Journal of Scientific Agriculture 2024, 8: 59-65
doi: 10.25081/jsa.2024.v8.8995
https://updatepublishing.com/journal/index.php/jsa

Research Article

ISSN: 2184-0261

Evaluation of different moisture conservation practices on maize production and productivity in Dallomanna Districts of Bale Lowland Southeastern Ethiopia

Regassa Gosa Telila*, Daniel Abagaja Naneso, Mulugeta Eshetu Diriba, Tesfaye Ketama Defar, Girma Getachew Gemechu

Sinana Agricultural Research Center, Oromia Agricultural Research Institute, Bale-Robe, Ethiopia

Received: May 19, 2024
Revised: August 14, 2024
Accepted: August 14, 2024
Published: September 03, 2024

***Corresponding Author:**
Regassa Gosa Telila
E-mail: regassagosa@gmail.com

ABSTRACT

The *in-situ* moisture conservation and mulching are techniques that help retain moisture at the root zone, reduce evapotranspiration, and increase the time of infiltration for maize production. This study was focused on the evaluation of the best moisture conservation techniques in combination with mulching under rain-fed conditions for maize production in the study area. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Five treatments, namely, control (without structure and mulching), mulching, furrow ridge with open-ended furrow with mulching, furrow ridge with closed-ended furrow with mulching, and tied ridge with mulching, were compared for two consecutive seasons (2021 and 2022) in terms of soil moisture conservation and maize grain yield. The highest mean grain yield (6134.84 kg ha^{-1}) and soil moisture content were recorded from the plot of T5 (Tied Ridge + Mulching). The result revealed that tied ridges with mulching showed better grain yield and conserved moisture over the others, followed by furrow ridges with close-ended furrows with mulching, respectively. Therefore, tied ridges with mulching as *in-situ* moisture conservation practices is an effective technique for storing moisture and increasing the time of infiltration as compared to other practices.

KEYWORDS: Maize, Mulching, Grain yield, Rainfed conditions

INTRODUCTION

Maize (*Zea mays* L.) is one of the most highly produced crops around the world (Orfanou *et al*., 2019). Ethiopia is the seventh maize-producing country in Africa. Maize production is the second in area coverage next to tef (*Eragrostis tef* Zucc.), with a total land area of 10,478,217 ha being under cereals, of which maize covered about 17.68% (2,274,305.93 ha) (CSA, 2019). In the Bale zone, Maize accounts for 27,909.21 of total areal coverage with 1,078,968.65 production in quintals which yields 38.66 Quintal per hectare in the Meher season (CSA, 2022). Despite the large area under maize production, its current national average yield is about 4.2 t ha^{-1} (CSA, 2019), which is far below the world's average yield of 5.8 t ha^{-1} (FAOSTAT, 2019).

An increase in agricultural productivity demands optimum utilization of natural resources like soil and water (Marwein *et al*., 2029). The sound performance of agriculture warrants the availability of food crops and also heralds a positive aspect of the economy. In regard to this, collective efforts are being geared to securing agricultural outputs of the desired level so that self-reliance in food supply can be achieved and disaster caused food shortages be contained in the shortest possible time in Ethiopia (CSA, 2022). Declining agricultural productivity has been a challenge in Sub-Saharan Africa (SSA) especially in the Bale lowlands. Low agricultural productivity has been attributed to factors such as poor farm management practices, soil moisture stress, soil infertility, and soil degradation (Ndegwa *et al*., 2023). Lack of maintainable soil management practices has led to huge land degradation and the loss of nutrients through soil erosion and leaching. In order to increase soil fertility, reduce soil depletion rates, and improve agricultural productivity, integrating soil fertility and soil and water conservation practices such as *in-situ* moisture conservation in the farming systems would be desirable (Martínez-Mena *et al*., 2020).To increase water availability to crops, it is necessary to adopt *in-situ* moisture conservation techniques including large-scale soil and water conservation practices and various water harvesting measures (Lannotti, 2007; Chavan *et al.*, 2009).

Mulching is one of the important practices for restoring water; among various mechanical and agronomic measures, it reduces soil erosion, increases *in-situ* soil moisture storage and improves the productivity of crops (Bhatt & Rao, 2005). Mulching can help to improve crop yield and optimize water use (Parmar *et al.*, 2013; Prasad *et al.*, 2014; Saikia *et al.*, 2014). Covering soils with mulch increases water productivity (WP) in arid and semi-arid areas in the dry season (Bu *et al.*, 2013). Smallholders practicing crop residues and different mulching materials on maize growth in Sub-Saharan Africa (Mupangwa *et al.*, 2016). Mulch influences soil properties giving rise to significantly better root growth and yield of maize compared to no mulch treatment due to increased soil water content resulting from reduced evaporation and increased infiltration (Agber *et al.*, 2017). Besides this mulch proved to be one of the weed protecting mechanisms in maize production (Anane *et al.*, 2020). Mulches are used for improving soil moisture content (SMC), water productivity (WP), and maize yield (Yisfa *et al.*, 2023). Mulching with dry leaves significantly increased crop growth and yield of maize. This mulching technology can be widely adopted by farmers to conserve soil moisture, reducing runoff, soil loss and nutrient losses (Shashikanth & Thimmegowda, 2022). The combination of mulch with N fertilizer application(Wang *et al.*, 2020), with drip irrigation techniques (Wang *et al.*, 2022) have been widely applied to save water and increase crop productivity. Straw strip mulching in maize production has shown a positive effect (Lan *et al.*, 2020).

Planting of Maize under soil and water conservation practices positively enhanced its production and maintained soil fertility while retaining soil moisture in place (Uwizeyimana *et al.*, 2018; Salifu *et al.*, 2019; Bekele, 2020; Gezahegn *et al.*, 2020; Kugedera *et al.*, 2020; Wolde *et al.*, 2020; Husen & Shalemew, 2021; Chakravarthy *et al.*, 2022; Wafula *et al.*, 2022; Handiso, 2023; Kamara *et al.*, 2023). Several researchers (Chiturike *et al.*, 2023) used *in-situ* moisture conservation and substantially increased maize production under dry condition. In many parts of the country particularly, eastern Ethiopian highlands with uses of crop residue in combinations of tied ridges and closed ended furrow planting was remarkably used to conserve soil moisture (Ademe *et al.*, 2018; Chimdessa *et al.*, 2019; Desta *et al.*, 2021; Abera & Sibhatu, 2022; Ayala *et al.*, 2023).The use of in situ moisture conservation techniques needs outstanding attention. Since, the efficiency of the soil physic-chemical properties and water conservation techniques depends on the soil type, climate, crop grown and the cropping methods followed. Therefore, planting crops using in situ moisture conservation reduces problems of soil moisture stress by reducing runoff through increased infiltration capacity of the soil and storage of water in the soil profile. Therefore, this study aimed to evaluate the best moisture conservation techniques in combination with mulching under rainfed conditions for maize production in the study area.

MATERIALS AND METHODOLOGY

Description of the Study Area

The study was conducted at the Dello-Menna District in the Southern Bale Zone of Southeastern Ethiopia (Figure 1). The district is located to the south of Robe town at the distance of 125 km or it is found at 555 km to the southeast of Addis Ababa, the capital city of Ethiopia (Abera, 2009). The district covers 483,335 hectares. Delo Mena District is located in the Oromia National Regional State in the Bale Administrative Zone, Ethiopia. Geographically, it lies between 5° 91' to 6° 71' N latitude and 39° 87' to 40° 26' E longitude. The dominantly major soil types are Chromic vertisol, Pellic vertisol, Chromic fluvisol and Eutric fluvisol. The altitude of the district ranges from 500 to 2464 meter above sea level and it increases from the south to north and from west to east. About 64% of the land is characterized as flat with a slope of less than 10% (BOFED, 2008).

Effect of Climatic Factors on Maize Yield

The district experiences bimodal rainfall type with the minimum of 628 mm and maximum of 775 mm per annum. The first rainfall season is a bit longer and extends from April to June and the second season starts in the middle of September and ends at the beginning of November. The mean annual temperature is 29.5 °C while the minimum and maximum temperatures of 21 °C and 38 °C recorded respectively (Mehadi *et al.*, 2016).

The three major climatic factors (Precipitation, Temperature, and Relative humidity) affecting maize yield were undergone time series analysis. These factors were analyzed for consecutive months during the maize growth stages (April-August) in the Delomena District. The observed temperature range is optimal to promote healthy growth and ensure proper reproductive process uniformly. The observed relative humidity range is balanced and moderate throughout the maize growth stages which are generally favorable (Figure 2).

Experimental Design and Treatments

Field experiments were conducted on farmers' fields in 2020/2021 in a randomized complete-block (RCBD) design with three replications and a plot size of 6 m x 8 m was used. The furrow ridge height of the ridges, furrow interval and spacing between consecutive furrows were 20 cm, 5 cm, and 75 cm respectively and 1.5 m distance between plots and block was used. Maize (Malkassa 2 variety) was sown on the plot area of 48 m^2 using the recommended seed rate of 30 kg ha^{-1} (144 g/plot). The treatments were arranged as;

T1 = Control (without structure and mulching)
T2 = Mulching
T3 = Furrow ridge with open ended furrow + Mulching
T4 = Furrow ridge with close ended furrow + Mulching
T5 = Tied ridge + Mulching

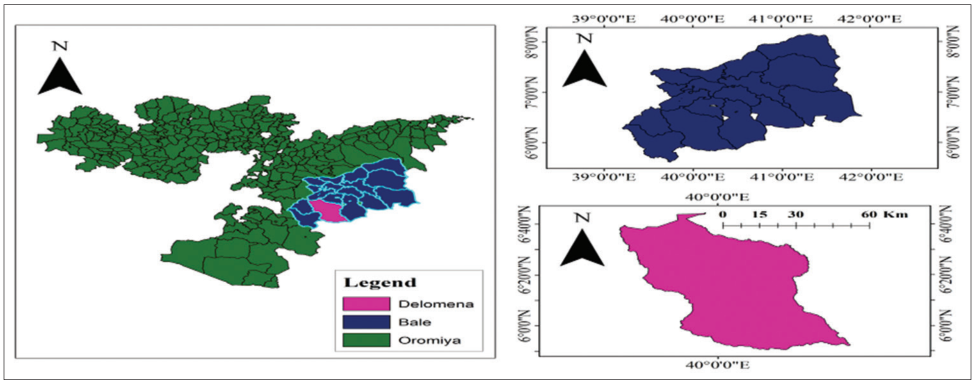

Figure 1: Location map of the study area

Soil Sampling Preparation and Laboratory Analysis

Soil samples were taken at different depths (0-20 cm, 20-50 cm) for physico-chemical analysis, and moisture storage measures from the experimental sites were prepared. The composite soil samples were labeled with necessary information then air dried and crushed using a mortar and pestle to pass through a 2 mm mesh sieve for most soil physicochemical properties. The initial available phosphorus below the critical concentration determined for the district was selected to conduct the experiment. The analyses were conducted following standard laboratory procedures at Sinana Agricultural Research Center Soil Laboratory. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Finally, the textural class of the soil was assigned using the USDA textural triangle classification system (USDA, 1987). The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Walkley and Black (1934) method was used for the determination of organic carbon. Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulveny (1982). Available P was determined following the Olsen method (Olsen, 1954) using ascorbic acid as a reducing agent.

Land Preparations and Managements

The experimental land was ploughed three times by oxen plough using the local Maresha before imposing any of the treatments. Mulching materials was prepared from easily accessible material (grass). A fertilizer of 100 kg ha^{-1} NPS and 100 kg ha^{-1} was uniformly applied based on the blanket recommendation of the districts.

RESULTS AND DISCUSSIONS

Selected Soils Physicochemical Properties

Even though soil is frequently referred to as the fertile substrate, not all soils are suitable for growing crops as affected by its physical, chemical, and biological parameters. The results of the analysis of soil parameters are shown in Table 1.

The observed textural class is clayey and the percent textural classes were sand (32%), silt (22%), and clay (46%). The analysis of selected soil chemical characteristics/parameters showed that all of them are categorized as low according to the standard rating as indicated in Table 2 particularly, the pH (7.23), soil organic matter (1.43), total Nitrogen (0.072), and Available Phosphorus (2.53). This result revealed the low availability of each parameter and that is why integrated *in-situ* soil moisture conservation and mulching are needed under maize plots.

Effect of Soil Moisture Conservation Techniques on Soil Moisture Storage

In the study, *in-situ* moisture conservation practices significantly affected the moisture storage of the soil. The greater soil moisture was recorded on the tied ridge with mulching followed by the furrow ridge with close ended furrow with mulching (Table 2). Soil moisture is an important component used as a medium for the supply of nutrients to growing plants. The grain yield (6134.84 kg ha^{-1}) and biomass (4525.00 ton ha^{-1}) were increased in the tied ridge with mulching were directly related to moisture present in the soil. The results of this study agreed with the findings of Solomon (2015) who reported that *in-situ* moisture conservation practices increase the moisture retention of the soil by reducing evapotranspiration and increasing the time of infiltration.

Yield and Yield Components of Maize

Results of the effect of different methods of moisture conservation practices on yield and yield components (PH, NPKE, BM, and GY) of maize at the Dallomanna district of Bale zone indicated that there were statistically higher significant differences between treatment groups whereas, NPKE and TKW were statistically non-significant (Table 3).

Grain yield

There was a significant variation in grain yield among all treatments. All *in-situ* moisture conservation plots had comparatively better maize grain yield and yield components over the control plot (farmer practices). This means farmer moisture conservation techniques/practices were performed at the lowest value of grain yield and yield components due to moisture shortage (moisture stress) in the Dallomana districts.

Table 1: Status of the selected soil parameters of the Dello Mena

Soil Properties	Result	Rating	Reference
Chemical			
pH (1:2.5 H_2O)	7.23	Neutral	Bruce & Rayment, 1982
SOM (%)	1.43	low	Emerson, 1991; Charman & Roper, 2000
TN (%)	0.072	low	Bruce & Rayment, 1982
Ava. P (ppm)	2.53	low	Cottenie, 1980
Physical			
Sand (%)	32		
Silt (%)	22		
Clay (%)	46		
Textural Class	Clayey		

SOM=Soil organic matter, TN=Total Nitrogen, Ava. P=Available Phosphorus

Table 2: Soil moisture contents under treatments

Treatments	Soil Moisture Content
T5	34.6[a]
T4	28.5[b]
T3	26.56[c]
T2	23.9[d]
T1	14.75[e]
Mean	25.66
LSD (0.05%)	1.02
CV (%)	2.11

Table 3: Mean yield and yield components of Maize under in-situ moisture conservation practices

Treatments	PH	NPKE	NRPE	BM	GY	TKW
T1	149.57[ab]	28.7[ab]	13.43	2072.92[c]	4371.05[c]	183.10
T2	139.83[b]	25.37[b]	12.60	2437.50[bc]	4422.05[c]	177.56
T3	146.86[ab]	27.20[ab]	13.20	3131.25[b]	4979.16[bc]	167.40
T4	165.32[a]	29.07[ab]	12.73	4258.33[a]	5641.95[ab]	188.30
T5	164.00[a]	30.63[a]	13.40	4525.00[a]	6134.84[a]	170.26
Mean	148.7	28.19	13.07	15.77	5110	177.3
LSD (0.05%)	19.21	4.74	NS	3.83	882.76	NS
CV (%)	10.55	14.14	7.73	20.44	14.52	17.98

T1=Control (without structure and mulching), T2=Mulching, T3=Furrow ridge with open ended furrow+Mulching, T4=Furrow ridge with close ended furrow+Mulching, T5=Tied ridge+Mulching, PH=Plant height (cm), NPKE=Number of productive kernels per Ear, NRPE=Number of rows per Ear, BM=Biomass yield (kg/plot), GY=Grain yield (quintal/hectare), TKW=Thousand kernels weight (g)

The highest mean grain yield (6134.84 kg ha^{-1}) was recorded from the plot of T5 (Tied ridge + Mulching) followed by mean grain yield (5641.95 kg ha^{-1}) and (4979.16 kg ha^{-1}) which recorded from the plot of T4 (Furrow ridge with close ended furrow + Mulching) and T3 (Furrow ridge with open ended furrow + Mulching) respectively (Table 3). The results of this study are in line with the findings of Taye and Yifru (2010), Ademe *et al.* (2018) and Chimdessa *et al.* (2019) reported that in situ moisture conservation practices (tied ridge) increase the yield and yield components of maize by reducing evapotranspiration and increasing the time for the water to penetrate the soil thereby retain soil moisture at root zone area for maize. Gebreyesus (2004) and Sibhatu and Qaim (2017) report that tied ridges and mulching have a positive interaction with soil moisture storage and yield of sorghum.

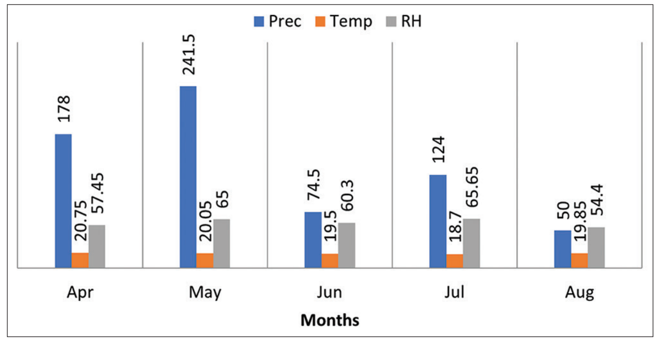

Figure 2: Climatic factors at Delomena

There was no statistically significant but numerically different variation between T1 (Control/without structure and mulching), and T2 (Control + Mulching) the plots from which the lower grain yields (4371.05 kg ha^{-1}, and 4422.05 kg ha^{-1} respectively) were recorded. This shows the low performance of farmer practices in the absence of *in-situ* soil moisture conservation measures.

Biomass

There was a significant variation in biomass between all treatment groups. The lowest Biomass yield (2072.92 kg ha^{-1}) was recorded from the plot of the control treatment (farmer practice). The highest Biomass yield (4525 kg ha^{-1}) recorded from the plot of T5 (Tied ridge + Mulching) was preceded by a biomass yield of 4258.33 kg ha^{-1} which was recorded from plots of T4 (Furrow ridge with close ended furrow + Mulching). The current result also agrees with the finding of Ademe *et al.* (2018), who reported that tied ridge cultivation could increase maize grain yield and biomass in the Vertic Andosol of Southern Ethiopia.

The results of this study revealed that there was a significant variation in plant height between treatment groups T5, T3, T2, and T1. There was no significant variation in plant height between T5 and T4. The lowest plant height (149.57 cm) was recorded from the plot of control treatment (farmer practice). The higher plant heights (165.32 cm and 164 cm) were recorded from the plot of T4 and T5 respectively. The result is agreed with Taye and Yifru (2010) who reported that under *in-situ* moisture conservation, maize recorded the highest plant height.

Germination and seedling stages

There was sufficient rainfall at the Germination and seedling stages (April). This shows that there was adequate moisture which is essential during this stage for proper germination. Under this stage, the corn seed absorbs water equal to approximately 50% of its weight (Plumblee, 2022; Larson, 2024).

Tasseling and silking stage

In this stage (June), the observed rainfall was low as per the maize water requirement. This mean the rainfall contribution is below the maize water requirement. Because of that, this stage is highly sensitive to water stress, and inadequate rainfall can significantly reduce pollination and kernel formation, leading to low grain yield as of control plot. Under this research, the moisture conservation measures significantly contributed to yield via retaining soil moisture in place (for instance, tied ridges). This result is similar to the finding of Teame *et al.* (2017) who report that *in-situ* moisture conservation and mulch had an influence on reducing environmental stress such as water stress by conserving moisture that serves the plant to facilitate growth and development.

Grain filling stage

In this stage (July), the observed rainfall was low as per the maize water requirement. Adequate moisture during grain filling is crucial for optimal kernel development and grain yield. A lack of water during this stage can reduce the size and weight of kernels. Therefore, the observed variation was not due to rainfall, it might be due to moisture conservation measures and treatment of tied ridge with mulch is better moisture around the root zone at this stage according to soil moisture storage data.

Maturation and harvest

In this stage (August), the rainfall showed a decreasing trend and the observed rainfall was optimal as per the maize water requirement at this stage. During the maturation phase, a decrease in rainfall is generally preferred as it aids in the drying of the crop before harvest. However, some moisture is still needed to maintain grain quality and this moisture is high in tied ridge with mulching treatments when compared to others.

CONCLUSION

Soil moisture shortage caused by erratic and poorly distributed rainfall has been one of the crop production constraints in rainfed agriculture of arid and semi-arid areas. However, *in-situ* moisture conservation and mulching are the best techniques to retain moisture in the root zone of crops and reduce evapotranspiration. This study was conducted to determine the best moisture conservation techniques with mulching for maize production under different rainfed conditions on maize. A comparative study between five treatments showed different moisture storage capacities. So based on the experiment conducted at Dallomanna districts for two consecutive cropping seasons (2021 and 2022), tied ridge with mulching showed a promising result on maize grain yield and soil moisture conservation as compared to other practices.

RECOMMENDATIONS

Based on this finding, it's better to further demonstrate tied ridge with mulching at first and a furrow ridge with close ended furrow with mulching at second to retain soil moisture in the soil and thereby maximize maize grain yield for the study area and similar agro-ecology.

ACKNOWLEDGMENTS

The authors would like to express great gratitude to OARI for financial support and Sinana Agricultural Research Center for logistic and vehicle support and allocation. The authors would likely express great gratitude to Sinana Agricultural Research Center soil fertility improvement team members for their contribution from initiation to the final research article.

REFERENCES

Abera, G. (2009). Commercialization of Smallholder Farming: Determinants and Welfare Outcomes. A Cross-Sectional Study in Enderta District, Tigrai, Ethiopia. MSc Thesis, University of Agder.

Abera, K., & Sibhatu, B. (2022). Influence of *in-situ* Moisture Conservation Techniques and N Rates on Agronomic Traits of Sorghum in Raya Valley, Northern Ethiopia. *British Journal of Environmental Sciences, 10*(5), 22-33.

Ademe, D., Bekele, B., & Gebremichael, A. (2018). On-farm Verification of the Soil Moisture and Yield Response of Tied Ridge on Maize Production in Dry Areas of SNNPR, Ethopia. *Journal of Environment and Earth Science, 8*(5), 1-5.

Agber, P. I., Akubo, J. Y., & Abagyeh, S. O. I. (2017). Effect of Tillage and Mulch on Growth and Performance of Maize in Makurdi, Benue State, Nigeria. *International Journal of Environment, Agriculture and Biotechnology, 2*(6), 2889-2896. https://doi.org/10.22161/ijeab/2.6.15

Anane, P.-S., Du, Y., Wang, T. Y., Huang, Z. Y., Bai, Y. C., Asiedu, M. A., & Liu, S. X. (2020). Cost and Benefit Analysis of Organic Mulching and Intercropping In Maize Cultivation. *Applied Ecology and Environmental Research, 18*(6), 7795-7812. https://doi.org/10.15666/aeer/1806_77957812

Ayala, G., Bulti, A., & Muleta, B. (2023). Evaluation of Mulching and Tied Ridges on Soil Moisture and Yield of Maize at Daro LebuDistrict, Western Hararghe Zone, Oromia, Ethiopia. *International Journal of Agricultural Economics, 8*(3), 116-121. https://doi.org/10.11648/j.ijae.20230803.16

Bekele, D. (2020). The Effect of Tillage on Soil Moisture Conservation : A Review. *International Journal of Research Studies in Agricultural Sciences, 6*(10), 30-41. https://doi.org/10.20431/2454-6224.0610004

Bhatt, R. M., & Rao, N. K. S. (2005). Influence of pod load on response of okra to water stress. *Indian Journal of Plant Physiology, 10*(1), 54-59.

BOFED. (2008). *Socio-Economic Profile of Bale Zone*. Oromia State Government: Bureau of Finance and Economic Development.

Bouyoucos, G. J. (1962). Hydrometer Method Improved for Making Particle Size Analysis of Soils. *Agronomy Journal, 54*(5), 464-465. https://doi.org/10.2134/agronj1962.00021962005400050028x

Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-Total. In A. L. Page (Eds.), *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties* (pp. 595-624) New Jersey, US: Wiley. https://doi.org/10.2134/agronmonogr9.2.2ed.c31

Bruce, R. C., & Rayment, G. E. (1982). Analytical Methods and Interpretations Used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Bulletin QB8 (2004), Indooroopilly, Queensland: Department of Primary Industries.

Bu, L., Liu, J., Zhu, L., Luo, S., Chen, X., Li, S., Hill, R., & Zhao, Y. (2013). The effects of mulching on maize growth, yield and water use in a semi-arid region. *Agricultural Water Management, 123*, 71-78. https://doi.org/10.1016/j.agwat.2013.03.015

Chakravarthy, G. A., Thiruppathi, M., Kandasamy, S., & Dhanasekaran, K. (2022). Effect of *in situ* soil moisture conservation practices on maize and its crop residue incorporation on yield and economics of succeeding transplanted rice Variety. *Journal of Applied and Natural Science, 14*(4), 1198-1203. https://doi.org/10.31018/jans.v14i4.3820

Charman, P. E. V., & Roper, M. M. (2007). Soil organic matter. In P. E. V. Charman & B. W. Murphy (Eds.), Soils, their properties and management (pp. 276-285) Melbourne, Australia: Oxford University Press.

Chavan, M. L., Phad, P. R., Khodke, U. M., & Jadhav, S. B. (2009). Effect of organic mulches on soil moisture conservation and yield of rabi sorghum (M-35-1). *International Journal of Agricultural Engineering, 2*(2), 322-328.

Chimdessa, G. C., Bedaso, N., & Eshetu, M. (2019). Evaluating the Effect of Soil Moisture Conservation and Management Practices on Yield and Yield Components of Maize Crop in the Midlands of the Bale Zone, Southeastern Ethiopia. *Irrigation & Drainage Systems Engineering, 8*(2), 1000234.

Chiturike, P., Nyamadzawo, G., Gotosa, J., Mandumbu, R., Nyakudya, I. W., Kubiku, F. N. M., & Kugedera, A. T. (2023). Evaluation of different rainwater harvesting techniques for improved maize productivity in semi - arid regions of Zimbabwe with sandy soils. *Journal of Sustainable Agriculture and Environment,* 2(1), 26-39. https://doi.org/10.1002/sae2.12033

Cottenie, A. (1980). *Soil and Plant Testing as a Basis of Fertilizer Recommendations*. FAO Soil Bulletin 38/2. Rome, Italy: Food and Agriculture Organization of the United Nations.

CSA. (2019). *Agricultural Sample Survey 2018/19 (2011 E.C.)*. Volume I, *Report on Area and Production of Major Crops* (Private Peasant Holdings, Meher Season), FDRE Statistical Bulletin, Addis Ababa: Central statistical Agency.

CSA. (2022). *Agricultural Sample Survey 2021/22 (2014 E.C.)*. Volume III, *Report on Farm Management Practices* (Private Peasant Holdings, Meher Season), FDRE Statistical Bulletin, Addis Ababa: Central statistical Agency.

Desta, G., Tamene, L., Abera, W., Amede, T., & Whitbread, A. (2021). International Soil and Water Conservation Research; Effects of land management practices and land cover types on soil loss and crop productivity in Ethiopia: A review. *International Soil and Water Conservation Research, 9*(4), 544-554. https://doi.org/10.1016/j.iswcr.2021.04.008

Emerson, J. D. (1991). Introduction to Transformation. In D. C. Hoaglin, F. Mosteller & J. W. Tukey (Eds.), *Fundamentals of Exploratory Analysis of Variance* New Jersey, US: Wiley.

FAOSTAT. (2019). World Food and Agriculture - Statistical pocketbook 2019. Rome.

Gebreyesus, B. T. (2004). Tied Ridging as *In-situ* Rainwater Harvesting Methods for Improving Sorghum Yield at Abergelle Area, Tigray Regional State. M. Sc. Thesis. Haremaya University.

Gezahegn, A. M., Desta, B. T., Takele, A., & Eshetu, S. (2020). Productivity of tef [Eragrostis tef] under conservation tillage practices in central Ethiopia. *Cogent Food & Agriculture, 5*(1), 1707038. https://doi.org/10.1080/23311932.2019.1707038

Handiso, M. A. (2023). Evaluation of Conservation Tillage Methods on Soil and Water Conservation, and Yield and Yield Components of Maize (*Zea mays* L.) in South Ari District, Southern Ethiopia. *Research Square,* 1-16. https://doi.org/10.1007/s44279-023-00008-9

Husen, D., & Shalemew, Z. (2021). Effects of *in-situ* moisture conservation techniques on maize (*Zea mays*) yield and yield components in moisture deficit area of Dugda Woreda, Ethiopia. *Journal of Engineering and Technology Research, 13*(1), 1-7. https://doi.org/10.5897/JETR2019.0670

Kamara, A. Y., Garba, M., Tofa, A. I., Mohamed, A. M. L., Souley, A. M., Abdoulaye, T., & Kapran, B. I. (2023). Heliyon Assessment of the impact of crop management strategies on the yield of early-maturing maize varieties in the drylands of Niger Republic : Application of the DSSAT-CERES-Maize model. *Heliyon, 9*(7), e17829. https://doi.org/10.1016/j.heliyon.2023.e17829

Kugedera, A. T., Mango, L., & Kokerai, L. (2020). Evaluating the effects of integrated nutrient management and *insitu* rainwater harvesting on maize production in dry regions of Zimbabwe. *International Journal of Agriculture Environment and Food Sciences, 4*(3), 303-310. https://doi.org/10.31015/jaefs.2020.3.9

Lan, X., Chai, S., Coulter, J. A., Cheng, H., Chang, L., Huang, C., Li, R., Chai, Y., Li, Y., Ma, J., & Li, L. (2020). Maize Straw Strip Mulching as a Replacement for Plastic Film Mulching in Maize Production in a Semiarid Region. *Sustainability, 12*(15), 6273. https://doi.org/10.3390/su12156273

Larson, E. (2024). *How to determine corn vegetative growth stages*. Starkville (MS): Mississippi State University Extension. Retrieved form https://www.mississippi-crops.com/2024/05/17/how-to-determine-corn-vegetative-growth-stages

Martínez-Mena, M., Carrillo-López, E., Boix-Fayos, C., Almagro, M., García Franco, N., Díaz-Pereira, E., Montoya, I., de Vente, J. (2020). Long-term effectiveness of sustainable land management practices to control runoff, soil erosion, and nutrient loss and the role of rainfall intensity in Mediterranean rainfed agroecosystems. *Catena, 187*, 104352.

Marwein, Y., Ray, L. I. P., & Dey, J. K. (2019). *In-situ* Soil Moisture Conservation with Organic Mulching under Mid Hills of Meghalaya, India. In R. Kumar, V. P. Singh, D. Jhajharia, R. Mirabbasi (Eds.), *Applied Agricultural Practices for Mitigating Climate Change* (Vol. 2, pp. 39-49) Boca Raton, Florida: CRC Press. https://doi.org/10.1201/9780429326400-4

Mehadi, S., Beriso, M., & Worku, Y. (2016). Full Length Research Paper Participatory Variety Selection of Improved Tomato (*Lycopersicum esculentum* Mill.) Varieties in the Lowlands of Bale, South-Eastern Ethiopia. *African Journal of Agricultural Economics and Rural Development, 4*, 458-462.

Mupangwa, W., Nyagumbo, I., & Mutsamba, E. (2016). Effect of different mulching materials on maize growth and yield in conservation agriculture systems of sub-humid Zimbabwe. *AIMS Agriculture and Food, 1*(2), 239-253. https://doi.org/10.3934/agrfood.2016.2.239

Ndegwa, J. K., Gichimu, B. M., Mugwe, J. N., Mucheru-muna, M., & Njiru, D. M. (2023). Integrated Soil Fertility and Water Management Practices for Enhanced Agricultural Productivity. *International Journal of Agronomy, 2023*(1), 8890794. https://doi.org/10.1155/2023/8890794

Olsen, S. R. (1954). *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate*. Washington, US: United States Department of Agriculture.

Orfanou, A., Pavlou, D., & Porter, W. M. (2019). Maize Yield and Irrigation Applied in Conservation and Conventional Tillage at Various Plant Densities. *Water, 11*(8), 1726. https://doi.org/10.3390/w11081726

Parmar, H. N., Polara, N. D., & Viradiya, R. R. (2013). Effect of mulching material on growth, yield and quality of watermelon (*Citrullus lanatus* Thunb) Cv. Kiran. *Universal Journal of Agricultural Research, 1*(2), 30-37. https://doi.org/10.13189/ujar.2013.010203

Plumblee, M. (2022). *2022 South Carolina corn production guide*. Clemson, SC: Clemson University Cooperative Extension. https://www.clemson.edu/extension/agronomy/_files/corn-production-guide.pdf

Prasad, B. V. G., Chakravorty, S., Saren, B. K., & Panda, D. (2014). Effect of mulching on physiological growth determinants of productivity in French bean (*Phaseolus vulgaris* L.). *HortFlora Research Spectrum, 3*(2), 162-165.

Rhoades, J. D. (1982). Soluble salts. In A. L. Page (Eds.), *Methods of Soil Analysis* (pp. 167-179) Madison, US: American Society of Agronomy, Inc.

Saikia, U. S., Kumar, A., Das, S., Pradhan, R., Goswami, B., Wungleng, V. C., Rajkhowa, D. J., & Ngachan, S. V. (2014). Effect of mulching on microclimate, growth and yield of mustard (Brassica juncea) under mid-hill condition of Meghalaya. *Journal of Agrometeorology, 16*(1), 144-145. https://doi.org/10.54386/jam.v16i1.1502

Salifu, E., Agyare, W. A., & Larbi, A. (2019). Effect of Soil and Water Conservation Methods on Maize Performance and Soil Water Retention in Northern Region of Ghana. *International Journal of Scientific & Technology Research, 8*(3), 116-120.

Shashikanth, M., & Thimmegowda, M. N. (2022). Growth and yield of Maize (*Zea mays*) influenced by organic mulching in rainfed Alfisols of Southern Karnataka. *The Pharma Innovation Journal, 11*(5), 484-488.

Sibhatu, K. T., & Qaim, M. (2017). Rural food security, subsistence agriculture, and seasonality. *PLoS One, 12*(10), e0186406. https://doi.org/10.1371/journal.pone.0186406

Solomon, T. (2015). On-farm verification of the effects of selected soil moisture conservation techniques on yield and yield components of early maturing maize varieties at Bako, Western Ethiopia. *International Journal of Advanced Remote Sensing and GIS, 4*, 254-264.

Taye, B., & Yifru, A. (2010). Response of maize (*Zea mays* L.) to tied ridges and planting methods at Goro, Southeastern Ethiopia. *American-Eurasian Journal of Agronomy, 3*(1), 21-24.

Teame, G., Tsegay, A., & Abrha, B. (2017). Effect of Organic Mulching on Soil Moisture, Yield, and Yield Contributing Components of Sesame (*Sesamum indicum* L.). *International Journal of Agronomy, 2017*, 767509. https://doi.org/10.1155/2017/4767509

USDA. (1987). *Soil survey manual*. Soil Survey Division Staff, Soil Conservation Service, US: Department of Agriculture.

Uwizeyimana, D., Mureithi, S. M., Karuku, G., & Kironchi, G. (2018). International Soil and Water Conservation Research Effect of water conservation measures on soil moisture and maize yield under drought prone agro-ecological zones in Rwanda. *International Soil and Water Conservation Research, 6*(3), 214-221. https://doi.org/10.1016/j.iswcr.2018.03.002

Wafula, K. M., Karanja, N. N., Karuku, G. N., & Esilaba, A. O. (2022). *In-situ* water harvesting technologies and fertilizer rates increase Maize and Bean yields in the Semi-Arid Katumani, Kenya. *Tropical and Subtropical Agroecosystems, 25*(3), 110. https://doi.org/10.56369/tsaes.4247

Walkley, A., & Black, I. A. (1934) An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. *Soil Science, 37*(1), 29-38. https://doi.org/10.1097/00010694-193401000-00003

Wang, C., Wang, J., Zhang, Y., Qin, S., Zhang, Y., & Liu, C. (2022). Effects of Different Mulching Materials on the Grain Yield and Water Use Efficiency of Maize in the North China Plain. *Agriculture, 12*(8), 1112. https://doi.org/10.3390/agriculture12081112

Wang, X., Wang, G., Turner, N. C., Xing, Y., Li, M., & Guo, T. (2020). Determining optimal mulching, planting density, and nitrogen application to increase maize grain yield and nitrogen translocation efficiency in Northwest China. *BMC Plant Biology, 20*, 282. https://doi.org/10.1186/s12870-020-02477-2

Wolde, B., Naba, W., & Gebremichael, A. (2020). Evaluation of *In-situ* Moisture Conservation Techniques for Maize Production in Moisture Stress Areas of Mirab Abaya Woreda, Southern, Ethiopia. *Advances in Crop Science and Technology, 8*(2), 1000442.

Yisfa, T., Grum, B., & Aregay, G. (2023). Comparison of different mulching options for improving water productivity and maize yield in a semi-arid climate, Northern Ethiopia, Tigray. *Discover Agriculture, 1*, 5. https://doi.org/10.1007/s44279-023-00005-y