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Research paper

Effects of Straw Mulch and Manure on Moisture Conservation, Yield and Yield Components of Maize (*Zea Mays* L.) in the Mid Rift Valley of Oromia, Ethiopia

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Water shortage is one of the major problems limiting crop productivity in arid and semi-arid regions. Suitable soil and water conservation measure that can be easily integrated into the existing farming operations while enhancing in-situ moisture conservation by reducing the direct impact of raindrops, maintaining soil infiltration, increasing surface storage and affecting soil temperature, and increasing nutrient is crucially needed. A field experiment was conducted under rainfall conditions in the mid rift valley in 2018 cropping season to investigate the effects of straw mulch and farmyard manure on soil water-nutrient status and sustainable productivity of maize. Twenty-seven experimental plots each with 3 m * 3 m area were used to conduct the experiment. The experimental design used RCBD with nine treatments and replicated three times. The results revealed that there was highly significant difference (P≤0.01) between the treatments regarding their effect on yield and yield components of maize while the amount of moisture conserved through growth stages show significant differences (P≤0.05). The moisture conserved through growth stages was increased more due to combined effect of straw mulch with manure up to 60 cm depth of the soil from emergence to maturity stages. The results showed that application of straw mulch and farmyard manure could increase the soil moisture content by 16 28% in the three soil depths in relation to the control. Also, the highest grain yields (11.8 tons ha^{-1} and 11.2 tons ha^{-1}) were obtained from the combined application of treatments. These results indicated that retaining crop residue and application of farmyard manure in the field could be used as soil moisture conservation measure for sustainable improvement of maize production under the low moisture stress and rainfall conditions of the study area.

Key words: Farmyard manure, Growth stages, Moisture content, Soil depth, Straw mulch

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INTRODUCTION

Water shortage is one of the major problems limiting crop productivity in arid and semi-arid regions. Crop productivity could be greatly influenced by even a small change in soil water storage (Liu *et al.,* 2010). In the integrated and ecological agriculture systems more attention is being paid to the longest possible period of soil coverage with plant mulches and mulches from straw left after cereal grain harvest (Borowy and Jelonkiewicz, 1999; Pabin *et al*., 2006). Mulch also reduces the depletion of water within the root zone because it suppresses evaporation. Straw mulch covers to be more effective at increasing infiltration than incorporation of organic matter (Adekalu *et al*., 2007).

Straw mulch has been carried out in arid and semi-arid region to improve crop yields (Liu *et al*., 2010; Cai *et al*. 2011; Li *et al*. 2012); however, the effects of straw mulch on soil water storage, maize yield and water use efficiency are not well documented. Even though wheat and maize account for approximately 70% of the world cereal production, their yields are significantly limited by the availability of water, especially in arid and semi-arid regions (FAO, 2015).

Addition of organic matter to soil improved both soil water infiltration and water holding capacity, through incorporation of plant residues or manures (Celik *et al*., 2010; Parija and Kumar, 2013). The farm-yard manure (FYM) improves soil physical, chemical and biological properties (Khan *et al*., 2010). Improvement in the soil structure due to FYM application leads to a better environment for root development (Prasad and Sinha 2012), and improves soil water holding capacity (Dejene and Lemlem, 2012). Use of organic fertilizers improves soil structure, nutrient exchange, and maintains soil health and has raised interest in organic farming (Khan *et al*., 2010). Other studies indicated that organic manure typically mineralized within only a few cropping seasons to obtain a sustainable and stable increase in yield. Therefore organic manure should be applied for consecutive years (Uzoma *et al*., 2011; Molina *et al*., 2014). In the area of arid and semi-arid climate region, where maize (*Zea mays L*.) is one of the most common crops, erosion occurs in top soil by water and wind, and evaporation of water from surface and subsurface (Li *et al.,* 2013). Mulching regulates the farm environment and enhances crop production by affecting soil temperature, leaching, evaporation, soil moisture content and nutrient loss due to run off (Shah *et al*., 2013). It also increases yield by improving soil physical conditions. Wheat straw mulch reduced evaporation by 50% under winter wheat, and saved about 80 mm of water during wheat growing season (Wang *et al*., 2017).

Consequently, consecutive organic manure input improved soil water uptake in more than 150 cm soil profile and maintained stable soil water conservation in the depth of 0-50 cm and below 150 cm (Wang *et al*., 2017). It was likely that organic manure improved the soil permeability (Liu *et al*. 2014; Zhao 2014) and stimulated root physiological function and adjusted soil water distribution for higher water penetration (Zhou *et al*., 2012; Mkhabela and Materechera, 2013).

In the study area maize is widely produced by small scale farmers using rain-fed system and use as basic cereal crop for providing food and as cash crop for the market. However, the productivity of maize in the area has been decreasing from year to year due to moisture deficit and depletion of soil nutrients. The rainfall came late in the cropping season or earlier offset before maturity of the crop. Even in the normal onset and offset season, the rainfall had no uniformity in intensity and frequency. On the other hand, most of the community produce the crop under required dose of chemical fertilizers for their land size, while few of the farmers produce without any fertilizer, because chemical fertilizers were costly to apply to their farm lands.

However, the combination of organic manure and chemical fertilizer increased the sustained supply of soil nutrients, while reduced the nutrient enrichment of synthetic fertilizer in soil environments (Wang *et al*., 2017). Many research findings have showed that neither inorganic nor organic fertilizers alone can result in sustainable productivity (Tadesse *et al*., 2013). Research on mulching and farmyard manure application was conducted separately in different agro-ecological conditions, especially in the area of high rainfall at different time. However, there were a limited number of research conducted on mulching and farmyard manure integrated with inorganic fertilizers in the low moisture stress area of the mid rift valley of the country. Therefore, this study was initiated to evaluate the effects of wheat straw mulch and farmyard manure on soil moisture content at different growth stages of maize, and to determine the effects of wheat straw mulching and farmyard manure on maize yield and yield components for sustainable productivity and production of maize in the Mid Rift Valley of Oromia, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

Adami Tulu Agricultural Research Center (ATARC) is geographically located between 7^{o} 50' 30" to 7^{o} 51'30" N latitude and 38^{o} 42'0" to 38^{o} 43'0" E longitude and at altitude of 1600 m.a.s.l. It is found in Adami Tulu Jido Kombolcha District of East Showa Zone of Oromia. The center is 7 km far from Batu (Zeway) town on the Hawassa main road and 167 km to the south of Addis Ababa.

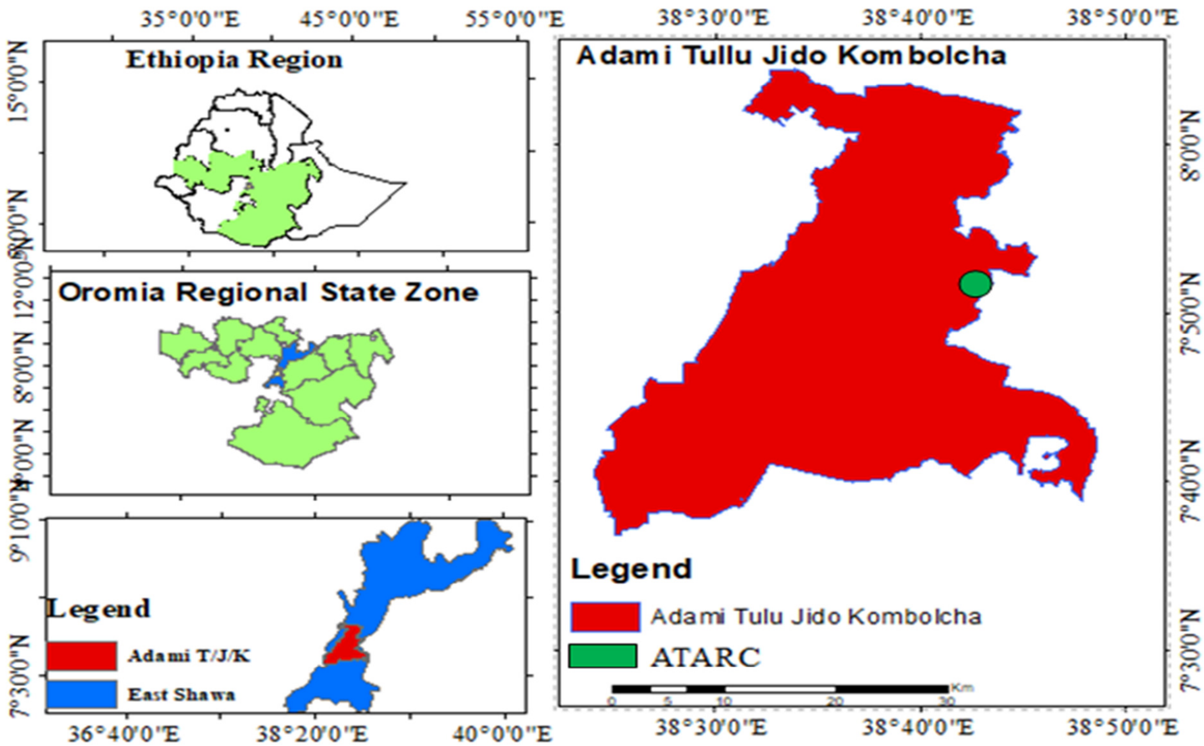

Figure 1. Map of Adami Tulu Agricultural Research Center

Most of the land of Adami Tulu District is topographically flat. The total coverage area of the district is about 1487.60 km^2 (Gemechu, 2016). The major soil type in the study area is Andosol. The major crops produced in the area are maize, wheat, teff, haricot bean, barley, sorghum, onion, cabbage, potatoes and tomatoes. Among the crops maize is the dominant one by area coverage and yield produced. It is the first and basic crop providing food in all households.

The study area is characterized by lowland and dry agro-climatic zone with a mean annual rainfall ranging from 619 to 750 mm for the last fifteen years. It exhibits bi-modal rainfall pattern with erratic condition and insignificant mean monthly precipitation. Rainy season is April to October and, the dry seasons cover other months. The solar radiation in the dry season was considerably high (>25 MJ m^{-2}) and reduced during rainy season, and most of the day time is sunny. The daily mean relative humidity was less than 50% in the dry and increased up to 80% in the rainy season. The temperature of the area ranges from 17 to 21°C during the rainy seasons and exceeds to 27°C during the dry seasons with an annual temperature ranging from 20 to 25°C (ÀTARC, 2017).

Treatments and Experimental Design

The experiment was conducted at ATARC in 2018/19 cropping season on twenty seven experimental plots. The experiment was consisted of nine treatments: T_1(3 ton ha^{-1} wheat straw mulch), T_2 (5 ton ha^{-1} wheat straw mulch), T_3 (3 tons ha^{-1} of farmyard manure), T_4 (5 tons ha^{-1} of farmyard manure), T_5 (3 ton ha^{-1} wheat straw mulch plus 3 tons ha^{-1} farmyard manure), T_6 (3 ton ha^{-1} wheat straw mulch plus 5 tons ha^{-1} farmyard manure), T_7 (5 ton ha^{-1} wheat straw mulch plus 3 tons ha^{-1} farmyard manure), T_8 (5 ton ha^{-1} wheat straw mulch plus 5 tons ha^{-1} farmyard manure) and T_9 (Control/farmer practice) were applied by a randomized complete block design (RCBD) with three replications. The size of each plot was 3 m x 3 m with spacing between row of maize 75 cm and 25 cm between plants. Space between each plot was 1 m and between blocks was 2 m and 1 m from the borders.

All experimental plots were tilled three times by hand before plating of the maize variety, BH-540 and sown in rows based on the recommended space between rows and plants. This hybrid was selected due to its tolerance to low moisture stress, high yielding and most widely grown in the area. Fertilizers (urea and DAP) were applied to T_1-T_8 by the half of the blanket recommended rate per hectare. Treatment nine (T_9) without mulching and FYM plot received a full dose of inorganic fertilizer as usual practice by the local farmers.

Soil Sampling and Moisture Determination Methods

Soil samples were collected throughout the growth stages from surface and subsurface during the 2018 to 2019 cropping season and its moisture content was determined. Moisture contents of the soil at different crop growth stages were determined by taking soil samples from 60 cm depth by 20 cm intervals from the middle of the plots at four growth stages of maize (2, 4, 8 and 10 weeks from sowing date), and the wet soil sample was weighted and oven dried at temperature of 105^{0}C for 24 hours. Then its gravimetric water content was determined using the expression:

$$\theta dw = \frac{Wws - Wds}{Wds} x100$$

Where, *Wws* = weight of wet soil (g), □□*dw* = water content expressed on a weight basis (%)
*Wd*s = weight of dry soil (g)

Meteorological and Agronomic Data Collection Methods

Meteorological data of the study area

Different meteorological data of the study area in the experimental year were collected from ATARC meteorological station nearby the experimental site. The collected data included rainfall, evaporation, air temperature, sun shine, relative humidity and soil temperature at 5, 10, 50 and 100 cm depths. The amount and distribution of the rainfall at the study area in the cropping seasons were compared with results obtained due to the effects of the treatments on the nutrient content, soil moisture conservation and yield and yield components of maize.

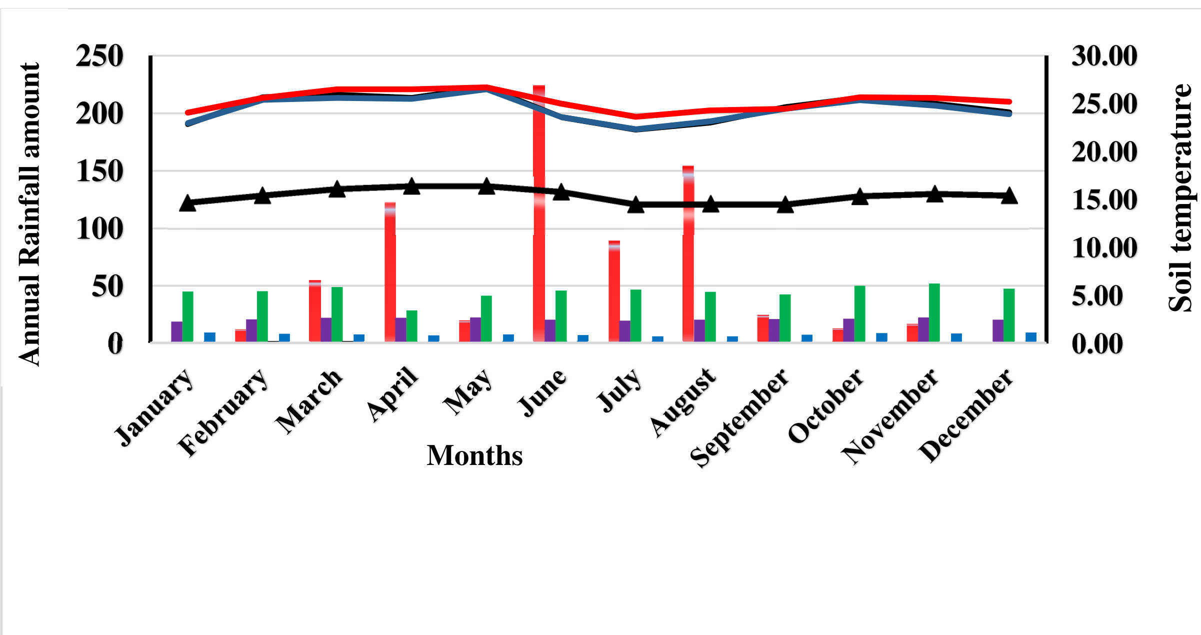

Figure 2. Distribution of climatic factors and soil temperature data of the study area

Growth parameters, yield and yield components of maize

Important agronomic data on maize such as growth parameters (plant height, days to 50% flowering and 50% physical maturity) yield and yield components (number of ear per plant, number of seeds per ear, thousand grain weight and total grain yield) were taken through the growth stages.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) in Randomized Complete Block Design (RCBD), replicated three times using statistical analysis systems (SAS) software (SAS, 2004 Version 9.1.2). General linear model (GLM) was employed and treatment means were compared using Duncan's Multiple Range Test at $P \leq 0.05$ significance level.

RESULTS AND DISCUSSION

Rainfall Amount and Distribution during the Cropping Season

The daily rainfall distribution for the cropping months (May to October) of the year 2018 to 2019 at the study area was recorded. The total rainfall (636.3 mm) recorded over the period of the cropping season was generally within the normal range (619 to 750 mm) in the study area but could not be considered as optimum for crop growth in the area provided that it was erratically distributed. The length of the growing period of the cropping season was long and matched with the cropping season of Maize (160 days) as compared to what experienced with local farmers (Gemechu, 2016). However, there was a serious shortage of rainfall at flowering and physiological maturity which highly affected the grain filling of the crop.

In addition to less amount of rain at the onset of cropping season and generally lower total seasonal rainfall, the distribution of rainy days within the duration of the cropping season was not uniform. For instance, either no or very small amounts of rains were recorded in the month of May 1 to 18 and 25 to 31, between August 1 to 8 and October 1 to 15. On the contrary, except for the on and off rain, considerable amounts of rainfall were received from early 1st to 16th of June (Figure 2). Therefore, it could be inferred that the erratic and insufficient rainfall and the resultant limited availability of soil moisture coupled with the exceptional risks of prolonged dry spells could be the major constraints for crop production in Adami Tulu area.

Soil Moisture Contents as Affected by Wheat Straw Mulch and Farmyard Manure Application

Effects of straw mulch and manure on soil moisture content at different growth stages

Soil moisture content in 2nd weeks (Emergence to vegetative stage)

The data on the soil moisture content at the first two weeks after sowing (Table 4) and analysis of variance revealed that there were highly significant ($p \leq 0.01$) differences due to the application of two levels of straw mulch and manure as compared to control in the soil depth of 0-20 and 20-40 cm, whereas a significant ($p \leq 0.05$) changes observed in the 40-60 cm soil layer. In the case of 40-60 cm depth the maximum moisture content (19.89%) was obtained from plots treated with 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of FYM, while the minimum (13.14% and 12.81%) was from the 3 tons ha^{-1} and 5 tons ha^{-1} of FYM treatments. This might be due to shortage of time for making a better soil structure by decomposing the manure through microbial activities and the production area was exposed to evaporation. The research finding reported by Cai1 *et al.* (2015) revealed that under 4.5 tons ha^{-1} of wheat straw mulch, the storage of soil water provided more soil moisture in sowing, which would be beneficial for the maize seeding and for promoting the emergence and survival rate of the maize.

Table 1. Gravimetric soil moisture content (%) in the second weeks at different soil depths

Treatments (tons/ha)	Soil depths (cm)			
	0-20	20-40	40-60	Mean
Control	16.52^{f}	16.36^{d}	15.38^{cd}	19.09^{d}
3 WSM	21.62^{cd}	23.14^{b}	19.22^{ab}	21.33^{bc}
5 WSM	25.95^{ab}	24.98^{ab}	19.15^{ab}	23.36^{ab}
3 FYM	17.17^{ef}	15.64^{d}	13.14^{d}	15.32^{d}
5 FYM	20.18^{de}	19.51^{c}	12.81^{d}	17.50^{d}
3WSM + 3 FYM	24.06^{bc}	22.70^{b}	15.95^{bcd}	20.91^{c}

Table 1. Continues

3 WSM +5 FYM	23.39^{bcd}	25.44^{ab}	19.27^{ab}	22.70^{bc}
5WSM + 3 FYM	24.54^{bc}	26.19^{a}	17.49^{abc}	22.74^{abc}
5WSM + 5FYM	28.31^{a}	27.07^{a}	19.89^{a}	25.09^{a}
LSD $_{(0.05)}$	3.52	2.89	3.36	2.36
CV (%)	9.07	7.47	11.48	6.63

Treatment values within a column followed by the same letter are not significantly different at P≤0.05, 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM= 5 tons per hectare of wheat straw mulch, 3FYM= 3 tons per hectare of farmyard manure, 5FYM= 5 tons per hectare of farmyard manure, CV=coefficient of variation, LSD $_{(0.05)}$ = least significant difference 5%

In general, it could be concluded that from Table 4 soil moisture content decreased with an increase in the soil sampling depth from 0-20 to 20-40 to 40-60 cm. This could be due to the occurrence of high rainfall during the first sampling time, resulting in infiltration into the soil and moisture through the soil profile but had no uniformity through the soil profiles. On the other hand it might be due to the depth of water table of the area. Further, it may be contented that the soil moisture retained in the deeper horizon is not important for plant growth because plant roots in the first stage are able to use only the water stored in shallow soil depth.

Soil moisture content in 4th weeks (Development stage)

A perusal of the data on the soil moisture content at the development stage demonstrated that application of both straw mulch and manure at 3 and 5 tons ha^{-1} had influence to increase moisture contents of the soil at three soil depth intervals compared to the control. The analysis of variance showed that there was highly significant difference (P≤0.01) between the treatments in 20-40 cm soil depth. This might be due to relatively high rainfall received by the study area and the rain was percolated down into subsoil as the soil was sandy loam but it could not infiltrate more down up to 60 cm during the week of the gravimetric soil moisture determined because of erratic rainfall. Li *et al*. (2013) reported that soil mulched with wheat straw conserved 106.9 mm water in the 0-200 cm soil layer during the maize growth stage.

Table 2. Gravimetric soil moisture content (%) in the fourth weeks at different soil depths

Treatments (tons/ha)	**Soil depths (cm)**			
	0-20	20-40	40-60	Mean
Control	17.06	13.68^{c}	12.23	14.88^{c}
3 WSM	19.78	16.92^{ab}	12.45	16.38^{bc}
5 WSM	19.95	19.83^{a}	16.25	18.68^{ab}
3 FYM	17.24	13.97^{bc}	13.31	14.84^{c}
5 FYM	18.20	16.99^{ab}	13.89	15.81^{bc}
3WSM + 3 FYM	20.85	17.50^{a}	16.13	18.16^{ab}
3 WSM +5 FYM	20.48	18.12^{a}	13.82	17.47^{abc}
5WSM + 3 FYM	23.09	19.17^{a}	16.80	19.69^{a}
5WSM + 5FYM	22.73	19.94^{a}	17.34	20.00^{a}
LSD $_{(0.05)}$	4.35	3.03	4.48	2.90
CV (%)	12.61	10.09	17.63	9.68

Treatment values within a column followed by the same letter are not significantly different at P≤0.05; 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM = 5 tons per hectare of wheat straw mulch, 3FYM = 3 tons per hectare of farmyard manure, 5FYM = 5 tons per hectare of farmyard manure, CV = coefficient of variation, LSD $_{(0.05)}$ = least significant difference at 5%

Soil moisture content in 8th weeks (Flowering stage)

From the analysis of variance soil moisture contents determined at this stage showed highly significant (p≤0.01) difference among the evaluated treatments in 0-20 and 40-60 cm soil depths. However, the soil moisture content was significantly (P≤0.05) affected in the 20-40 cm depth as treated by the straw mulch and farmyard manure. Also looking at the surface soil layer (0-20 cm), the soil moisture was increased from 14% to 19.82% due to the impact of straw mulch.

Table 3. Gravimetric soil moisture content (%) in the eighth weeks at different soil depths

Treatments (tons/ha)	Soil depths (cm)			
	0-20	20-40	40-60	Mean
Control	14.01^{c}	15.04^{d}	10.25^{b}	13.10^{e}
3 WSM	17.68^{ab}	18.16^{abc}	11.42^{b}	15.75^{bc}
5 WSM	19.82^{a}	18.79^{abc}	11.58^{b}	16.73^{abc}
3 FYM	15.45^{bc}	16.30^{cd}	9.85^{b}	13.87^{de}
5 FYM	19.13^{a}	16.92^{bcd}	9.97^{b}	15.34^{de}
3 WSM + 3 FYM	18.65^{a}	17.45^{bcd}	12.48^{b}	16.19^{bc}
3 WSM +5 FYM	17.43^{ab}	17.63^{bcd}	12.48^{b}	15.85^{bc}
5 WSM + 3 FYM	19.50^{a}	19.57^{ab}	12.67^{b}	17.25^{ab}
5 WSM + 5 FYM	18.52^{a}	20.82^{a}	16.34^{a}	18.56^{a}
LSD $_{(0.05)}$	2.81	2.92	2.86	1.85
CV (%)	9.13	9.44	13.91	6.72

Treatment values within a column followed by the same letter are not significantly different at P≤0.05; 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM = 5 tons per hectare of wheat straw mulch, 3FYM = 3 tons per hectare of farmyard manure, 5FYM = 5 tons per hectare of farmyard manure, CV = coefficient of variation, LSD $_{(0.05)}$ = least significant difference at 5%

The moisture contents enhanced by 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of the farmyard manure were found as 20.82% and 16.34% in 20-40 cm and 40-60 cm depths, respectively. Cover with crop straw mulch on soil surface is important to promoting soil moisture content (Li *et al*. 2012), improving crop yields and water use efficiency (Wang *et al*. 2009).

Apparently, in this growth stage, the minimum soil moisture was recorded in manure treatments next to the control through the three soil depths. This might be because of the major part of the rain water was forced to infiltrate due to the mulch applied and soil type. Once infiltrated the opportunity of back evaporation was less in mulched plots as compared to the manure and control treatments. Similar trends were observed in the mean of soil moisture at 60 cm as in the case of three soil depth intervals, the maximum moisture content was obtained in plot treated with 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of farmyard manure.

Under the traditional practices represented by the control plots (uncovered), the water is lost as runoff and evaporation, hence not used for crop production. This result was parallel with Wang *et al*. (2018) report, compared without straw mulch, soil gravimetric water content was improved in the 0-200 cm profile by straw mulch, due to the deep underground water supply was ignored, the more water loss in without straw mulch was consumed by evaporation in surface.

Soil moisture content in 10th weeks (Maturity stage)

The analysis of variance revealed that the soil moisture content was more affected due to application of farmyard manure (Table 7). The soil moisture content at first and the third soil depths did not show significant effect due to the surface management practices evaluated compared to the control.

Soil moisture content was highly significantly (p≤0.01) influenced (Table 7) due to the uses of straw mulch and farmyard manure in 20-40 cm soil depth and the maximum moisture storage was resulted due to application of 5 tons ha^{-1} of farmyard manure. This might be as a result of manure capacity to hold moisture within the soil that was infiltrated to the root depth through the growth stages sequentially. Manure had improved soil moisture holding capacity at the tasseling and grain filling stages, and decreased evaporation at the jointing–big trumpet and tasseling–grain filling stages (Wang *et al*. 2018). Soil moisture content was increased in the maturity stage due to the soil water holding capacity improved slowly after the manure decomposed by microbial activities (Li *et al*. 2012), and the straw mulch also decomposed and incorporated into the soil. Therefore, as soil structure and bulk density (soil aggregate) improved, the infiltration and water holding capacity (moisture content) increased by the increases of straw mulch and farmyard manure levels.

Table 4. Gravimetric soil moisture content (%) in the ten weeks at different soil depths

Treatments (tons/ha)	Soil depths (cm)			
	0-20	20-40	40-60	Mean
Control	11.74	10.85^{de}	13.55	12.04^{c}
3 WSM	12.81	12.49^{cde}	15.17	13.93^{bc}
5 WSM	13.11	13.31^{bcd}	15.82	14.08^{bc}
3 FYM	10.36	9.91^{e}	15.24	11.84^{c}
5 FYM	18.12	16.91^{a}	16.29	17.11^{a}
3WSM + 3 FYM	13.34	14.03^{abc}	16.29	14.55^{abc}
3 WSM +5 FYM	11.23	13.45^{bcd}	16.75	13.81^{bc}
5WSM + 3 FYM	15.13	15.90^{ab}	16.27	15.77^{ab}
5WSM + 5FYM	15.78	16.74^{a}	16.49	15.88^{ab}
LSD $_{(0.05)}$	4.60	3.02	4.53	2.75
CV (%)	19.67	12.71	16.61	11.10

Treatment values within a column followed by the same letter are not significantly different at P≤0.05; 3WSM = 3 tons per hectare of wheat straw mulch, 5WSM = 5 tons per hectare of wheat straw mulch, 3FYM = 3 tons per hectare of farmyard manure, 5FYM = 5 tons per hectare of farmyard manure, CV = coefficient of variation, LSD $_{(0.05)}$ = least significant difference at 5%

Effect of Moisture Conservation on Crop Phenological Development, Yield and Yield Components of Maize

Soil moisture and nutrient content variability have a remarkable effect on crop growth habit. In this regards the effects of different soil moisture and nutrient contents from straw mulch and farmyard manure on different growth parameters and yield of maize are described below.

Effect of moisture conservation on crop phenological development

Days to 50% flowering and physiological maturity

Analysis of variance indicated that means of days to flowering were highly significant (p≤0.01) as a result of straw mulch and farmyard manure applied; also, days to 50% physiological maturity showed very highly significant (p≤0.001) among the evaluated moisture conservation practices. The number of days to 50% flowering and physiological maturity was decreased as the impact of the combined application of the treatments. This might be due to the availability of adequate amounts of nutrient and soil moisture that may favor the plant to grow faster and mature earlier, in addition to the crop variety (tolerant to mid rift valley weather conditions). So, the minimum number of days to flowering (60 and 59 days) and days to physiological maturity (98 and 99 days) were observed from the plots treated with 5 tons ha^{-1} of straw mulch plus 3 tons ha^{-1} of FYM and 5 tons ha^{-1} straw mulch plus 5 tons ha^{-1} of manure, respectively .

Table 5. Growth parameters of maize as affected by straw mulch and farmyard manure

Treatments (Tons/ha)	Parameters		
	NFD	DPhM	Plant Height (m)
Control	67^{a}	108^{ab}	2.14^{c}
3 WSM	64^{ab}	105^{b}	2.52^{b}
5 WSM	63^{bc}	107^{ab}	2.53^{b}
3 FYM	67^{a}	109^{a}	2.40^{bc}
5 FYM	63^{abc}	105^{b}	2.51^{b}
3 WSM+3 FYM	65^{ab}	107^{ab}	2.34^{bc}
3 WSM+5 FYM	63^{bc}	106^{b}	2.51^{b}

Table 5. continues

5 WSM+3 FYM	60[cd]	98[c]	2.83[a]
5 WSM+5 FYM	59[d]	99[c]	2.85[a]
Mean	63	105	2.51
LSD(0.05)	3.75	4.28	10.26
CV (%)	3.41	2.36	5.89

Treatment values within a column followed by the same letter are not significantly different at P≤0.05, NFD = days to 50% flowering, DPhM = Days to 50% physiological maturity, CV = coefficient of variation and LSD = Least significant difference (5%)

However, the maximum days (delay to flowering and physiological maturity) were observed from plots treated with 3 tons ha^{-1} of manure (67) for days to flowering and 109 days to physiological maturity, respectively (Table 5). This result indicates that improving the soil moisture content and nutrient availability by using the integrated straw mulch and manure with inorganic fertilizers, the maize variety delays to flowering and physiological maturity could be reduced by 11 to 13% and 10 to 11% correspondingly, and this may save the crop from the offset of rainfall before maturity in the mid rift valley of low moisture stress area. According to Lee (2007)*,* the decrease of maize production happens when the crops experience low water stress in flowering phase and during the pollination period.

When the maize entered flowering stage, the crop experienced moisture stress, especially on the non- mulch treatments (Sahindomi *et al*., 2013). Days to physiological maturity can illustrate the response of plants whereby growing under unfavorable condition tried to make adjustments to the environment through modification of their normal physiological growth, development processes and morphological behavior under non-conducive conditions in order to assure and maintain the survival of the species that was long/late maturity crop phases high yield reduction. The growth parameter and maize yield components significantly reduced due to soil moisture deficits and delayed flowering due to water stress (Abayomi, 2012).

Plant height

Statistical analysis revealed that there was highly significant (p≤0.001) difference in plant height among the effects of wheat straw mulch, farmyard manure and their combinations compared to the control. The tallest plant height (2.85 m) was measured from plots treated with 5 tons ha^{-1} of straw mulch with 5 tons ha^{-1} of farmyard manure and followed by 5 tons ha^{-1} of straw mulch with 3 tons ha^{-1} of farmyard manure (2.83 m), 5 tons ha^{-1} of straw mulch (2.53 m), while the shortest (2.14 m) was measured in control plots which was lower by about 33% from the tallest plant (Table 8).

Application of the combinations of straw mulch with farmyard manure by integrating with chemical fertilizers promoted plant growth (height, weight, flowering, etc.) compared to mineral fertilized Sheikha (2016) and combination of 8 tons ha^{-1} of wheat straw mulch with the sowing system increased the plant height from almost 5 to 13% (Shah *et al.,* 2015). The potential mechanism of straw mulching can help to improve maize yield and yield components because it can effectively improve soil nutrient availability, increase plant growth (Fang *et al*. 2011), and influence soil physical and chemical properties. Plant height was positively correlated with average soil moisture content measured at flowering and maturity growth stages. It showed a linear relation with average soil moisture content measured in both growth stages (Figure 4). This indicates that soil with higher soil moisture content had tallest plant height at flowering and physical growth stages.

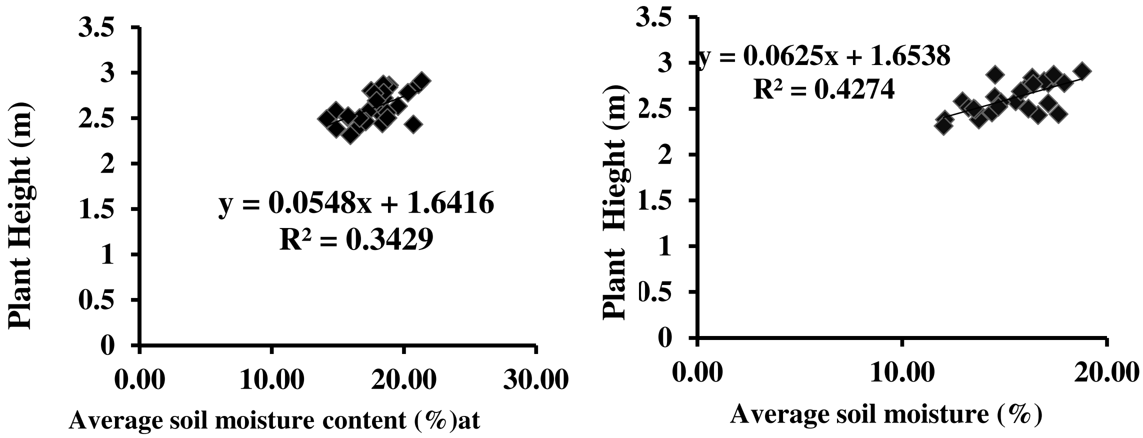

Figure 4. Relation of plant height with average soil moisture content at flowering and maturity stages

Effects of soil moisture conservation on yield and yield components of maize

Since this study was conducted in the low moisture stress area, the crop obtained adequate moisture in the cropping season for growth and high yield production. The grain yield and yield components were increased significantly according to the availability of moisture in the treatments. This was in agreement with the previous studies of Muhammad *et al*. (2015) and Kho-darahmpour (2011).

Number of seeds per ear

The analysis of variance showed that the combined and sole application of wheat straw mulch and farmyard manure had highly significant (p≤0.01) effects on the number of seeds/ ear. The maximum number of seeds (686) per ear was counted from the plots received 5 tons ha^{-1} of wheat straw mulch plus 5 tons ha^{-1} of farmyard manure and followed by 5 tons ha^{-1} of wheat straw mulch plus 3 tons ha^{-1} of farmyard manure (674) while the minimum number of seeds (364) per ear counted in the control plots which indicated reduction of about 89% and 85%, respectively. This might be due to the synergistic effects of treatment combinations that improved soil moisture conservation, nutrient use efficiencies and normal development of maize with increasing number of seeds/ear, ear per plant and thousand seed weights. The study conducted by Tolessa et al. (2015) discussed that application of mulches brought the higher number of seeds per ear obtained from the maize.

Table 6. Yield and yield components of maize as affected by straw mulch and farmyard manure

Treatments (tons/ha)	Parameters			
	NEPP	NSPE	THGW (g)	GY (tons ha^{-1})
Control	1.00	364^{c}	282.40^{d}	5.397^{c}
3 WSM	1.33	419^{bc}	346.07^{cd}	6.463^{bc}
5 WSM	1.67	549^{ab}	408.67^{bc}	8.313^{b}
3 FYM	1.00	404^{bc}	354.33^{bcd}	5.587^{c}
5 FYM	1.67	432^{bc}	360.20^{bc}	6.797^{bc}
3WSM+3FYM	1.33	412^{bc}	427.00^{b}	8.073^{b}
3WSM+5FYM	1.67	665^{a}	404.07^{bc}	8.523^{b}

Table 6. Continues

5WSM+3FYM	2.00	674[a]	537.00[a]	11.157[a]
5WSM+5FYM	2.00	686[a]	539.17[a]	11.837[a]
LSD $_{(0.05)}$	NS	157.33	77.386	2.310
Mean	1.5	512	406.55	8.016
CV (%)	27.62	17.76	10.99	16.65

Treatment values within a column followed by the same letter are not significantly different at P ≤0.05; NEPP= number of ears per plant, NSPE=number of seeds per ear, THGW=thousand grain weight, GY=grain yield, CV=coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% and NS=non-significant

Thousand *grain weight*

The analysis of variance revealed that thousand seed weight was very highly significantly (P≤0.001) influenced by the application of moisture conservation practices (Table 6). The soil with suitable amount of moisture content had brought maximum number of seeds and had an implication for seed weight. Similarly, the seeds, which were supplied with adequate moisture, matured well to have heavier seed weight than those exposed to low moisture stress like planting with only inorganic fertilizer (Shah *et al*., 2013).

Similar to the number of seeds/ ear, the maximum thousand seed weight was obtained from plots treated with 5 tons ha^{-1} of straw mulch plus 5 tons ha^{-1} of manure (539 g), followed by 5 tons ha^{-1} of straw mulch plus 3 tons ha^{-1} of manure (537 g) that increased about 90.92% and 90.16%, respectively, over the control. The increased in thousand grain weight might be due to the better integration of organic fertilizers with inorganic fertilizer for better growth and grain filling of maize in addition to the moisture availability as a result of combined surface management practices. The improvement in yield and yield components due to the management practices was related to the enhanced water availability during the grain filling stage due to increased infiltration and the nutrient availability that has resulted in increased individual grain weight and number of grains per plant (Admasu *et al*. 2014).

Grain yield

The mean grain yield was increased very highly significantly (p≤0.001) under moisture conservation system (Table 6). This result showed that the combined effect of 5 tons ha^{-1} of straw mulch with 5 tons ha^{-1} of farmyard manure and 5 tons ha^{-1} of straw mulch with 3 tons ha^{-1} of manure treatments were improved total grain yield to (11.8 tons ha^{-1} and 11.16 tons ha^{-1}), respectively, which enhanced the yield by 119.3% and 106.7%, respectively compared to the control (5.4 tons ha^{-1}). Water deficit causes a decrease in maize yield potential of 50-60% and decrease of 40% when the water deficit in the flowering phase (Bruce *et al*. 2002), yield decrease of 40% in tasselling phase and yield decrease of 66-93% when water deficit in ear formation (Cakir, 2004). Almost every plant processes affected directly and indirectly by the availability of water in the soil. Cover with crop straw mulch on soil surface is important to promoting soil moisture content improving crop yields and water use efficiency (Wang *et al.,* 2016).

In addition, study by Zhao *et al*. (2014) found that farmyard manure application with chemical fertilizer causes higher yield in maize, total N, soil organic matter, and available P compared with those found under mineral fertilizer treatment. The research reported by Misganaw (2014) revealed that the highest grain yield (8.159 tons ha^{-1}) was obtained in the treatment 4 tons ha^{-1} of farmyard manure plus 0.075 tons ha^{-1} N and 0.060 tons ha^{-1} of P compared to alone inorganic fertilizers and high dose of farmyard manure applied.

CONCLUSIONS AND RECOMMENDATIONS

Generally results of this study indicated that application of the combination of wheat straw mulch with farmyard manure had enhanced the productivity of maize by affecting soil moisture content at different growth stages in low moisture stress area of the mid rift valley of the country.

From the results of this experiment, the following recommendations are given.

The farmers are advised to use 5 tons/ha of straw mulching with 3 tons/ha of farmyard manure and/or 5 tons/ha of straw mulching with 5 tons/ha of farmyard manure for better effectiveness and higher yield of maize in the area.

To come up with actual conclusive generalizations of soil moisture holding status and maize productivity from the applied treatments, this experiment should be repeated on the same area at least for three years and economic analysis is required for provision of appropriate recommendations.

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REFERENCES

Abayomi Y.A (2012). Comparative evaluation of water deficit tolerance capacity of extra-early and early maize genotypes under controlled conditions. *Jour. of Agri. Science*, 4 (6):256-263.

Adekalu, K.O., Olorunfemi, I.A., and Osunbitan, J.A (2007). Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. *Bio Resource Technology,* 98:912-917.

Adimassu Zenebe, Mekonnen Kindu, Chilot Yirga and Kessler, A (2014). Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia. *Land Degradation and Development*, 6 (25):554-564.

ATARC (Adami Tulu Agricultural Research Center) (2017). Meteorological data of Adami Tulu Agricultural Research Center since 1996-2017 years, ATARC, OARI, Ethiopia.

Borowy, A. and Jelonkiewicz, M (1999). Weed infestation and yielding of eight species of vegetables cultivated using a method of direct sowing into the rye mulch. *Zesz. Problem Post. Nauk Roln,* 291.

Bruce, W.B., Gregory O. Edmeades, Thomas C. Barker (2002). Molecular and physiological approaches to maize improvement for drought tolerance. *Jour. of Exper. Botany*,53 (36):13-25.

Cai T., Zhang, C., Huang, Y., Huang, Yang, H.B., Zhao, Z., Zhang, J. and Jia, Z. (2015). Effects of different straw mulch modes on soil water storage and water use efficiency of spring maize (*Zea mays* L.) in the Loess Plateau of China. *Plant Soil Environment,* 61 (6): 253-259.

Cai, T.Y., Jia, Z.K., Huang, Y.W., Huang, H.J., Meng, L.,Yang, B.P. and Li, H (2011). Effects of different straw mulch rates on soil water conservation and water-saving benefits in spring maize field. *Transactions of the Chinese Society of Agricultural Eng*ineering, 27:238-243.

Cakir, R (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Field Crops Research*, 89 (1): 1-16.

Celik, I (2010). Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediter. Soil conditions. *Geoderma*, 160:236-243.

Dejene Mengistu and Lemlem Mekonnen (2012). Integrated agronomic crop managements to improve *tef* productivity under terminal drought, *In: I. Md. M. Rahman and H. Hasegawa, Eds., Water Stress, In. Tech. Open Science,* 235- 254.

Efthimiadou, A., Bilalis, D., Karkanis, A. and Froud-Williams, B (2010). Combined organic/ inorganic fertilization enhances soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. *Australian Journal of Crop Science*, 4(9):722-729.

El Sheikha AF (2016). Mixing manure with chemical fertilizers, why? and what is after? *Nutrient Food Technology*, 2(1):1-5.

Fang, S.Z., Xie, B.D., Liu, D. and Liu, J.J (2011). Effects of mulching materials on nitrogen mineralization, nitrogen availability and popular growth on degraded agricultural soil. *New Forests,* 41:147-162.

FAO (Food and Agriculture Organization of the United Nations) (2015). FAO Cereal Supply and Demand Brief. http://www.fao.org/world food situation/.

Gemechu T (2016). Impact of climatological parameters on crop water use of maize and sorghum: A Case of Adami-Tulu Jido-Kombolcha woreda, Central Rift Valley of Ethiopia. *Journal of Earth Science and Climate Change,* 10(7):1-6.

Khan, N. I., Malik, A. U., Umer, F. and Bodla, M. I (2010). Effect of tillage and farm yard manure on physical properties of soil. *International Research Journal of Plant Science*, 1(4):75-82.

Kho-darahmpour, Z (2011). Effect of drought stress induced by polyethylene glycol (PEG) on germination indices in corn (Zea mays L.) hybrids. *African Journal of Biotechnology*, 10(79):18222-18227.

Lee, C (2007). Corn growth and development. www.uky.edu/ag/grain crops.

Li, R., Hou, X.Q., Jia, Z.K., Han, Q.F. and Yang, B.P (2012). Effects of rainfall harvesting and mulching technologies on soil water, temperature, and maize yield in Loess Plateau region of China*. Soil Research, 50*: 105-113.

Li, S.X., Wang, Z.H., Li, S.Q., Gao, Y.J. and Tian, X.H (2013). Effect of plastic sheet mulch, wheat straw mulch, and maize growth on water loss by evaporation in dryland areas of China. *Agricultural Water Management*, 116: 39-49.

Liu, J.L., Bu, L., Zhu, L., Luo, S., Chen, X. and Li, S (2014). Effect of organic manure and fertilizer on soil water and crop yields in newly built terraces with loess soils in a semi-arid environment. *Agriculture Water Manage*, 117: 123-132.

Liu, Y., Li, S.Q., Chen, F. and Yang, S.J. and Chen, X.P

(2010). Soil water dynamics and water use efficiency in spring maize (*Zea mays* L.) fields subjected to different water management practices on the Loess Plateau, China. *Agricultural Water Management,* 97:769-775.

Misganaw R. Beyza (2014). Outcome of rich farmyard manure and inorganic fertilizers on grain yield and harvest index of hybrid maize (BH-140) at Chiro, eastern Ethiopia. *African Journal of Agronomy*, 2 (8):194-199.

Mkhabela, T.S. and Materechera, S.A (2013). Influence of kraal manure application time on emergence, growth and grain yield of maize grown in two soils with contrasting textures. *Journal of Food and Agriculture Environment,* 11: 422-427.

Molina Oscar, I., Tenuta, M., Abdelbasset, E., Buckley, K., Cavers, C. and Fouad, D. (2014). Potato early dying and yield responses to compost, green manures, seed meal and chemical treatments. *American Journal Potato Research*, 1-15.

Muhammad, A., Muhammad, A. M. and Cengiz, R (2015). Drought stress in maize (Zea mays L.) effects, resistance mechanisms, global achievements and biological strategies for improvement. Netherland, (1-79)

Negassa Wakene, Getaneh Fite, Deressa Abdena and Dinsa Berhanu (2007). Integrated use of organic and inorganic fertilizers for maize production. In Utilisation of Diversity in Land Use Systems: *Sustainable and Organic Approaches to Meet Human Needs, Tielkes, E. (Ed.). Cuvillier Verlag, Gottingen, Germany.*

Pabin, J., Włodek, S., Biskupski, A (2006)**.** Effect of cultivation simplifications in a monoculture of winter rye on yields and changes in the soil environment. .

Parija, B. and Kumar, M (2013). Dry matter partitioning and grain yield potential of maize (Zea mays L.) under different levels of farmyard manure and nitrogen. *Journal Plant Science Research,* 29(2): 177-180.

Prasad, B. and Sinha, S. K (2012). Long-term effects of fertilizers and organic manures on crop yields, nutrient balance, and soil properties in rice-wheat cropping system in Bihar, In: India.

Sahindomi Bana, Sugeng Prijono, Ariffin and Soemarno (2013). The effect of soil management on the availability of soil moisture and maize production in dryland. *International Journal of Agriculture and Forestry*, 3(3): 77-85.

Shah, S. S. H., Ahmad, S. B., Shah, S. H. H., Muhmood, A., Nawaz, A., Niaz, A., Wakeel, A. and Majeed, A (2015). Mulching effects on water productivity, maize yield and soil properties in bed and flat sowing methods. *International Journal of Plant and Soil Science,* 8(1): 1-7.

Shah, S.S.H., Khan, A.H., Ghafoor, A. and Bakhsh, A (2013). Soil physical characteristics and yield of wheat and maize as affected by mulching materials and sowing methods. *Soil and Environment*; 32(1):14-21.

Tadesse Tilahun, Dechassa Nigussie, Bayu Wondimu and Gebeyehu S (2013). Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. *American Journal of Plant Sciences*, *4*(02):309-316.

Tolessa Taye, Natol Bekele and Yonas Shimalis (2015). Response of maize to inter row mulch application at different growth stage of maize for small scale agro-pastoralist. *Global Journal of Food Science and Technology*, 3(7):204-206.

Uzoma, K. C., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A. and Ni shihara, E (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. *Soil Use Management,* 27:205-212.

Wang, L.F., Chen, J. and Shangguan, Z.P (2016). Yield responses of wheat to mulching practices in dryland farming on the Loess Plateau. *PLoS one,* 10(5): e0127402.

Wang, X. and Xing, Y (2017). Effects of mulching and nitrogen on soil nitrate-N distribution, leaching and nitrogen use efficiency of maize (Zea mays L.). *PLoS one*, 11(8):1371-1376.

Wang, X. J., Jia, Zh. K., Liang, L. Y. and Kang, Sh. Zh (2018). Effect of manure management on the temporal variations of dryland soil moisture and water use efficiency of maize. *Journal of Agricultural Science Technologies,* 15: 1293-1304.

Wang, Z., Feng, H., Wu, P. and Du, J (2009). Effects of soil amendment fertilizers on yield and water use efficiency of spring maize. *Transactions CSAE,* 25(11):114-119.

Zhao, Y., Yan, Z., Qin, J. and Xiao, Z (2014). Effects of long-term cattle manure application on soil properties and soil heavy metals in corn seed production in Northwest China. *Environmental Science Pollution Research,* 21(12):7586-7595.