi-Arid Areas of Tigray, Ethiopia

Mulu Hagos Teklehaimanot [a*] and Tblets Gebregergs [b]

[a] Department of Natural Resources Research, Axum Agricultural Research Center, Axum, Ethiopia.
[b] Department of Socio-economic and Extension Research, Axum Agricultural Research Center, Axum, Ethiopia.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The experiment took place during the 2019 cropping season in two peasant associations (PAs) located in the Adwa and Tahitay-maichew districts.

Objectives: To demonstrate the effectiveness of the Tied-ridges moisture conservation technique and to raise awareness among farmers about the benefits of adopting this practice.

Methods: Two moisture deficit districts were selected purposefully. From each district, farmer research extension groups (FREG) containing 20 farmer members were formed. Each FREG members were prepared two plots of size 20m*20m, one plot for the tied ridge while the other plot for the farmers practice demonstration. Training were organized for a total of 80 farmers, 8 experts,

**Corresponding author: E-mail: muluhagos12@gmail.com;*

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and 4 Development Agents (DAs) taken from both districts. Half of the farmer participants were from FREG, while the other half were non FREG members. Data on yield and farmers perception on maize yield and Tied ridge moisture conservation was recorded and analyzed using descriptive statistics.

Results: The average yields achieved using the tied ridge method were 31.43 and 32.62 qha^{-1} in the Tahitay-maichew and Adwa districts, respectively. In comparison, the average yields from traditional farming practices (without tied ridges) were 23.72 and 25.73 qha^{-1} in the two districts. The implementation of tied ridges for in-situ moisture conservation led to a significant increase in yield in both areas. The economic analysis revealed that the net benefits per hectare from using tied ridges were $603.92 in Tahitay-maichew and $599.28 in Adwa.

Conclusion: The study suggests that scaling up the adoption of tied ridges for moisture conservation in similar agro-ecological zones could lead to even greater economic gains. It is recommended that the Agricultural and Natural Resources Development Office prioritizes the promotion and expansion of this technology in moisture-deficient areas within the districts and other comparable agro-ecological settings.

Keywords: Farmers practice; FREG; maize yield; tied ridge; training.

1. INTRODUCTION

Moisture stress significantly limits crop yield in cereal-based cropping systems in Eastern and Southern Africa [1,2]. Ethiopian semi-arid and arid regions are experiencing reduced crop yield due to various biophysical issues [3-5]. Low agricultural productivity in these areas is attributed to both land degradation and insufficient moisture [6,7]. Moisture stress is characterized by prolonged periods of inadequate precipitation leading to water shortages and lack of soil moisture for crop growth [8,9]. Rainfall in the dry lands of Ethiopia is seasonal and erratic; further exacerbating moisture stress and hindering rain-fed agriculture productivity [10].

In the northern part of Ethiopia, particularly Tigray, high moisture deficit is a major challenge for small-scale farmers [11-16]. Variability in rainfall onset and cessation poses significant problems for agriculture in these districts. The insufficient and uneven distribution of rainfall may be a key factor contributing to low crop yield. Implementing soil and water conservation structures is proposed as an alternative approach to address these challenges. Dry spells often coincide with critical crop growth stages, necessitating improved water productivity strategies in the study areas. Demonstrating in-situ moisture conservation techniques is crucial for sustaining crop production. However, there is currently limited research on these techniques specifically aimed at enhancing maize yield in the study area. The objectives of the experiment include evaluating the effects of selected in-situ moisture conservation practices on maize yield, assessing the cost implications, and raising awareness among farmers.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was carried out in the Central Zone of Tigray, specifically in the Adwa and Tahitay-maichew districts, situated at a distance of 970 km from Addis Ababa. Geographically, it lies between 14° 07' 48'' N latitude and 38° 46' 48'' E longitude (Fig. 1). The elevation of the study area ranges from 1500 to 1650 meters above sea level and is categorized under the Semi-arid conditions.

2.2 Climate

Based on weather data collected in 2018 from the Axum meteorological station, the total annual rainfall in the area is 650 mm, with minimum and maximum temperatures recorded at 14°C and 25°C, respectively for the Adwa district. The average annual temperature in the Tahitay-maichew district ranges from 15 to 25°C, while the annual rainfall varies between 600 and 800 mm.

2.3 Site and Farmer Selection

The study was conducted in two peasant associations (PAs) in the Adwa and Tahitay-maichew districts. In each PA, 20 farmers were chosen to participate in the experiment on their land. The PAs and farmers were purposefully selected from areas facing high moisture stress, with the help of district coordinators, animators, and DAs. Each farmer's plot for the experiment measured 20m*20m (400 m^2). A total of 1.6 ha of land from both districts was used for the experiment. Prior to constructing tied ridges for on-site moisture conservation, the land was prepared. The tied ridges were built at a distance of 5m from each other. The demonstration in the study area involved the practice of in-situ moisture conservation using tied ridges, compared to farmers' practices without tied ridges.

2.4 Plant Agronomic Management

The study utilized BH-540 maize variety planted in rows as the test crop. The recommended fertilizer application rates of 150 kg ha^{-1} DAP and 100 kg ha^{-1} urea was applied, with one-third of the urea and full DAP dosage applied at the time of sowing. The remaining two-thirds of the urea was applied 30 days after planting. All essential field management practices, from land preparation to harvesting, were implemented, while all other agronomic practices remained consistent across both treatments based on local cultural norms.

2.5 Economic Analysis

The cost for each treatment, including Tied-ridges and farmers' practice without tied-ridges, was documented. Additionally, the revenues from each treatment were noted. The grain yield and crop residues were converted to current market prices. The profit from the treatments was calculated by deducting the total cost from the total revenues. This calculation is represented as:

$$\text{Net profit} = \text{TR} - \text{TC} \quad (1)$$

$Where, TR = Total\ Revenue,$

$TC = Total\ Costs\ (Total\ Fixed\ Costs + Total\ Variable\ Costs)$

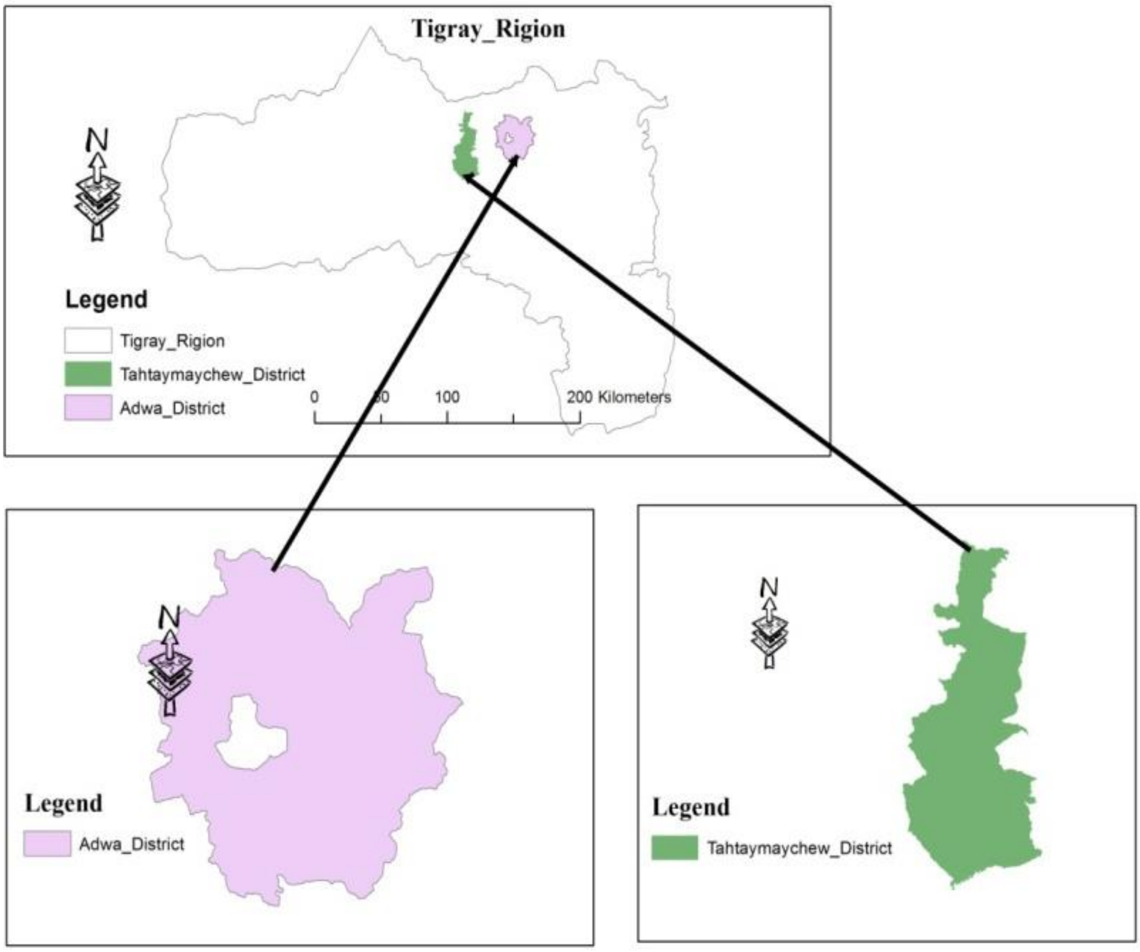

Fig. 1. Study area map

2.6 Data Collection and Analysis

Samples of eight and seven farmers were taken to obtain Grain yield data from Tahitay-maichew and Adwa districts, respectively. Economic and perception data were collected using data collection sheets. Simple financial analysis was employed to analyze the costs required for the experiment and the net benefit gained from the production of each in-situ moisture conservation practice. The data was analyzed using excel and the mean results were presented using tables. The perception data was collected from all the FRG members through focus group interview to the technology adopters.

3. RESULTS AND DISCUSSION

3.1 Capacity Development

3.1.1 Farmers Research and Extension Group (FREG) establishment

A group of farmers formed under the Farmers Research and Extension Group (FREG). Two FREG units were established and took part in demonstration activities (Table 1) in two districts. Each FREG member represents 20 farmers.

3.1.2 Training

Before commencing the experiment, farmers received training on technology demonstration. Farmers, district coordinators, and DAs from two districts participated in an introductory training session. The training focused on the primary limiting factors in the study area, in-situ moisture conservation technologies, and their impact on increasing maize yield during rainfall shortages, including the construction of tied ridges. The purpose of the training was to familiarize FREG, Animators, and DAs with the technical aspects of the trial that was carried out. Additionally, the training aimed to address specific gaps in implementing and managing the activity.

Fifty farmers from both districts' peasant associations participated in the training. A total of 80 farmers, 8 experts, and 4 DAs took part in the training (Table 2 and Fig. 2). Among them, 40 farmers were FREG members, and 40 were non-FREG members. The training covered the objectives and targets of activities related to in-situ moisture conservation structures and their impact on yield. All FREG and non-FREG members attended the training to gain a theoretical understanding. Farmers, Animators, district coordinators, and DAs were present and informed about in-situ moisture conservation technologies.

3.2 Yield Performances

The average yield from tied ridges and farmer practices without tied ridges were 31.43 and 23.72 q/ha, respectively, in the Tahitay-maichew district (Table 3). Similarly, the average yield from tied ridges and farmer practices without tied ridges were 32.62 and 25.73 q/ha, respectively in the Adwa district (Table 3). The yield from tied ridges outperformed that of farmer practices without tied ridges in the study areas, likely due to tied ridges retaining more moisture compared to traditional farmer practices. These findings align with [17,18] who reported that tied ridge cultivation could increase maize grain yield by 54%, 35%, and 26% over traditional practices in southern Ethiopia.

In-situ water harvesting can enhance soil moisture levels, leading to improved crop yields and positive impacts on moisture conservation and agricultural productivity [19,20]. The experimental results suggest that maize yield is influenced by specific in-situ moisture conservation practices, with the moisture-conserving advantages of these technologies being particularly crucial in arid [21,22].

3.3 Budget Analysis

3.3.1 Experimental costs

The combined estimated cost for implementing the tied ridge and farmer's practice was 562.5 and 544.64USD/ha at Tahitay-maichew and 526.78 and 508.92USD/ha at Adwa, as shown in Tables 4. Due to its labor-intensive nature, the tied ridge structure incurred higher expenses compared to the farmer's practice.

Table 1. FREG establishment and number of FREG

District	Kebeles	Established FREG	No. of farmers in each FREG
Tahitay-maichew	Whedet	1	20
Adwa	Mai-tuem	1	20
Total		2	40

Fig. 2. Training to Farmers, DAs, animators and other participants

Table 2. Number of farmers, DAs, and district experts participated in the training

Districts	Kebeles	No. of Trainers						Total
		Farmers		DAs		Experts		
		F	M	F	M	F	M	
Adwa	Mai-tuem	30	10	-	2	-	4	46
Tahitay maichew	Wuhdet	30	10	-	2	1	3	46

Table 3. Mean yield of maize as affected by tied ridge at T/maichew and Adwa Districts

District	Treatments	Yield(q/ha)	Increase (%)	District	Treatments	Yield(q/ha)	Increase (%)
Tahitay-maichew	Tied ridge Farmers Practice	31.43 23.72	24.05	Adwa	Tied ridge Farmers Practice	32.62 25.73	19.93

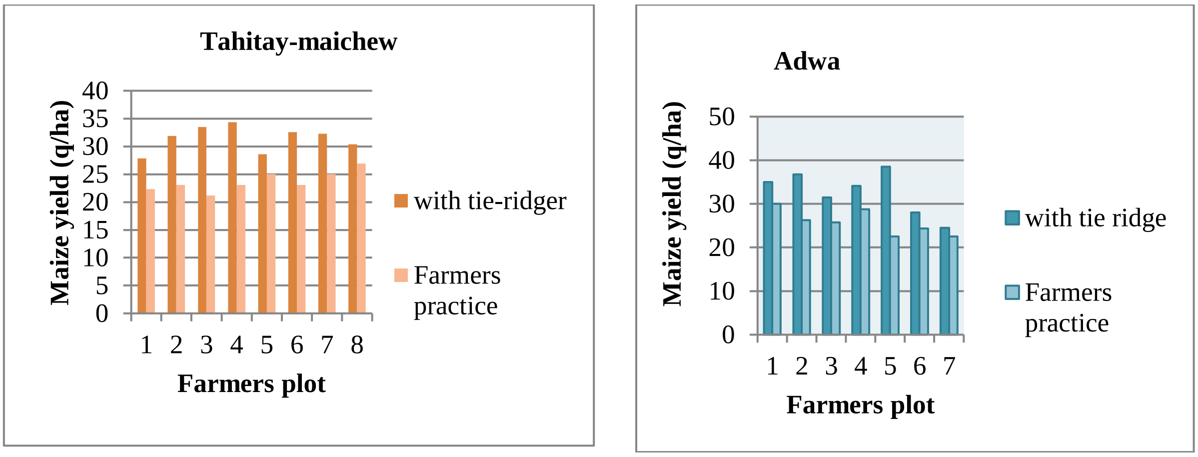

Fig. 3. Yield of maize per selected farmers plot as affected by tied ridge at T/maichew and Adwa districts

Table 4. Summary of costs for the demonstration Experiment

Description	District	Subtotal Costs (USD/ha)		District	Subtotal Costs (USD/ha)	
	Tahitay-maichew	Tied ridge	Farmers Practice	Adwa	Tied ridge	Farmers Practice
Total Fixed Costs (TFC)						
Land rent Costs		428.57	428.57		392.85	392.85
Total Variable costs (TVC)						
Labor & transport		71.42	53.57		71.42	3000
Agricultural inputs		26.78	26.78		26.78	26.78
Land preparation		35.71	35.71		35.71	35.71
Total Costs (TC)		562.5	544.64		526.78	508.92

Table 5. Revenue obtained from the demonstration

Description	District	Total revenue (USD/ha)		District	Total revenue (USD/ha)	
	Tahitay-maichew	Tied ridge	Farmers Practice	Adwa	Tied ridge	Farmers Practice
Yield		2245	1694.28		2330	1837.85
Crop residual		178.57	107.14		214.28	89.28
Total		2423.57	1801.42		2544.28	1927.14

Table 6. Summary of net benefit obtained from the demonstration

District	Net Benefit (USD/ha)		Net Benefit (USD/ha) from Tied ridge over farmers practice
	Tied ridge	Farmers Practice	
Tahitay-maichew	1861.07	1256.78	603.92
Adwa	2017.5	1418.21	599.28

Table 7. Farmers perception on tied ridge moisture conservation practice

Technology attributes	Valid N	Perception level (%)				
		Very low	low	No change	high	Very high
Applicability	50	10	90	0	0	0
Labor consuming	50	20	80	0	0	0
Yield increase	50	0	0	0	70	30
Drought tolerance	50	0	0	0	70	30

3.3.2 Revenue obtained from the demonstration experiment

In Tahitay-maichew and Adwa districts, maize yields of 31.43 and 32.62q/ha were achieved fromtied ridge farming respectively and sold at 71.4USD/q (Table 5. Conversely, without using tied ridge, farmers in the same districts obtained maize yields of 23.72 and 25.73q/h also sold at 71.4 USD/q. Total revenues estimated from tied ridge farming were 2423.57USD and 1801.42USD in Tahitay-maichew district, and 2544.28USD and 1927.14USD in Adwa district (Table 5). The revenue from tied ridge farming surpassed that of farming without tied ridge in both districts, indicating that tied ridge farming conserved more moisture and generated higher revenue compared to conventional farming practices.

3.3.3 Net benefit obtained

The net benefit from demonstrations is calculated by subtracting total costs from total revenue. The total net benefit from tied ridges was 1861.07 and 2017.5USD/ha in Tahitay-maichew and Adwa districts, respectively. Additionally, the total net benefit from farmers' practices was 1256.78 and 1418.21USD/ha in the same districts. This indicates that the net profit from tied ridges surpassed that of farmers' practices in both areas. These findings align with reports suggesting that tied ridges have a direct positive impact on crop production and economic returns, primarily due to their superior moisture retention capabilities [23,24,13]. Moreover, the moisture-conserving practices of tied ridges enabled farmers to achieve a net benefit of 603.92 and 599.28USD/ha in Tahitay maichew and Adwa districts, respectively, compared to traditional farming methods (Table 6).

3.4 Farmers Perception

Fifty farmers who are part of FREG were surveyed to gather perception data on the attributes of the tied ridge moisture conservation practice in comparison to their own farming practices. The perception data was then analyzed using SPSS. The findings in Table 7 indicated that the farmers have a positive perception of using tied ridges for moisture conservation, increasing yields, and improving drought tolerance. Overall, the farmers responded positively to most of the technological attributes.

4. CONCLUSIONS

Moisture conservation at the farm level is currently a crucial issue worldwide, especially in the study area, for sustainable crop production. The low crop productivity in Tigray, specifically in the study area, can be attributed to insufficient soil moisture, unpredictable, and unevenly distributed rainfall. This underscores the necessity of developing effective in-situ moisture conservation strategies. The implementation of the tied ridge technique resulted in improved maize productivity compared to traditional farming practices without tied ridges. Tied ridges demonstrated a significant increase in maize yield, showcasing its economic advantages over conventional methods. Scaling up the tied ridge in-situ moisture conservation practice in the study area and similar agricultural ecosystems is recommended for addressing moisture deficiencies and enhancing land productivity. It is essential to disseminate the findings to end-users and garner support from agricultural and natural resource authorities to promote awareness and adoption of this technology for combating moisture deficits and enhancing land productivity in the study area and similar agricultural settings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author affirms that no generative AI technologies, such as Large Language Models (ChatGPT, COPILOT, etc.), or text-to-image generators were utilized during the writing or editing of the manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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