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Research Article

Evaluation of Land Surface Management on Moisture Conservation, Yield and Yield Components of Maize (*Zea Mays* L.) in East Shewa Zone of Oromia, Ethiopia

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Abstract

Maize is an important food crop in Ethiopia and it is one of the main smallholder food crops in the rift valley of Oromia, although shortage of rainfall and erratic occurrence was caused soil moisture content stressed yields reduced. Suitable soil and water conservation measures that can be easily integrated into the existing farming operations while enhancing in-situ moisture conservation. The study was conducted on land surface management to increase soil moisture content, amend soil nutrients and enhance yield and yield components of maize. The experiment was conducted during the 2021 and 2022 main cropping seasons at Adami Tulu Agricultural Research Center on-station using RCBD that had five tested treatments. Maize variety Melkasa-II was used as a testing crop for its familiar to local communities. The results indicated that soil moisture content was enhanced by 5.8% to 26.4% in maturity and vegetative stages up to 60 cm depths. Soil physico-chemical properties were improved and the highest grain yield was obtained from 5 tha^{-1} (SM+FYM) plus NPS fertilizer and 5 tha^{-1} of straw mulch plus inorganic fertilizers treatments that increased by three to four fold of the organic fertilizer applied and control treatments orderly. This result implies that retaining crop straw mulch and application of farmyard manure in the field within profitable cost can be used as soil moisture conservation tool for sustainable improvement of maize production in the study area.

Keywords

Farmyard Manure, Growth Stages, Soil Depth, Straw Mulch

1. Introduction

Water stress is the main factor limiting plant growth and crop yield in arid and semi-arid environments [23]. Low productivity in many arid and semi-arid rain-fed agricultural systems is often due to degraded soil fertility and limited water and nutrient inputs. The negative impacts of the repeatedly occurring terminal moisture stress are more pronounced because of the low water holding capacity of the soil and high evaporation of soil surface.

Maize (*Zea mays L.*) is a widely grown crop with respect to area cultivated and production, it exemplify among cereal crops the third important crop in the world after wheat and rice [4, 6, 18]. Similarly it is one of the most important cereal crops in Ethiopia and about 40% of the total maize growing areas are also located in low-moisture stress areas, where it contributes less than 20% to the total annual production [29]. This is because; rainfall in the region is unpredictable (may

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start early or very late in the season) in term distribution and amount (even some times less than 600 mm/annual). Worsening water storage and soil nutrients content consequently impairs soil quality [33] and then restrains crop production [15].

Crop productivity could be greatly influenced by even a small change in soil water storage [16]. Cover with crop straw on soil surface, straw mulch is considered important to promoting soil moisture content [14]. Because soil water storage in arid regions is significantly influenced by straw mulch, there is an increasing requirement for understanding the responses of soil water dynamics and crop productivity to straw mulch, and a lot of methods have been applied to study the effects of straw mulch on soil properties and crop productivity [13]. Straw mulch has been carried out in arid and semi-arid region to improve crop yields [7]. Emerging evidence indicated that integrated soil fertility management involving the judicious use of combined organic and inorganic resources is a feasible approach to overcome soil fertility constraints [10]. The application of straw mulch and farmyard manure could increase the soil moisture content by 16% to 28% in the three soil depth in relation to the control [5].

On the other hand, organic matter to soil improved both soil water infiltration and water holding capacity, through incorporation of plant residues or manures [35]. Notably, the positive effects of organic manure on soil water retention should be in consideration of soil quality, which contributes to sustainable production in the moisture stress areas.

Consequently, consecutive organic manure input improved soil water uptake in more than 150 cm soil profile and maintained stable SWC in the depth of 0-50 cm and below 150 cm [34]. This study confirms that the increased levels of N, P and Soil organic matter positively associated with crop yield increase beyond the manure application years [15]. FYM supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as micronutrients (Fe, Mn, Cu and Zn). Hence, it acts as a mixed fertilizer [9]. Integrated nutrient management in which both organic matters and inorganic fertilizers are used simultaneously is the most effective method to maintain a healthy and sustainably productive soil [9] while reduced the nutrient enrichment of synthetic fertilizer in soil environments [34].

The research on mulching and farmyard manure application has been conducted in different agro-ecological condition, especially in the area of low rainfall by rain-fed system. Though, there were a limited number of research conducted on mulching and farmyard manure integrated with inorganic fertilizers. Therefore, the objectives of this study were to investigate water conservation and associated with nutrients under surface management, determine productivity of maize under straw mulch and manure and determine economic feasibility of straw mulch and manure on maize productivity.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in Adami Tulu Agricultural Research Center on-station based on moisture stress and the maize crop production potential of the surrounding area. Adami Tulu Agricultural Research Center (ATARC) is geographically located between 7° 50' 30" to 7° 51'30" N latitude and 38° 42'0" to 38° 43'0" E longitude. It is found in Adami Tulu Jido Kombolcha district of East Shewa zone of Oromia Regional State. The center is 7 km far from Batu town on the Hawassa road and 167 km away to the south of Addis Ababa. It is found at the altitude on 1651 m.a.s.l. The vegetation is characterized by scattered acacia woodland.

Adami Tulu district is characterized by lowland and dry agro climate with annual rain fall of 670-750mm followed by bi-modal rainfall pattern with erratic condition and insignificant mean monthly precipitation. The temperature of district ranges 17 to 25 ℃ during the rainy seasons and exceeded to 30 ℃ during the dry season and result with annual temperature ranging from 20 ℃ to 25 ℃. Average annual temperature varies from 10 to 25 ℃, while the annual rainfall varies between 800 and 1200 mm. The major crops produced in the area were maize, teff, haricot bean, barley, wheat, sorghum, onion, cabbage, potatoes and tomatoes. From these crops maize is the dominant crop area coverage and the yield produced.

2.1.1. Experimental Treatments and Design

The experiment consists of five treatments and it was applied using randomized complete block design (RCBD) with three replications by a total of fifteen experimental plots. The treatments were arranged in the Table 1 below:-

Table 1. Treatments arrangement and its descriptions.

Treatments	Description of the treatments
T_1	Control (without application of fertilizers or mulch)
T_2	100kg/ha of urea +100kg/ha of (Urea and NPS)
T_3	5 tons/ha of Straw mulch + 100 kg/ha of (Urea and NPS)
T_4	5 tons/ha of Farmyard manure +100 kg/ha of NPS
T_5	5 tons/ha of (Straw mulch + Farmyard manure) + 100 kg/ha of NPS

The size of each plot was 3mx4m (12m^2) with the row to row distance as 75cm and plant to plant 30cm with a total plant population of 56 in each plot. Each plot had a distance of 1m apart and block to block distance as 1.5m and 1m from border.

2.1.2. Land Preparation and Field Management

All experimental plots tilled three times by hand at different soil depth before plating of cultivar. An agronomic aspect for the crop; weeding and hoeing of the maize was performed twice (15 to 20 and 35 to 40 days after seedling emergence). The different chemicals have been sprayed to control stock borer and American geer worms happens to cultivar. Maize (*zea mays L.*) Melkasa-2 was sown by line with indicated spacing between rows and plants as testing crop. This variety was selected due to its tolerant to moisture stress and widely grown in the areas. Inorganic fertilizers (Urea and NPS) were applied by blanket recommended rate per hectare for each plots and urea was applied by split of 1/3 at the time of sowing, while the left 2/3 applied at second round cultivation of the crop.

2.1.3. Manure and Wheat Straw Application

Cattle manure was collected from the farmers' barn nearby the experimental site and heaped for about one month prior to the initiation of the experiment. After removing the outer part of the heap, the manure was air dried at room temperature and incorporated to the plots uniformly at specified rate one week before sowing of the cultivar. The wheat straw purchased from local farmers around the study area by quintal (Qt) and dried in the uniform condition until the day of sowing. The straw was weighed and mulched on the plots at the specified rate uniformly soon after sowing.

2.2. Methods of Data Collection

2.2.1. Soil Sampling and Analysis

The composite soil samples were collected diagonally from three locations for all plots at uniform depth of 30 and 60 cm using auger prior to the application of the treatment, but after harvest with similar procedure soil samples was taken from each plots at 0-20, 21-40 and 41-60 cm soil depths. The collected soil samples were analyzed for total nitrogen (TN), available phosphorous (P), available potassium (K), organic carbon (OC), cation exchange capacity (CEC), electric conductivity (EC), soil pH and soil texture determination. In addition, soil moisture content and bulk density was analyzed and evaluated at three soil depths through four growth stages of maize crop.

Texturing analysis of soil: The samples was taken to the laboratory, air-dried, crushed, and sieved to pass through a 2 mm mesh. The physical and chemical properties of the soil were determined as standard procedures; soil texture was determined by hydrometer method and the soil textural class judged using the textural triangle of USDA system as described by [22].

Soil bulk density: Bulk density of the soil was determined by gravimetric method after undisturbed samples taken by core samplers of known volume after oven dried to constant weight at 105 ℃ for 24 hours and calculated as:

$$\rho b = \frac{Ms}{V} \tag{1}$$

Where:

ρb= bulk density in (g/cm^3)

Ms = mass of the oven dry sample in (g)

V = volume of sample as determined by the volume of core ring in (cm^3)

Organic carbon content, pH, cation exchange capacity and associated nutrient of soil before and after experiment: Organic carbon content of the soil was determined by potassium dichromate wet combustion procedure [32]. Soil to water suspensions of ratio 1:2.5 was shaken for one hour and left to stand for 30-60 minutes before reading. Soil pH was potentiometrically measured in the supernatant suspension of 1:2.5 soils: water ratio [19]. The available phosphorus content of soil was determined by 0.5M sodium bicarbonate extraction procedures [11]. Total nitrogen content of the soil was determined by wet oxidation procedures of the Kjeldahl method and exchangeable potassium was determined by Flame photometer [31].

Moisture content determination through growth stages: To determine the soil moisture content status at different growth stages using gravimetric method the wet soil samples were collected and placed in an oven set at a temperature of 105 ℃ and dried for 24hrs then, determined using the following equation.

$$\theta dw = \frac{Wws - Wds}{Wds} \tag{2}$$

Where: - Wws= weight of wet soil (g),

θdw = water content expressed on weight basis in (%)

Wds = weight of dry soil (g) and the volumetric water content will be calculated from the gravimetric water content using the following expression,

$$\theta v = \frac{\rho b \times \theta dw \times 100}{\rho w} \tag{3}$$

Where: - θdw= water content expressed on weight basis in (%)

θ_v= volumetric moisture content in (%)

ρb = soil bulk density (g/cm^3), and

ρw = water density g/cm^3 (1g/ cm^3)

2.2.2. Meteorological and Agronomic Data Collection Methods

Meteorological data of the study area: The meteorological data of the study area in the experiment conducted year (2021-2022) were taken from the Ziway meteorological station that is nearby the experimental site. The amount and distribution of the rainfall at the study area in the cropping seasons was compared with result obtained due to the effects of the treatments on the nutrient content and soil moisture conservation of the cropping seasons.

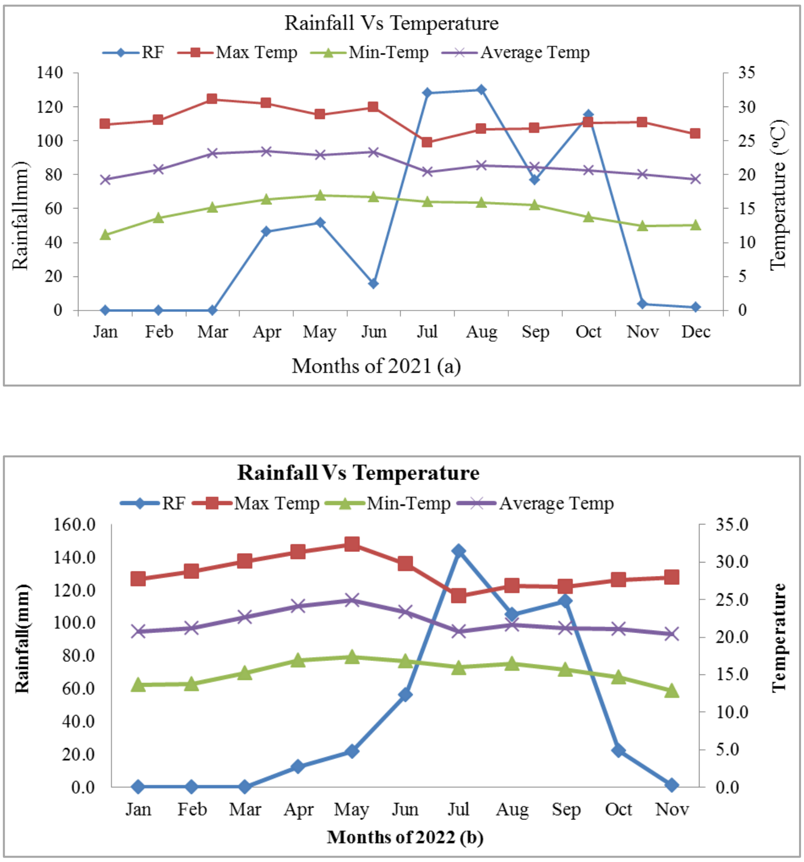

***Figure 1**. Annual rainfall and temperature of (a) and (b) for ATARC.*

2.2.3. Growth Parameters, and Yield and Yield Components of Maize

Growth component (plant height): The average height of the plant was measured to the nearest centimeter from the base to top at physical maturity stage of the crop. The mean height of the 10 randomly selected plants from the two middle rows were taken as the score for each plot. Days to 50% flowering: Number of days from planting to when 50% of the plants in plots shed pollen and emerge 2-3 cm long silk was recorded by observing the plots and counting the budded stand. Days to 50% physiological maturity: The numbers of days from planting to 50% of the kernels on the ears show black layer on the tip of the kernel were recorded by observing the stand in the plots. Number of ear per plant*:* Numbers of ears were recorded when the plant reach the maturity stage, by counting ears on stands selected from the middle rows, those tagged for plant height measurement and the average value was taken as ear per plant. Number of seeds per ear: The total number of seeds of the ear was counted from selected plants for numbers of ear per stands and, then the average value was used as seeds per ear for each plot. Thousand grain weight: One thousand seeds were counted from each treatment of experimental units and adjusted to 12.5% moisture level. The seed was weighted using sensitive balance, and average weight grain yield was taken for the replication of the treatments.

Total grain yield: The total grain yield from all the ears of each experimental unit was recorded as per treatments and it was adjusted to 12.5% moisture level using moisture tester, then the grain yield per hectare was estimated.

Economic analysis: Economic analysis such as partial budget, total variable cost ratio, and marginal rate of return of maize yield was evaluated. The costs of fertilizers were 22.9 ETB kg^{-1} for urea, 22.09 ETB kg^{-1} for NPS, cost of wheat straw mulch and farm yard manure estimated as 1033 and 872 ETB per ton respectively. The cost of fertilizer transportation was considered as 80 ETB per 100 kg fertilizer and labour cost of fertilizer application ETB 150 per day for 8 hours for 100 kg fertilizer. Whereas, the transportation and application cost of manure and straw mulching were considered in cost of purchased. The Local market selling price of one-kilogram of maize in Ethiopia birr at the Adami Tulu district were twenty five birr for the average of past three year. The average yield was adjusted downward by 10% and was used to reflect the difference between the experimental field and the expected yield from farmers' fields with farmers' practices from the same treatments [3]. Analysis of marginal rate of return (MRR) was carried out for non-dominated treatments and the MRR were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment [8].

2.3. Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD) and replicated three times using Genstat software 15th edition. General linear model (GLM) was employed and treatment means were compared using Least Significant Differences (LSD) by Duncan's test at 0.05 significance level.

3. Results and Discussions

3.1. Soil Physical and Chemical Properties

3.1.1. Selected Physico-Chemical Properties of Soil Before Application of the Treatment

The soil analysis result indicated that, the soil textural class in the study areas was found to be sandy loam (Table 2). The bulk density values of 1.0 to 1.5 g/cm^3 categorized as a favorable physical condition of soils for plant growth and it is in the range of fertile soil as it was confirmed by [28]. The study area soil was slightly to moderately alkaline in reaction (pH at 8.1-8.3) in both 0-30 and 31-60 cm of soil depths [30]. The result also indicated that soil had low organic carbon (1.23 to 1.79 %) and medium to high total nitrogen (0.42 to 0.66%) at 31-60 and 0-30 cm of soil depths respectively.

Table 2. *Selected soil physico-chemical properties of surface and subsurface soil before treatments application.*

Soil properties	Soil Depths (cm)	
	0-30	**30-60**
Sand (%)	75	70
Clay (%)	19	14
Silt (%)	16	16
Textural class	Sandy Loam	Sandy Loam
Bulk density (BD)(g/cm3)	1.28	1.29
pH-water (1:2.5)	8.1	8.3
Cation Exchange capacity (CEC) (dS/m)	12.25	10.89
Organic carbon (%)	1.79	1.23
Total nitrogen (%)	0.66	0.42
Available phosphorus (mg/kg)	8.63	7.65
Available potassium (mg/kg)	648	779

The cation exchange capacity of study area was fallen in low the Olsen extractable available phosphorus content of the soil with values of 7.65 to 8.63 mg/kg, which was found in the rage of moderate to high compared to the critical limit of 8 mg/kg established by [30] for some Ethiopian soils. Available potassium was also categorized into very high which is more exceeds the 300 mg/kg value that was the maximum for the high category rating of available potassium. The analyzed result indicated that, the soil in the study area was poor in natural fertility, especially organic carbon content and nitrogen content was categorized as low and medium, while the soil rich in available phosphorus and available potassium high in natural fertility.

3.1.2. Selected Soil Physico-Chemical Properties of Soil After Harvesting

The effects of mulching and farm yard manure treatments on soil bulk density were illustrated in Tables 3, 4 & 5. It was observed that soil bulk density in the treatments increased gradually with increasing soil depth from 0 to 60 cm. Soil depth affected statistically significantly ($P \leq 0.001$) for the first depth ($P \leq 0.01$) at second soil depth on bulk density, while there is no statistical difference between the treatments at 41-60 cm soil depth. Likewise result indicated that higher mean values (1.61 g cm^{-3}) of bulk density were recorded under control compared with lowest mean value of 1.11 g cm^{-3} recorded from mulch with farmyard manure treatment. The bulk density increased with depth because of decrease in soil organic matter (OM) content and soil aggregation, as it was indicated by the significant negative correlation between the two properties [21]. In the first and second soil depth application of straw mulch and farm yard manure decreased the soil bulk density compared to un-mulched treatments. This may be due to the effect of farmyard manure on soil aggregate formation and an increase of in soil infiltration capacity by conserved moisture. Farmyard manure affect soil physical structure; as volume of soil decreased porosity and infiltration simultaneously increased that could affect bulk density to be decreased [5].

The analysis of variance indicated that there was no significant difference pH reaction between the treatments in the three soil depth of the study site. The mean pH value of the soil in the area ranges from slightly neutral to moderate alkaline (7.3 to 8.4) as rated by [30] rating. This implies that presence of high amount of soil pH in all soil depths indicated absence of substantial quantity to exchangeable hydrogen ion since the experiment was conducted only one times in two year duration. The finding of Liang *et al*., (2012) stated the decrease in pH of the surface layer in the inorganic fertilizers might be attributed to the nitrification and acidification processes, stimulated by application of organic fertilizers as well as by H^+ released by the roots.

The organic carbon (OC) and total nitrogen (TN) of the soils contents decreased with depth has positive relationship. The statistical analysis indicated that application of straw mulch and farm yard manure has a highly significant (p≤0.01) effect on the soil organic carbon and total nitrogen. The highest OC (4.2%) and TN (0.37%) recorded from 0-20 cm soil depth mulched with 5 tha^{-1} of straw mulch and 5 tha^{-1} of farm yard manure as compared to the other treatments whereas, the lowest OC (1.07) and TN (0.05%) was obtained from 41-60 cm soil depths from control treatments. The difference in OC and total N content among the treatments could be attributed to the effect of variation in the farm yard manure application with mulching and without mulching. Total N content decreased with depth in all soil while available potassium increased as soil depth increased with inconsistence trends between the treatments and soil depth (Tables 3, 4 and 5). Similarly analysis of variance in the availability of phosphorus shown there was a highly significant (p≤0.01) difference in 21-40 cm soil depth and very highly significant (p≤0.001) between the treatments in 41-60 cm soil depths for Adami tulu research center site (Tables 3, 4 and 5). The results indicated that, the application of 5 tha^{-1} of straw mulch with HUNPS and sole application of HUNPS affect highly available phosphorus in the soil as compared to other treatments as it has applied more amount of phosphorus nutrient through urea and NPS fertilizers used. Even though, the available phosphorus was not inconsistent relationship with treatments; there was a decreasing trend down the soil depth.

Statistical analysis revealed that application of straw mulch and farm yard manure had highly significant (p≤0.01) effect on CEC at all soil depth (Table 5). The highest CEC (22.74 (dS/m)) was recorded from the plot received 5 tha^{-1} of straw mulch with farm yard manure plus NPS fertilizer in the first soil depth. Whereas, the lowest CEC (5.45 (dS/m)) was obtained from HUNPS applied treatments. Cation exchange capacity decreased along the soil depth and the minimum value was found in the 41-60 cm soil depth. This might be due to applied mulch and easily nutrient mineralization by the stored moisture as evaporation reduced and infiltration increased in the first soil depth to the second. This result is in parallel with study of [21] cation exchange capacity (CEC) of the soils across the surface and subsurface horizons ranged from 15.4 to 28.8 cmol(+) kg^{-1} and the surface soil CEC was the highest in the upper pedon followed by the depression while the lowest was observed in the middle pedon.

Table 3. Selected soil physico-chemical properties after harvesting in 0-20 cm soil depth.

Treatments	Parameters							
	Tex. C	BD (gcm-3)	pH	OC (%)	TN (%)	Ava. P (mg/kg)	Ava.K (mg/kg)	CEC (dS/m)
Control	SL	1.38a	8.28	1.86c	0.16b	7.77	433.7	9.88c
HUNPS	SL	1.27abc	8.33	1.91c	0.16b	8.40	627.2	14.43bc
5SM+HUNPS	SL	1.14bc	8.27	2.26bc	0.18b	7.90	590.8	16.27b
5FYM+HNPS	SL	1.37ab	8.28	3.26ab	0.30a	7.44	474.5	19.67ab
5(FYM+SM)+NPS	SL	1.11c	8.29	4.20a	0.37a	8.81	530.2	22.74a
CV (%)	-	10.7	0.3	13.6	8.5	24.3	9.9	7.4
LSD (0.05)	-	0.16	0.06	1.02	0.054	5.44	146.2	3.41
P value	-	***	Ns	**	**	ns	Ns	**

Table 4. Selected soil physico-chemical properties after harvesting in 21-40 cm soil depth.

Treatments	Parameters							
	Tex. C	BD (gcm-3)	pH	OC (%)	TN (%)	Ava. P (mg/kg)	Ava. K (mg/kg)	CEC (dS/m)
Control	SL	1.46ab	8.36	1.56c	0.13c	3.87b	574.2	9.19b
HUNPS	SL	1.33ab	8.31	1.52c	0.17bc	7.03a	669.0	9.40b
5SM+HUNPS	SL	1.23b	8.33	1.96b	0.24abc	5.55ab	718.2	10.67b
5FYM+HNPS	SL	1.59a	8.33	1.86bc	0.30ab	4.89b	692.2	14.77ab
5(FYM+SM)+NPS	SL	1.31ab	8.37	2.71a	0.35a	4.72b	757.0	21.35a

Treatments	Parameters							
	Tex. C	BD (gcm-3)	pH	OC (%)	TN (%)	Ava. P (mg/kg)	Ava. K (mg/kg)	CEC (dS/m)
CV (%)	-	12.6	0.2	4.5	13.3	7.6	10.3	13.8
LSD (0.05)	-	0.18	0.05	0.24	0.09	1.10	194.9	5.00
P value	-	**	ns	***	**	**	Ns	**

***Table 5.** Selected soil physico-chemical properties after harvesting in 41-60 cm soil depth.*

Treatments	Parameters							
	Tex. C	BD (gcm-3)	pH	OC (%)	TN (%)	Ava. P (mg/kg)	Ava. K (mg/kg)	CEC (dS/m)
Control	SL	1.61	8.39	1.07	0.05c	3.33c	792.2	7.83ab
HUNPS	SL	1.45	8.37	1.22	0.11abc	3.99bc	835.0	5.45b
5SM+HUNPS	SL	1.33	8.37	1.32	0.15ab	5.58ab	799.2	12.02ab
5FYM+HNPS	SL	1.38	8.35	1.52	0.07bc	3.17c	803.8	12.32ab
5(FYM+SM)+NPS	SL	1.17	8.43	1.47	0.17a	6.94a	892.2	17.66a
CV (%)	-	20.9	0.5	18	17.6	8.8	3.4	21.7
LSD (0.05)	-	0.27	0.11	0.66	0.05	1.12	78.81	6.67
P value	-	Ns	Ns	Ns	**	***	Ns	**

HUNPS = Hundred kg of Urea and NPS fertilizers, 5SM=5 tons per hectare of wheat straw mulch, 5 FYM= 5 tons per hectare of Farmyard manure, CV=coefficient of variation, $LSD_{(0.05)}$ = Least significant difference at 5% and ns=non-significant, * = Significant ** = High significant difference and *** = Very Highly significant difference

3.2. Effects of Straw Mulch and Manure on Soil Moisture Content at Different Growth Stages

The application of straw mulch had significant effect on moisture storage in the soil, while addition of sole FYM show less impact as compared to un-mulched plots in the three soil depths of the four maize growth stages (Table 6). The maximum moisture contents through growth stages and in the three soil depths were recorded from plot received 5 tha^{-1} of straw mulch with FYM followed by of 5 tha^{-1} of straw mulch treatment. Since the rainfall was erratic and high moisture stress occurred in the area mulched plots was protected from direct sunlight and back evaporation of soil moisture due to the straw mulch applied. In the first consecutive growth stages soil moisture content among the treatments varies at 0-20 and 21-40 cm soil depths, while at the flowering to maturity stages the more effects were observed in the third soil depth. This implies that gradually downward water infiltration started after vegetation growth stage because of maize canopy cover the area and amount of surface evaporation become constant and mulching materials also incorporated into the soil and more of soil subsurface amendment as farm yard manure decomposed and its moisture competition decreased in the soil. On the other hand, in some soil depths there was less or no moisture difference between the treatments. This might be due to a shortage of time for making a better soil structure by decomposing the manure through microbial activities or date of soil sampled versus rainfall occurred.

Table 6. *Soil moisture contents as affected by wheat straw mulch and animal manure application.*

Treatments	**Maize Growth Stages (in three soil depths)**					
	Vegetative (cm)			**Development (cm)**		
	0-20	**21-40**	**41-60**	**0-20**	**21-40**	**41-60**
Control	10.46c	13.93c	12.36c	13.11c	14.17	11.77b
HUNPS	14.58^{bc}	19.84^{b}	15.50^{bc}	13.48^{c}	12.55	12.51^{ab}
5SM+HUNPS	20.35^{ab}	24.88^{a}	18.99^{ab}	18.33^{ab}	12.09	16.58^{a}
5FYM+HNPS	15.65^{bc}	19.41^{b}	15.50^{bc}	13.97^{bc}	11.74	12.42^{ab}
5(FYM+SM)+NPS	22.26^{a}	26.44^{a}	22.29^{a}	19.17^{a}	14.25	16.27^{ab}
CV (%)	23.1	12.0	17.8	16.4	25.2	19.7
LSD (0.05)	4.62	3.01	2.28	3.06	3.92	2.08
P- value	***	***	**	***	Ns	*
Treatments	Flowering (cm)			Maturity (cm)		
	0-20	21-40	41-60	0-20	21-40	41-60
Control	12.00^{c}	14.17	10.54^{b}	4.13	6.35	6.14^{ab}
HUNPS	14.86^{bc}	12.55	11.58^{ab}	4.06	6.01	6.30^{ab}
5SM+HUNPS	18.99^{a}	12.09	13.82^{ab}	5.81	6.76	7.54^{ab}
5FYM+HNPS	15.83^{abc}	11.74	12.60^{ab}	3.74	5.91	5.78^{b}
5(FYM+SM)+NPS	18.68^{ab}	14.25	15.76^{a}	5.97	5.92	7.80^{a}
CV (%)	14.8	25.2	19.5	28.6	19.2	16.2
LSD (0.05)	2.85	3.92	1.90	1.62	0.90	0.82
P- value	***	Ns	*	ns	ns	*

Treatment values within a column followed by the same letter are not significantly different at P ≤0.05; CV=coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% and ns=non-significant

The findings showed that, the content of soil water was higher in mulched treatments as compared to control or without mulch treatments. Straw mulch is likely to have created favorable soil moisture conditions for the growth of maize. This study was in lined with the findings, mulching materials in crop production plays a pivotal role in minimizing the weed menace, decreasing dispersion of soil particles by rain drops and containing soil erosion, balance of soil temperature and moisture conservation [12]. Mulching materials of organic origin are found to be major stakeholders in more moisture retention in the root zone depth and improved soil physical properties, nutrients supply and enhanced growth, yield and quality of crop and up on decomposition adds organic matter to the soil. The soil water content increased after mulch application and increase in the moisture content may be due to reduced evaporation from the soil surface [18]. Also [25] reported that, the lowest water content (3.661%) was observed in no much, while the highest water content (5.096%) was recorded in 16 tha^{-1} of mulch and soil water content in 10 cm soil depth from plots treated with chemical fertilizer plus organic amendment was significantly greater (9.9%) than in plots treated with chemical fertilizer alone during all the three years of study [26].

3.3. Effect of Moisture Conservation and Soil Amendment on Crop Phonological Development

Days to 50% flowering and physiological maturity: The results of means indicated that number of days to flowering was highly significant (p≤0.01) and days to 50% physiological maturity showed significant (p≤0.05) difference as a result of straw mulch and farmyard manure applied (Table 7). The minimum number of days to flowering (58.7) from 5 tha^{-1} of straw mulch plus inorganic fertilizers and days to physiological maturity (88) from 5 tha^{-1} (straw mulch plus of manure) treatments were observed (Table 7). This might be due to the availability of adequate amounts of soil moisture and nutrient that may favor the plant to grow faster and mature earlier, in addition to the crop variety. The number of days to flowering and physical maturity was shown difference between the treatments that might be due to occurrence of rainfall intensity and water holding capacity of the soil among the treatments. This study in lined with the finding the microclimate around the plant is controlled fully or partially to protect the crop from adverse conditions and presently it is catching up in tropical countries for high value flower and vegetable cultivation [17].

On the other hand, the longest 50% days to flowering and physical maturity were observed from plot treated with 5 tha^{-1} of farmyard manure with NPS fertilizer (Table 7). This result shown that, application of farmyard manure at moisture stress area without use of moisture conservation practice and maize cropping without fertilizers could delay the crop growth performance of 50% days to flowering by 12.7% and physical maturity by 11.5% as compared to mulched treatments. This also accordance with study growth parameter and maize yield components significantly reduced due to soil moisture deficits and delayed flowering due to water stress [1]. Similarly, the seeds, which were supplied with adequate moisture, did mature well to have heavier seed weight than those exposed to moisture stress like planting with only inorganic fertilizer [24].

Table 7. *Growth parameters of maize as affected by straw mulch and farmyard manures.*

Treatments	Parameters		
	NDF	DM	PH (cm)
Control	62.5	99.0 b	168.5
HUNPS	65.2	98.8	177.1
5SM+HUNPS	58.7	88.5	165.2
5FYM+HNPS	66.2	99.7	151.2
5(FYM+SM)+NPS	62.2	88.2	166.0
CV (%)	3.4	1.9	7.0
LSD	3.6	3.17	19.8
P value	***	**	ns

NDF= Number of Days to 50% flowering, DM = Days to 50% physical maturity, PH = plant height

Plant height: Statistical analysis of data shown that, there was no significant ($p \geq 0.05$) difference in plant height between the treatments though there was a numerical difference within the treatments. The tallest (177 cm) plant height was measured from plots treated with only inorganic fertilizers followed by 168.5 cm from control treatments, while the shortest (151 cm) was measured from 5 tha^{-1} of farmyard manure with NPS fertilizer plots (Table 7). This might implies that due to less number of seed germinated per rows (many seed missed per rows) as high moisture competition and evaporation occurs in plots treated by only animal manure and without mulch plots, and the germinated plant seeds were competed with those treated by straw mulch. The study reported by [18] recommended that increase in plant height due to mulching effects could have resulted from more soil moisture retention over the growth period in combination with lower soil temperature.

3.4. Effects of Wheat Straw Mulch and Animal Manure on Yield and Yield Components of Maize

The previous soil moisture content analysis of variance revealed that mulched treatments were influenced on soil moisture content in all depth throughout the four growth stages. All mulched treatments similarly stored highest moisture content, whereas the no mulched treatment had conserved the lowest except in some case moisture fluctuation due to high rainfall occurrence at the time of soil sample collection and gravimetrically analysis. Since this study was conducted in the moisture stress area and the crop requires the adequate amount of moisture in the cropping season for growth and high yield production.

Number of ear per plant: All mulching treatment statistically had nearly similar number of ear per plant. The higher mean number of ear per plant (2) was scored under 5 tha^{-1} of mulch plot, while the lowest (1.2 and 1.3) were scored under control (without mulch and only inorganic fertilizers) treatments (Table 8). This could be due to the conserved amount of water on mulched plot which was essential for biological and physiological process of the plant such as transporting of nutrient from the soil via the root and translocation of assimilate to the sink from the source. On the contrary, farmyard manure and other un-mulched treatments did not convert its flower effectively to more ear per plant like that of straw mulch and straw mulch combined with farmyard manure; moisture stressed maize plants did not form auxiliary flowers that produce ear.

Ear length and diameter: Statistical analysis of variance indicated that length of ear shown highly significant ($p \leq 0.01$) difference as affected by the treatments (Table 8) while, ear diameter has no significant difference among the treatments. The longest ear was measured from the plot received 5 tha^{-1} of straw mulch plus inorganic fertilizers without organic fertilizer as the area faced high moisture stress between the vegetative to flowering stages and that may bring moisture competition in the soil. The results implied that mulching was used to timely required nutrient mineralized as encouraging moisture was conserved and soil evaporation reduced from the soil and shift to maize energy transfer of ear formation and its length.

Number of seed per ear: Mulching very highly significantly ($p \leq 0.001$) affect the number of seed per ear as compared to un-mulched plots. The maximum number of seed per ear (551) was counted from 5 tha^{-1} of straw mulch with farmyard manure plus 100 kg ha^{-1} of NPS fertilizer. The increase in the number of seed per ear might be due to lower bulk density under mulching and combination of mulching with farmyard manure, that might have facilitated plant root proliferation in the soil and increased the rate of water, air and nitrogen movement. This study agreed with finding of [18] who stated that, the last plays an important role in tissue development, cell division, enhance plant growth, and thereby increased number of grains per cob. Similarly supported by the study of [36] who reported that mulching materials had a significant effect on the number of grains per cob, with maximum number of grains per cob (459.89) obtained where stalk mulch was used followed by grass clipping mulch, while the plots without mulch gave the minimum number of grains per cob (340.29).

Thousand grain weight: The analysis of variance revealed that thousand seed weight was influenced very highly significantly ($P \leq 0.001$) by the application of moisture conservation practices. The thousand seed weight (Table 8) result had a similar trend with data of the number of seeds per ears in the same table. The maximum and minimum thousand seed weight were obtained from plots received 5 tha^{-1} of straw mulching plus 100 kg of Urea and 100 kg of NPS fertilizers, and control treatments respectively at both sites. Many research findings have shown that neither inorganic nor organic fertilizers alone can result in sustainable productivity [27].

Hence, the soil with suitable amount of moisture content had brought a maximum number of seeds had an implication for seed weight. This study indicated that when soil moisture stress was imposed during heading and seed formation, the seed size could be reduced and ultimately resulting in lower thousand seed weight and low grain yield in the control plots. This result was in accordance with finding of [20] mulching treatments significantly affected weed growth, soil carbon and yield components of maize and significant differences for 1000-grain weight under different mulching treatments were obtained. So the higher thousand seed weight for mulched treatments might be due to alleviation of soil compaction causing increased uptake of the essential nutrient. This was agreed with study find that suggested stressful environment during grain filling can result in reduced kernel weights, while good conditions will result in increased kernel weights [2].

Total yield: The mean comparison of total yield revealed that there was very highly significant ($P \leq 0.001$) difference between the treatments due to the influence of mulching in the study area. The maximum yields (9,274 kg) was obtained from plots applied 5 tha^{-1} of straw mulch plus 100 kg of Urea and 100 kg of NPS fertilizers followed by 5 tha^{-1} of straw mulch & 5 tha^{-1} of farmyard manure plus blanket recommended rate of NPS fertilizer. The minimum yield (2,691 kg) was recorded from control treatment (Table 8). Mulch treatments increased the storage of soil water compared with control treatment, thereby significantly raising the maize yield. This was possibly attributed to decreased evaporation of soil water, increased water into the soil and improved preservation of soil water, while applying straw mulch during the time of the experiment. This study was in accordance with [20] recommendation, keeping in view the sustainable agriculture approach it is suggested that application of wheat straw mulch at 4 tha^{-1} is useful for obtaining high maize yield, controlling weeds without any herbicide application, improving soil organic matter and organic carbon contents.

Similar study reported that for maize the mean effect of straw mulch on maize yield was 20%, independent of water input level [23] and mulching treatment of 4 tha^{-1} of wheat straw had the largest positive effects on maize yield [18]. Also other study suggested that, the grain yield was advanced by 66.4 % and 52.48 % were obtained from mulches applied at sowing time over the farmers' practice or no mulched plots [29]. They also pointed out that yield variations resulted from delayed plant development due to lower soil temperatures, the amount of water stored, how much water stress occurred, the amount and distribution of precipitation, and evaporative demand. The highest grain yield (11.8 tha^{-1} and 11.2 tha^{-1}) were obtained due to application integration of 5 tha^{-1} of (straw mulch plus farmyard manure) and 5 tha^{-1} of straw mulch plus and 3 tha^{-1} of farmyard manure respectively [5].

Table 8. *Effects wheat straw mulch and animal manure on yield and yield components of maize.*

Treatments	**Parameters**					
	ED (cm)	**EL (cm)**	**NEPP**	**NSPE**	**TGW (g)**	**TY (kg ha-1)**
Control	4.21	14.56	1.2	363.1	255.6	2691
HUNPS	4.19	14.44	1.3	452.1	264.1	4528
5SM+HUNPS	4.48	16.58	1.8	467	368.8	9274
5FYM+HNPS	4.21	15.49	1.2	488.8	277.0	6032

Treatments	Parameters					
	ED (cm)	EL (cm)	NEPP	NSPE	TGW (g)	TY (kg ha-1)
5(FYM+SM)+NPS	4.36	15.65	1.5	550.9	326.9	7602
CV (%)	6.6	6.0	18.5	6.6	13.1	14.5
LSD $_{(0.05)}$	0.34	1.12	0.3	37.3	47.8	1094.1
P value	Ns	**	**	***	***	***

Yield parameters; NEPP= number of ears per plant, NSPE= number of seeds per ear, TGW= thousand grain weight, TY=Total grain yield, HUNPS = Hundred kg of Urea and NPS fertilizers, 5SM=5 tons per hectare of wheat straw mulch, 5 FYM= 5 tons per hectare of Farmyard manure, CV=coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% and ns=non-significant, ** = Very significant difference and *** = Very Highly significant difference

3.5. Partial Budget Analysis for Mulching and Farmyard Manure

The partial budget analysis and marginal rate of return were carried out for the use of mulching and farmyard manure in maize production. The cost of mulch and manure was estimated based on its local market price. As indicated in the Table 9, the maximum net benefit (198,970.5 ETB ha^{-1}) were obtained from treatment of 5 tons ha^{-1} of straw mulch plus HUNPS inorganic fertilizers and followed by (159,476 ETB) treatments of 5 tha^{-1} of (straw mulch plus farmyard manure) with 100kgha^{-1} of NPS fertilizer at study area. The highest net benefits gained treatments were in accordantly selected by the maximum marginal rate of return recorded after its total variable cost considered. Current crop production can be substantially increased; perhaps three fold by optimizing soil water and nutrient management [33].

This implies that application of 5 tha^{-1} of wheat straw mulch with 100kgha^{-1} of urea and100kgha^{-1} of NPS could be enable the farmers to earn a return of 20.5 ETB for every 1 ETB investments or as second option16 ETB for every 1 ETB funds around the study area for sustainable land management. So, high profit of maize obtained due to the use of mulching of local available materials.

Table 9. *Partial budget analysis of straw mulching and animal manure on Maize production.*

Treatments	GLY kg ha^{-1}	Adjusted grain yield (10%)	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	TVC (ETB ha^{-1})	MRR (%)
Control	2,691	2,421.5	60,536.2	60,536.2	0	D
HUNPS	4,528	4,075.2	101,880	95,769.5	6,110.5	15.7
5SM+HUNPS	9,274	8,346.6	208,665	198,970.5	9,694.5	20.5
5FYM+HNPS	6,032	5,428.3	135,708.8	127,719.8	7,989	16.0
5(FYM+SM)+NPS	7,602	6,841.8	171,045	159,476	11,569	13.8

D=dominated, GLY=grain yield, GFB =growth field benefit in Ethiopian birr per hector, NB=net benefit in Ethiopian birr per hector, TVC= total cost that vary, MRR=marginal rate of return in percent

4. Conclusion and Recommendation

Water shortage is one of the major problems limiting crop productivity in rift valley of Ethiopia, especially around Adami Tulu Jido kombolcha district. The crop productivity could be greatly influenced by even a small change in soil water storage and nutrient deficiency. By considering the integrated and ecological agriculture systems the longest possible period of soil coverage with plant mulches from straw left after cereal grain harvest and crop required of fertilizers was conducted. The findings of two rainfall cropping season's field study on maize showed that mulching provides greater soil properties and agronomic benefits compared to un-mulched and farm yard manure. Mulching increased soil moisture content that enhanced the productivity of maize with required inorganic fertilizers. Application of straw mulch with farmyard manure in moisture stress area basically improved soil physiochemical properties and moderately increased soil moisture content and yield compared to non-mulched treatments beside sustainable soil water holding capacity improvement.

Based on the result obtained from study area, it is advised to use 5 tha^{-1} of wheat straw mulch with 100kg of urea and 100kg of NPS for study areas and similar agro ecology for better maize yield production that have been economical profitable. As the second option five tha^{-1} of (straw mulch plus farmyard manure) plus 100$kgha^{-1}$ of NPS fertilizer technology is recommended for farmers as sustainable soil management by reducing cost of urea fertilizer. Further promotion of this technology in the area and similar agro ecology, agricultural research center/institutes/ should conduct research as demonstration and pre-scaling up.

Abbreviations

ATARC	Adami Tulu Research Center
RCBD	Randomized Complete Block Design
tha^{-1}	Ton Per Hectare

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Conflicts of Interest

The authors declare no conflicts of interest.

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