EFFECTS OF CROP RESIDUE MANAGEMENT AND ANIMAL MANURE STORAGE SYSTEMS ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.) IN JIMMA AREA, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

BY

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Effects of Crop Residue Management and Animal Manure Storage Systems on Growth and Yield of Maize (*Zea mays* L.) in Jimma Area, Southwestern Ethiopia

M.Sc. Thesis

By

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DEDICATION

This thesis work is dedicated to my father ADAMU KENO RIBBI who passed away without seeing my achievements and also dedicated to my wife Sosina Tamiru, who has sown the interest of learning in my heart and wishing me a great career throughout my life.

STATEMENTS OF THE AUTHOR

I, the undersigned, declare that this thesis is my work and is not submitted to any institution elsewhere for the award of any academic degree, diploma, or certificate and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. degree at Jimma University, College of Agriculture, and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library.

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Place: Jimma University, Jimma, Ethiopia
Date of Submission...June 10/2020 Signature..............................

BIOGAPHICAL SKETCH

The author Mr. Bikila Adamu Keno born from his father Adamu Keno and his mother Mrs. Assegedech Nura in 1984 G.C in Ulmaya Kebele, Bilo Napha district, Ilubabor Administrative Zone, Oromia Regional State. When his age reached (1992 G.C.) to education, he pursued his elementary education at Ulmaya Elementary School at Ulmaya. In 1998 G.C. he enrolled at Hurumu Junior and Senior Secondary School and completed Senior Secondary School in May 2001 G.C. Subsequently, he joined Bako Agricultural TVET College in 2002 and graduated with a Diploma in Plant Sciences in July 2004 G.C. He was employed by the Ministry of Agriculture (MOA), Ilubabor Zone Agricultural Development Department in September 2005 G.C. He worked as a development agent in Bedele and Bilo Nopa District from September 2005 G.C. up to September 2010. He joined Jimma University (College of agriculture and veterinary medicine) in October 2010 G.C. for his first degree and graduated with a B.Sc. in Plant Sciences in July 2011 G.C. Afterwards, he was employed by the same organization in 2012 G.C. as field crop experts and served in different positions up to September 2017 G.C. He served as coffee agronomist expert at Ilu Aba Bor Zone in Zonal agricultural office until he joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue a graduate study, in Master of Science degree in Agronomy.

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TABLE OF CONTENTS

PAGES

Table of contents *continueoued*

LISTS OF TABLE

LISTS OF APPENDIX TABLE

PAGE

LISTS OF ABBREVIATIONS AND ACRONMYS

ANOVA	Analyze of variance
BH	Bako hybrid
CEC	Cation exchange capacity
CRM	Crop residue management
CSA	Central Statistics Agency
CUE	Carbon utilization efficiency
DTMA	Drought Tolerant Maize for Africa
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
GR	Grass roofed
INM	Integrated nutrient management
m.a.s.l	Meter above sea level
MSS	Manure storing system
Ppm	Parts per million
SOC	Soil organic carbon
SOM	Soil organic matter
SNNPR	South Nation and Nationality People Region
SR	Steel roofed
SSA	Sub-Saharan Africa

ABSTRACT

Maize is a key source of food and livelihood for millions of people in many countries of the world. However, its productivity is highly constrained by low soil fertility status among other factors. This experiment was conducted in Omonada and Mana districts in Jimma zone, Southwestern Ethiopia, between November 2018 and October 2019 to evaluate the effect of crop residue management (RM) and animal manure storage system (MSS) on soil fertility and growth, yield and yield components of maize (Zea mays L.*). The trial involved two factors with five levels of RM (control, 25%, 50%, 75% and 100%) and four levels of MSS (control, open, steel roofed (SR) and grass roofed (GR)) laid out in randomized complete block design and replicated three times at two locations. Crop phenology (days to 50 % tasseling, silking and physiological maturity), growth parameters (plant height and leaf area) and yield and yield components of maize were recorded. It was observed that available NPK, organic carbon and organic matter in the soil after harvest increased with application of crop residue and animal manure. Growth, yield and yield components were highly significantly influenced by location, and RM and MSS treatments, but the three ways interaction was not significant for all those parameters. The highest value for all maize growth, yield and yield component parameters was recorded from Omonada district. The highest (6,703.2 kg ha*$^{-1}$*) grain yield was recorded for 100 % followed by 75% residue incorporation with the respective increment of 15.7% and 14.7% over the control plot. Similarly, GR manure storage system gave the maximum grain yields (6,887.0 kg ha*$^{-1}$*) and resulted in highest values of all plant parameters. Grain yield was also significantly (P=<0.05) and positively correlated with various yield attributes of maize, such as cob length, cob weight, number of ears plant*$^{-1}$*, number of kernels row cob*$^{-1}$*, kernel number cob*$^{-1}$*, kernel number row*$^{-1}$*, thousand seed weight, grain yield per plant, dry biomass yield plant* $^{-1}$*, and above ground dry biomass yield hectare* $^{-1}$*. The result of partial budget analysis showed that 75% residue incorporation and GR manure storage system either alone or in combination gave greater economic benefit with higher MRR. The combination of 75% crop residue with GR manure gave the highest net benefit (44,882.1Birr ha*$^{-1}$*) with MRR of 721.6%. Therefore, it was concluded that combined application of 75% crop residue and GR manure storage system can be tentatively recommended for production of maize in the study area and in other areas with similar agro-ecological conditions. However, since the experiment was conducted for one season at only two locations, it is suggested that it has to be repeated over seasons and locations using this and other improved maize varieties to make a conclusive recommendation.*

Key Words: ***Grain yield, Grass roof, Steel roof, Storage system***

1. INTRODUCTION

Maize (*Zea mays* L.,) is an important cereal crop belonging to the tribe Maydeae~~,~~ of the grass family, Poaceae, Genus Zea, Species mays. Even though it is still controversial, the most common opinion shows that Mexico is its center of origin (Piperno and Flannery, 2001). Maize is the major food crop, next to rice in the world, contributing 34 % of the overall grain production (WFP, 2019). It serves as a primary staple food in most developing countries and provides about 60% of all human calories along~~-~~with rice and wheat (Cassman *et al*., 2003; Khalil *et al*., 2011).

In Africa, maize is staple food and source of income for small holder farmers and the need will be doubled in 2050 worldwide especially in developing countries including Ethiopia (Ranum *et al*., 2014; Abate *et al*., 2017; FAO, 2017; Law-Ogbomo *et al.,* 2018). It accounts for 40% of the cereal production in Sub-Saharan Africa (SSA), where more than 80% is used as food (Aylward *et al.,* 2015). It is commonly grown and widely traded in domestic and international markets in SSA, and exhibits high variability in yields among countries (Aylward *et al.,* 2015). Average productivity of maize in Ethiopia is higher as compared to African average but lower than the world average and much lower than that of developed countries (Gissa, 2016). The small holder farmers that comprise some 80 percent of the population are both the primary producers and consumers of maize in Ethiopia (Alemu *et al.,* 2008). Maize ranks first in productivity and total grain production and second in total area coverage after *teff* with national average yield of 3940 kg/ha (FAO, 2017; CSA, 2018)

Oromia region has wide agro ecologies suitable for maize production, and Jimma Zone is one of the highest potential areas in the region (CSA, 2017). In Jimma Zone, maize is the second most cultivated crop and the first in production with average yield of about 4,200 kg/ha (CSA, 2017) which is far lower than the world average (5,750 kg/ha) (FAO, 2017). Therefore, narrowing the yield gap - *i.e*., the gap between actual farmers yield and potential yield by improving productivity will be essential to meet the growing food demand without greater reliance on cereal imports and/or expansion of arable lands (Van Ittersum *et al*., 2016).

Soil acidity and fertility are the major constraints affecting crop productivity. Soil acidity affects about 43% of the cultivated land in humid and sub-humid highlands of Ethiopia. To fulfill the increasing demand for food and raw materials, soil health and fertility has remained as the major factor to increase and sustain crop yields (Getachew *et al.,* 2019). Maize productivity is highly constrained by the environment especially by low soil fertility status among other factors (Mutiro *et al*., 2004, Law-Ogbomo *et al*., 2018). Current indications of poor soil nutrient management across Ethiopia are low nutrient reserves in arable soils, negative nutrient balances in cropland and farming practices with few or no external nutrient inputs (Tsigie and Tesfaye, 2012). Soil nutrient depletion in Ethiopia has several causes such as limited applications of organic fertilizers like crop residues and manure, and socio-economic problems in the use of mineral fertilizers (Aseffa, 2005). However, due to increased costs of mineral fertilizer, deterioration of soil health and environmental concerns, the use of organic manures has become important (Yaduvanshi, 2003). Therefore, organic manure based indigenous fertilizer formulation could be an alternative to improve soil health and crop productivity, complement inorganic fertilizers and reduce dependence on external inputs (Berhanu *et al*., 2015).

Crop residue incorporation is a way of directly recycling nutrients into the soil taken by the plants from the soil earlier (Tedla, 2010). Crop residues, usually considered a problem, when managed correctly can improve soil organic matter dynamics and nutrient cycling, thereby creating a rather favorable environment for plant growth (Bahadur *et al*., 2015). According to Power *et al*., (2010) and Bahadur *et al*., (2015); returning crop residue to soil improves water conservation and storage, nutrient availability and crop yields, and reduces bulk density and increases the porosity of the soil. In Ethiopia, crop residues are mostly used for livestock feed and as biofuel source.

In study areas, farmers rarely retain crop residue on farm lands and the practice of crop residue management is also not well known. Farmers remove maize stovers primarily for use as fuel and as animal feed. Some farmers even burn the residue shortly before planting the next crop (Tolessa *et al*., 2001). Such trends result in depletion of soil organic matter and ultimately the soil turns unproductive unless a huge amount of chemical fertilizers are applied to intensify maize production. As a result, poor soil fertility status and widespread soil degradation are currently the main constraints to improve crop yields in Ethiopia specifically in Jimma area.

Animal manure is the prime source of soil fertility management for many farmers of Ethiopia. Specifically, in the study area, cattle are typically housed (either grass roofed or steel roofed house) on earth floors, sometimes with maize straw as bedding material. But, manure is often stored without a proper impermeable floor and a roof, leaving it liable to nutrient losses by rain and sun. Thus, manure produced in such a way is a solid mixture of faeces, some urine, bedding material and spoiled feed. This solid manure produced by cattle is regularly scrapped off the floor and composted in unsafe way before its use as fertilizer and for soil amelioration. According to Ndambi *et al*., (2019), none of smallholder farms in Ethiopia have waterproof floors nor roofing/cover for manure storage. Hence, effective managements and use of these locally available organic matters is very important to reduce nutrient losses through volatilization and leaching during storage.

Collection and handling of manure are critical steps where nutrients may get lost that could otherwise be used as fertilizer (Rufino *et al*., 2006). It has been reported that improved manure management practices increased maize grain yields by 18%, compared with that generated from farmer's traditional practice (Zake *et al*., 2010). However, such improved practices have not been tested under Jimma condition. Therefore, research is required to test and determine the suitability and benefits of manure and crop residue management practices for maize production and provide evidences or information to the farmers. Accordingly, the present study was initiated with the following objectives.

General Objective:

To investigate the potential effect of crop residue management in combination with animal manure storage systems on maize production.

Specific Objectives:

To investigate the effects of crops residue managements and animal manure storage systems on maize growth, yield and yield components.

To identify economically feasible of crop residue management and/or animal manure storage system.

2. LITERATURE REVIEW

2.1 Importance of Maize in Ethiopia

Maize (*Zea mays* L.) is the second most popular staple crop in Ethiopia after *teff* (*Eragrostis tef*) and its production in the country has doubled in less than two decades. In Ethiopia, maize is one of the most important and major strategic food crop among cereal, ranking second after *teff* in area coverage and first in production and productivity with national average yield of 3.73 t/ha (CSA, 2017; FAO 2017)**.** It is Ethiopia's leading cereal in terms of production, with 8.395 million tons produced in 2016/17 by 10.86 million farmers across 2.135 million hectares of land (CSA, 2018).

The small-scale farmers that comprise some 80 percent of Ethiopia's population are both the primary producers and consumers of maize in Ethiopia (Alemu *et al.,* 2008*)*. In terms of regional distribution, 46.5% of the producers are found in Oromia, 28.7% in Amhara, 15.2% in SNNP, 6.26% in Tigray, and 2.03% in Benishangul Gumuz regional states. Accordingly, the total grain cropped area reported for Oromia, Amhara, S.N.N.P.R, Tigray and Benshangul-Gumuz Regions have increased by about 0.78%, 0.81%, 1.55%, 0.45% and 1.23% over last year 2016/17 (2009 E.C) post-harvest estimate, respectively. Following the same pattern the harvested volume of production reported for the above mentioned regions have increased by about 4.99%, 5.50%, 9.97%, 0.77% and 7.57% over last year's 2016/17 (2009 E.C) post-harvest estimate of the regions. From the maize producer zone of the country; Jimma is among the top maize producer zone (CSA, 2018). Currently, maize is the cheapest source of calorie intake in Ethiopia, providing 20.6 % of per capita calorie intake nationally and constitutes more than 60% of the caloric intake of a typical household (Dawit *et al*., 2014, Rashid *et.al*.,2019).

2.2 Challenges and Opportunities of Maize Production in Ethiopia

Minot, (2013) and Rashid *et al*., (2010) have identified some of the constraints in the development of the maize sector in Ethiopia. The lack of markets and down-stream processing and inconsistent export policies are among the major bottlenecks. "Demand sinks" in the poultry and livestock sectors are potential market opportunities for stimulating growth of the maize sector. Soil fertility, insect and disease, Price problem, lack of inputs (chemicals, Fertilizers, Seed, etc.), lack of appropriate threshing facilities and storage facilities, high post-harvest losses, lack of farming oxen, lack of rural credits, lack of education and lack of rural feeder roads are part of major constraints of maize production in Ethiopia (Bultossa, 2018). Maize productivity is highly constrained in the environment owing to low soil fertility status among other factors (Mutiro *et al.,* 2004 and Law-Ogbomo *et al.,* 2018). Anthropogenic factors such as inappropriate land use systems, mono-cropping, nutrient mining and inadequate supply of nutrients are aggravated the soil fertility degradation situation in Ethiopia (Negassa *et al.,* 2007). However, exchange of information among farmers was limited to small geographical areas, narrowing the possibilities of farmers to learn from others, reducing the adoption rate of recommended manure management practices (Ndambi *et al.,* 2019). Others have looked at the tradeoffs in crop residue utilization in the context of Ethiopia (Mekonnen *et al*. 2017).

Ethiopia has wide suitable agro ecologies for maize production (CSA, 2017). Maize grows from sea level to over 2,600 m.a.s. from moisture deficit semi-arid lowlands, mid-altitude and highlands to moisture surplus areas in the humid lowlands, mid-altitudes and highlands (Abduselam *et al.*, 2017). If production can be significantly expanded, the potential for maize export to all the neighboring countries is very high although the national demand is expected to continue to grow in the coming years. Maize for industrial use has also supported growing demand (Abate *et al.,* 2015). The other opportunities for maize production in Ethiopia; were found to be, availability of motivated and hardworking farmers, good access to agricultural marketing's and good weather condition. Policies, plans and programs should target rural community. The construction of rural feeder roads, either, mechanization of the farming sector or provision of sufficient farming oxen is indispensable (Bultossa T.W., 2018). About one third of the farmers in Ethiopia had invested money in improving manure management within the last 5 years and was happy with the outcome of their investments (mainly higher crop yields) (Ndambi *et al.,* 2019).

2.3 Effects of Residue Management on Crop Growth, Yield and Yield Components

Crop residues influence agricultural sustainability by enhancing productivity. Productivity increases with residue returned are greater with low rates of fertilizers (Lal, 1995) and the largest net return was obtained from the maize under the conventional tillage with residue incorporation (Meena *et al.*, 2015). Greater production in the plots previously treated with 150% residue rate to improved water retentions in the soil for both plant growth and microbial activity, which enhanced nutrient cycling (Wilhelm *et al.,* 2004).

The crop residue management practices showed significant improvement in grain, stover yield over control in maize (Raghavendra *et al*., 2017). According to Shittu and Fasina, (2006); Baruah, (2015), application of organic residues resulted in a considerable variation in plant growth, biomass production and carbon utilization efficiency (CER) of the crops at maturity. Field dry cob weight and maize yield was significantly influenced by the residue management (Shittu and Fasina, 2006). Maize grain yield was higher in residue treated plots relative to the without residue plot (Mbah and Nneji, 2011). Residue incorporation increased performance of maize showing good results for ears per plant and grains per ears (Shah *et al*., 2006) . The plots in which no residues were incorporated performed poorly and resulted in least values of ear length and weight, grain ear^{-1}, grain weight, grain and biological yields parameters (Arif and Al, 2011). Similarly, according to Sadeghi *et al., (*2015), numbers of spike per plant, grains per spike, grain per plant and 1000-grain weight were significantly increased with increased residue rates.

Residue removal reduces grain and residue yields by amounts equal to 10% and 30%, respectively, of the quantity of residue removed (Ghimire *et al*., 2017). The treatment with 4.0 tonnes ha^{-1} CR was significantly superior with respect to grain yield (4.79, 5.24 tonnes ha^{-1} in maize; 5.01, 5.29 tonnes ha^{-1} in wheat) and stover/straw yield (8.31, 8.93 tonnes ha^{-1} in maize; 8.26, 8.76 tonnes ha^{-1} in wheat) as compared to no CR and it was on par with 6.0 tonnes ha^{-1} CR (Raghavendra *et al*., 2016). The residue-removed treatment produced an average of 6.10 Mg grain ha^{-1}, and the residue-returned treatment produced 6.67 Mg grain ha^{-1} (Wilhelm *et al.,* 2004). But according to Kenney *et al.,*(2015), stover removal at 50, 75, and 100% resulted in increased grain yield by 4.75, 5.03, and 4.21 Mg ha^{-1}, respectively, compared with no removal. 75 and 100% residue removal rates resulted in an increase in grain yield by an average of 1.04 Mg ha^{-1} compared to 0 and 25% removal. Residue effects on crop yield were induced mainly through changes in soil water and soil temperature (Wilhelm *et al.,* 1986)

2.4 Effects of Crop Residue Management on Soil Chemical Properties

Crop residue incorporation is an environment friendly strategy which is becoming a common soil management practice for sustainability of soil fertility (Shah *et al.*, 2006). Crop residues contain significant quantities of plant nutrients and their judicious application will have positive effect on nutrient management in maize-wheat system (Minz *et al.,* 2018). It is returned affect a soil's chemical and nutritional properties, both directly and indirectly. Directly, they add plant nutrients. Indirectly, they affect volatilization and leaching losses, increase nutrient cycling and root-soil interaction, and improve intensity and capacity factors of water and nutrients in soil through the increase of a soil's organic matter content. Overall, crop residues returned to the soil increase nutrient use efficiency (Lal, 1995).

Leaving an insufficient amount of crop residue on the soil surface can be detrimental for soil quality, result in loss of soil organic matter (SOM), and increase soil erosion, whereas leaving excessive amounts can impair soil-seed contact, immobilize N, and/or keep soils cool and wet (Clay *et al.*, 2019).

Available total soil N (from 73.0 to 82.3 kg N ha^{-1}), soil available P (16.7to 20.3kg ka^{-1}), soil organic matter (OM) (g/kg), PH, CEC cmol kg^{-1} and exchangeable bases (cmol kg^{-1}) were increased, but non-significant values of total N with incorporated amounts of previous crop residue (Power *et al.*, 2010; Mbah and Nneji, 2011). Residue removal is reduces macro (e.g., K, P (P content in soil significantly decreased in the 0–30 cm soil layer for all crop residue treatments), N, Ca, and Mg) and micronutrient (e.g., Fe, Mn, B, Zn, and S) pools in the soil by removing nutrient rich residue materials and by inducing losses of soil organic matter (SOM) enriched sediments in runoff (Taylor *et al.*, 2009). As Meena *et al.*, 2015 identified the residue addition resulted in improvement of soil C content in the plough layer and resulted in lowering the bulk density under similar type of soils. Wilhelm *et al.*, (2004) reported that crop residues clearly influence crop production. Returning 0, 50, 100, and 150% of the residue produced by the previous crop to the soil resulted in SOM contents (to 30 cm) of 24.7, 25.3, 26.2, and 27.4 g kg^{-1}, respectively.

2.5 Effects of Manure Storage Systems on Maize Yield and Yield Components

Various studies have been conducted in SSA showing the positive effects of manure application on crop yield, however effective use of livestock manure as a fertilizer depends critically on methods of manure handling and storage, and on synchronizing mineralization of manure N with crop uptake (Rufino *et al*., 2006). Integrated Manure Management (IMM) mainly involves improved practices in collection, treatment, storage, and application of manure to soils (Teenstra *et al*., 2015) that can improve crop yields. Animal manure is rich in absorbable plant nutrients and an appropriate addition of manure into the soil respond to high crop productivity than use of commercial fertilizer (Minase *et al.*, 2015). Efficient nutrient management plans and strategies are needed to maximize crop productivity while minimizing the potential environmental impact due to the high amount of nutrients being applied today (FAO, 2018). Animal manure forms an essential source of nutrients for soils in order to sustain crop productivity for the majority of small-holder farming systems in Africa (Giller *et al.,* 2002).

The manures stored under different management condition except the farmer manure improved grain yield compared with the unfertilized control, despite the higher N application rate with the farmer manure. Of the manures stored under different condition, the greatest yield was significantly higher than the lowest yield. All manure stored under deferent storage condition gave higher maize grain yields than the farmer manure (Lekasi *et al.*, 2012). The application of cattle manure generated from simple improvements in management practices resulted in 50% and 44% increases in dry matter yield of maize grain above the control where no fertilizer was applied under intensive and semi-intensive cattle manure management systems, respectively. Furthermore, dry matter of maize grain yields were greater by 10% and 18% for manure generated from improved management practices compared with that generated from farmer's manure management practices under intensive and semi-intensive cattle management systems, respectively (Zake *et al*., 2010). Absolute amounts of N recycled with improved manure management may have little immediate impact on crop productivity (Rufino *et al*., 2007).

2.6 Effects of Manure Storage Systems on Soil Nutrient and Organic Matter Content

In addition to N, P, and K, manure contains other elements essential to plant growth such as calcium, magnesium, sulfur, boron, manganese, copper and zinc (Madison *et al*., 1914), and also provides organic matter to agricultural soils – a key determinant of soil health (FAO, 2018). Volatilization of ammonia due to high temperature and leaching of nitrate, phosphorous and potassium into the soil due to rainfall results in the loss of manure nutrients during storage (Minase *et al*., 2015).

As FAO, (2018) stated manure may be collected and/or treated in various storage systems for later applications to fields and its storage and management choices will further determine the final N composition of treated manure. Cattle manure enhances soil mineral N content if managed correctly (Markewich *et al*., 2010). Roofing had a significant impact on the mass fractions of NH4-N and NO3-N (Tittonell *et al*., 2010). Rufino *et al*., (2007) found that manure covered with a plastic film and stored with roofing lost 20% of nitrogen compared to 55% nitrogen loss in manure that was stored in open heaps. Covering the manure heaps with a plastic film had a stronger effect on mass and N losses than the presence of a roof. On average, about 6% of the initial N total was lost from the covered heaps whereas this fraction was 12% from the roofed, 21% from the stockpiled, and 33% from the open composted heaps (Shah et al., 2016). Another study also found that manure stored in open pits had lower mass fractions of N than manure in heaps under roof and in open heaps (Tittonell *et al*., 2010). Most of the mineral N in the manure stored in pits was NH4-N, whereas NO3-N was predominant in the manure stored in heaps. The improved manure management practice, which involved collection of cattle dung every day and heaping it under the shade of a tree until enough material accumulated to enable its preparation for crops, was greater by 36% and 21% for total N (Zake *et al*., 2010). The uncovered heaps underwent aerobic decomposition and lost about 55% of the initial dry mass and 50% of the initial N, whereas those that were covered and roofed lost about 30% of their mass and about 20% of their N during the storage (Rufino *et al*., 2007). The nitrogen content in the indoor composted manure (1.96 % DM) and kraal manure (1.13 % DM) (Jackson *et al.,* 2005). Indoor composted manure had the lowest C/N ratio while kraal manure had the highest C/N ratio (Pimentel, 1997). Under shade manure storage facilities as much as possible in order to reduce exposure to high temperatures and subsequent N losses, as well as limiting exposure to rainfall, and thus minimizing nutrient losses due to leaching. Shorter storage periods also reduce N losses (Snijders *et al*., 2013).

The conditions under which manure was stored affected manure P composition. The manure stored in pits in the open air had slightly lower of P. Twenty five percents of the P contained in fresh manure could be lost by leaching (Tittonell *et al*., 2010). The improved manure management practice, which involved collection of cattle dung every day and heaping it under the shade of a tree until enough material accumulated to enable its preparation for crops, was greater by 42% and 52% for total P (Zake *et al*., 2010). Study in Western Kenya found that manure stored in open pits had lower mass fractions of P than manure in heaps under roof and in open heaps. The efficiencies of phosphorus nutrient retention during storage varied between 34-38% for P (Tittonell *et al.*, 2010).

The mass fraction of K was notably larger in the manure stored under roof, and did not differ significantly between the pit and heap in the open air. The efficiencies of potassium nutrient retention during storage varied between 18–34% for K, with the heaps under a roof having greater efficiencies of retention of K (Tittonell *et al*., 2010). Manure composted in the barn was found to have relatively higher K (1.75 % DM) than kraal manure (0.94 % DM), pit composted manure (0.94 % DM) and manure piled outside (0.84 % DM) (Jackson *et al.,* 2005). The improved manure management practice, which involved collection of cattle dung every day and heaping it under the shade of a tree until enough material accumulated to enable its preparation for crops, was greater by 67% and 44% for total K+ (Zake *et al*., 2010).

Manure is often the main input of C to the soil when crop residues are removed from the fields (Tittonell *et al*., 2010). The improved manure management practice; which involved collection of cattle dung every day and heaping it under the shade of a tree until enough material accumulated to enable its preparation for crops, was greater by 48% and 55% for total OC (Zake *et al*., 2010). The stored manure lost 45% of its C in the open air and 69% under roof. Manure is often the main input of C to the soil when crop residues are removed from the fields (Tittonell *et al*., 2010). At least 53% of the variability in SOC stock differences compared to mineral fertilized or unfertilized reference treatments (Maillard *et al.,* 2014).

SOM depletion is one of the major factors causing degradation of ecosystem services and loss of ecosystem resilience (Feller *et al*., 2012). Thus, numerous studies have suggested that organic soil amendment is an alternative for sustaining economically viable crop production with minimal environmental pollution. Indeed, organic fertilization has been shown to improve SOM content, microbial biomass and activity, to suppress plant diseases, especially those caused by soil-borne pathogens, and to improve soil resistance against erosion (Thiele-Bruhn *et al*., 2012). The total amount of manure organic matter decreased to about a quarter of its initial amount after 3 months of storage, partly as a result of changes in the mass fraction of organic matter in the stored manure (Tittonell *et al*., 2010).

3. MATERIAL AND METHODS

3.1 Description of the Study Area

The study was carried out on farmer fields in Mana and Omonada districts of Jimma zone, which is found at about 345 km away from Addis Ababa in Southwestern Ethiopia. Omonada district is located at a distance of about 71 km from the zonal capital, Jimma town, and specific experimental sites in the district (in Sayo Adami *Kebele*) are located at 7°68' to 7°69' N latitude and 37°21' to 37°283' E longitude and at an altitude range of 1696-1798 m.a.s.l. The area receives a bi-modal rainfall pattern with unpredictable short rains from March to April and the main rainy season from June to September. The total annual rainfall of the area ranges from 1,066 mm to 1,200 mm, with mean minimum and maximum temperatures of 18° C and 25° C, respectively (Eyasu *et al.*, 2015). On the other hand, the experimental sites in Mana district (in Somodo *kebele*) are located between 7°74' -7°75'N latitudes and 36°78'-36°80' E longitudes and at an altitude range of 1922-2019 m.a.s.l. The mean minimum and maximum temperatures of the area are 18°C and 20°C, respectively, with mean total annual rainfall ranging between 1,300 mm and 1,700 mm with bi-modal pattern of small rains between April and May while the long rainy season occurs from June to August (Worku, 2008).

Table 1. Description of the Experimental Sites

District/Sites	Altitude (m.a.s.l)	Latitude	Longitude
Omonada (Sayo Adami *Kebele*)			
Farmer (replication 1)	1798	7^0 69’N	37^0 21’E
Farmer (replication 2)	1774	7^0 69’N	37^0 21’E
Farmer (replication 3)	1696	7^0 68’N	37^0 23’E
Mana (Somodo *Kebele*)			
Farmer (replication 1)	2019	7^0 75’N	36^0 80’E
Farmer (replication 2)	1922	7^0 74’N	36^0 78’E
Farmer (replication 3)	2010	7^0 75’N	36^0 80’E

GPS data recorded in 2018/19

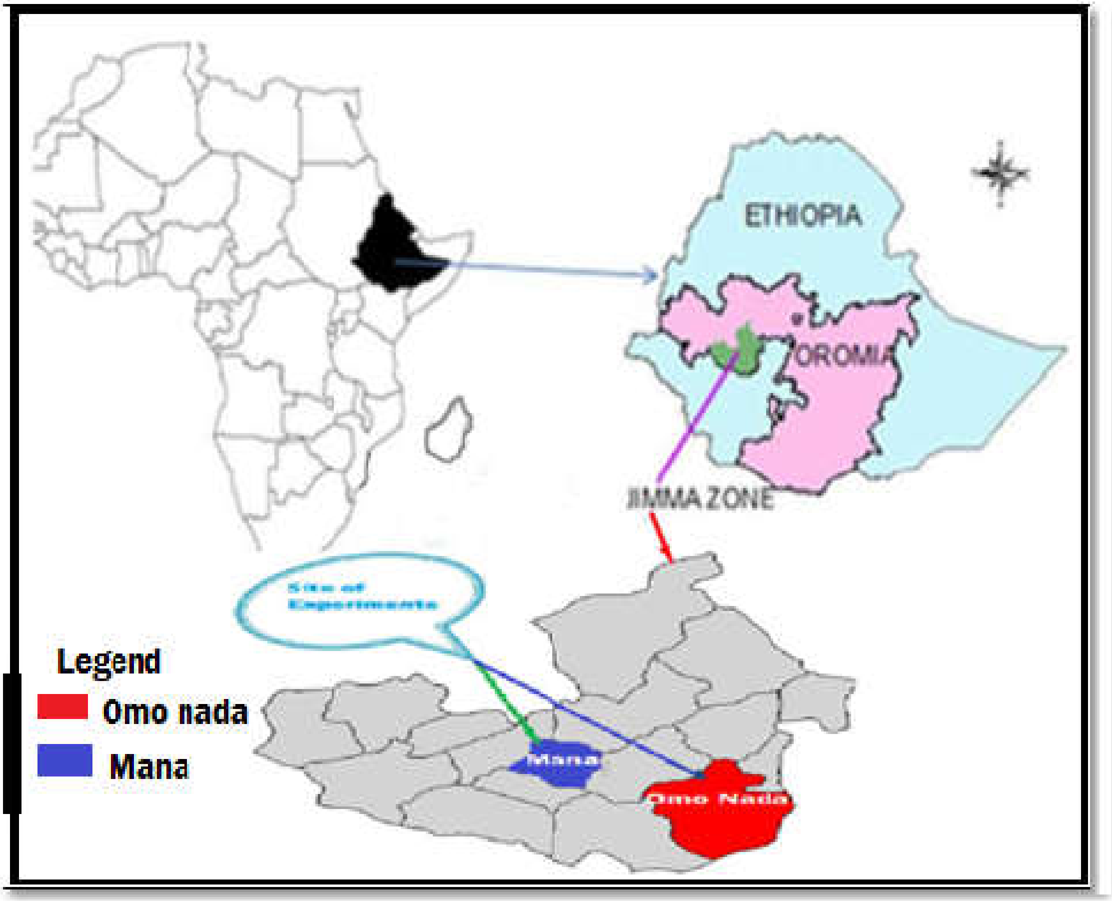

Figure 1:- Map of the experiment area

3.1.1 Pre-Sowing Soil Analysis

Results of pre-sowing soil analysis showed that soils of the experimental sites in Omonada and Mana districts have pH values of 5.26 and 4.9, respectively, both with strongly acidic nature. The textural class of the surface soil was clay loam with particle size distribution of 34% sand, 38% silt and 28% clay for Omonada and 40% sand, 31% silt and 29% clay for Mana. It implies that essential plant nutrients are fixed in soil colloidal particles and became unavailable to plant growth. According to the classification of Bray and Kurrtiz, (1945), available P was found in the low (8.58 ppm) range at Mana and moderate (10.5 ppm) range at Omonada location. Average organic carbon content of the soils was 1.31% and 0.76% at Omonada and Mana, respectively, which is also categorized in the low range according to the classification of Nelson and Sommers, (1996). According to the characterization made by Sáez-Plaza *et al*., (2009), the total soil nitrogen contents are also within very low (0.067%)

and low (0.12%) range at Mana and Omonada locations, respectively, indicating that all the experimental sites were deficient in most essential plant nutrients. Moreover, the pre-sowing soil analysis revealed that the soils were moderate in cation exchange capacity (CEC) (17.94 and 17.98 cmol(+)/kg soil) and low in OM content (2.2% and 1.2%) at Omonada and Mana location, respectively (Table 2). Therefore, the soils require amendment with different sources of nutrients to ameliorate their fertility status.

Table 2. Pre-sowing physical and chemical properties of soils of the experimental site

Soil parameter	Omonada		Mana		References
	Rating	Description	Rating	Description	
Depth (cm)	0-30		0-30		
Textural class	Clay loam		Clay loam		Gee, 2002
pH	5.26	Strongly acidic	4.9	Strongly acidic	McLean, 1982
TN (%)	0.12	Low	0.067	Very low	Sáez-Plaza *et al*., 2009
OC (%)	1.28	Low	0.72	Very low	Nelson and Sommers, 1
Av.P (ppm)	10.5	Moderate	8.58	Low	Bray and Kurrtiz , 1945
OM (%)	2.2	Low	1.20	Low	Ryan et al., 2001
K (m/kg)	8.4		8.25		
CEC(cmol(+)/kg)	17.94	Moderate	17.98	Moderate	Jackson, 1958

Where: pH (power of hydrogen), Av. p (available Phosphorous), OC (organic carbon), TN (t nitrogen), CEC (cation exchange capacity), OM (Organic matter)

The study areas have high potential for mixed livestock-crop production systems. Livestock and crop production are integrated farm activities at household farm level as animal draught power is used for plowing, threshing, and transporting of agricultural goods and services. However, crop residues have traditionally been used for multiple purposes including fuel and animal feed, which conflict with their use in soil amendment to improve its fertility. The remaining crop residue is burned for land clearing purposes. The current study was preferably emphasized on amounts or proportion of residue managements rather than emphasizing on the time of residue incorporation, because the importance of residue was not well known in the study areas. Initially, it is good to familiarize the best residue management for crop production with the area. Therefore, this study stressed on residue management at these locations.

Manure management practice (MSS) trend in the study areas include among others delayed and irregular collection patterns after deposition by cattle. Dried animal manure is used extensively as a source of fertilizer. However, most farmers in these areas do not apply recommended manure management practices, such as roofing animal housing, having a water-proof floor or covering manure during storage, minimizing nutrient losses during manure storage, and increasing the quality of manure as a fertilizer.

3.2 Experimental Materials

Maize variety BH661 was used for the study. BH661, promoted under the auspices of the Drought Tolerant Maize for Africa (DTMA) project, is of particular significance because of its drought tolerance, resistance to major diseases, higher yield potential and wide adaptability. BH661 is a late (up to 160 days) maturing maize variety released in 2011 by Bako Agricultural Research Center, performing well in agro-ecological range of 1600-2200 m.a.s.l with rainfall range of 1000-1500 mm. It can give 8500 kg/ha and 9500 – 12000kg/ha grain yields under on-station and on-farm experiments, respectively. It is dominantly used in the study area (Worku, 2012).

Fresh manure was obtained from the surrounding and stored without mixing with any other bedding material. Steel roofed and grass roofed houses that were already constructed by farmers for animal housing purposes were used for manure storage treatments. Maize residue from the previous crop on the experimental field was used for residue management treatments.

3.3 Experimental Design and Treatments

The experiment was laid down in a randomized complete block design with factorial arrangement in three replicates. It was conducted on three farmer fields (used as replications) at each of the two (Mana and Omonada) sites. The treatments include factorial combinations of five residue management practices (no residue incorporation, 25% residue incorporation, 50% residue incorporation, 75% residue incorporation and 100% residue incorporation) with four types of manure storage systems (control without manure, manure stored without shade (on open space), manure stored under steel roof and manure stored under grass roof).

The total area of the experimental field for one farmer was 3.2 m x 83m (265.6 m^2) with 80 cm inter-row and 40 cm intra-row spacing of maize plants. The size of each plot was 4.8 m X 3.2 m (15.36 m$^{2)}$ and 1 m spacing was used between plots. Maize was sown by hand with two seeds hole^{-1}. Number of rows per plot and number of seeding hole per row were six and eight, respectively. The outermost rows at both sides of plots were considered as borders and the middle ones were harvestable rows.

Table 3: Treatment combination in details

Residue management	Animal MSS			
	WOM	Open	Steel Roofed	Grass Roofed
0%	0% + WOM (T1)	0% + Open (T6)	0% + USR (T11)	0% + UGR (T16)
25%	25% +WOM (T2)	25% + Open (T7)	25% + USR (T12)	25% + UGR (T17)
50%	50% +WOM (T3)	50% + Open (T8)	50% + USR (T13)	50% + UGR (T18)
75%	75% + WOM (T4)	75% + Open (T9)	75% + USR (T14)	75% + UGR (T19)
100%	100%+WOM (T5)	100%+ Open (T10)	100% + USR (T15)	100% + UGR (T20)

Where: MSS= Manure storage system WOM=Without manure, USR=Under steel roof, UGR=Under grass roof

3.4 Experimental Procedures and Crop Management

3.4.1 Farmer selection

Three volunteer farmers were selected from each district in mid of December 2018, depending on the availability of all manure storage systems (which were already constructed for animal housing purpose) and fenced experimental plots which were previously occupied by maize crop.

3.4.2 Residue managements

Crop residue management practices were done in January 2019 immediately after the previous maize crop was harvested and field plot layout was done. Animals were not allowed to enter the experimental field and no crop residue was removed for any other purpose. Then, chopped maize residues were incorporated in to the soil during the first tillage based on the treatment level. The crop residues were applied 3 to 4 weeks after harvest and the subsequent crop was sown about 18 to 19 weeks after residue incorporation. The experimental field was prepared by using local plough (*maresha*) according to farmers' conventional farming practices. The fields were ploughed four times, the first plough was in January 2019 and the fourth and last ploughs were done at the end of April 2019 before planting the crop.

3.4.3 Manure storage

The manure storage systems (MSS) reflect farmers' traditional and potential methods in the study areas. All the manure treatments were used to capture the effects of nutrient volatilization due to solar heating (temperature). For all the treatment, impermeable plastic sheet (0.15 mm thick polyethylene film) was lined at the bottom. The animal manure was stored in mid of December 2018 for five months up to mid of May 2019. Manure storage was completed within three days to eliminate time effects. The treatments involved storage in open space, and in steel roofed and grass roofed houses constructed for livestock shelter. Animal manure was applied to the field at the rate of 10 ton ha^{-1} (Arif and Al, 2011) two weeks before maize seeds were sown and thoroughly incorporated in to the soil as per its assigned treatment.

3.4.4 Crop managements

Maize seeds were sown in rows at 5-10 cm depth in May 18 and 24/2019 at Omonada and Mana districts, respectively. At time of sowing, all plots received a basal application of locally recommended rate (150 kg ha^{-1}) of blended fertilizers (NPSB) (18.1% N, 36.1% P_2O_5, 6.7% S, 0.0 Z%, and 0.71% B) and hoeing was done a week after emergence. Recommended rate of N (200kg/ha) was applied in the form of urea (46% N) in split application (half at 40 days after planting and the second half before tessiling immediately after weeding).

Weeds were controlled manually by hand hoeing and subsequent weeding was done based on the farmers practice. All other necessary cultural practices and plant protection measures were followed uniformly for all the plots during the entire period of experimentation.

3.5 Data Collection

3.5.1 Soil data

Soil samples of the experimental site were collected before planting and after harvesting from the top 0-30cm depth in zigzag sampling pattern by using auger. Samples taken before planting were composited and two duplicate samples were prepared for analysis. After harvesting, soil samples were collected and composited for each treatment, and analyzed in the laboratory for selected chemical and physical properties. The collected soil samples were cleaned to make free from plant root and other foreign materials, air-dried, mixed and crushed by using mortar and pestle and then passed through a 2 mm mesh sieve.

The well prepared soil samples were analyzed for soil texture, OM, OC, EC, pH, CEC, K, total nitrogen and available phosphorus in the laboratories at JUCAVM. Soil determination for texture was done by hydrometer method (Gee, 2002). Soil pH was determined in 1:2.5 (w/v) soils to water (H2O) suspension ratio using a glass electrode attracted to a digital pH meter (McLean, 1982). Organic carbon (%OC) was determined by Walkley-Black Method (Nelson and Sommers, 1996). Total nitrogen content (% tN) was determined by Kjeldhal Method (Sáez-Plaza *et al*., 2009). Organic matter (OM) percentage was determined by multiplying the organic carbon with a factor of 1.724 as the procedures described by (Ryan *et al*., 2001). Available P in the soil samples was determined following the procedure of Bray-II method (Bray and Kurtz, 1945). K was determined by flame photometer method (Mehlich, 1953) whereas Cation Exchange Capacity (CEC) was determined by Ammonium Distillation Method (Jackson, 1958).

3.5.2 Crop parameters

Phenological parameters

Number of days to tasseling: it was recorded as the time taken from date of emergence till more than 50% of plants in each treatment developed tassel.

Number of days to silking: it was recorded when more than 50% of plants in each treatment developed silks.

Number of days to maturity: it was counted from emergence till 50% of the plants attain physiological maturity stage.

Growth parameters

Plant height: it was recorded at 50% maturity for five randomly selected plants in each plot. It was measured from the soil surface to the tip of the terminal stem using a measuring tape and mean values of the five plants was then determined.

Total leaf area per plant: it was determined using five randomly selected plants per treatment by measuring the length and width of five middle leaves with a measuring tape and then calculating using the following formula:

$$\mathrm{LAPP} = \mathrm{L} * \mathrm{W} * 0.75 * \mathrm{LNPP} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where; LAPP=total leaf area per plant; L=leaf length; W=maximum leaf width; LNPP=leaf number per plant and 0.75 = a constant value (Montgomery, 1911).

Yield and yield components

Number of ears per plant: it was counted using five randomly sampled plants per plot at the end of harvest and the average value was calculated.

Number of kernels rows per cob: it was counted for the same five randomly selected plants, using five selected cobs per plant at the end of harvest in each plot and the mean values were taken.

Number of kernels per cob: it was determined by using the same five randomly selected plants and from those only five cobs were selected at the end of harvest in each plot and each cob was threshed and kernels counted by seed counter.

Cob length: it was measured as the length of the cob from the tip to the bottom for the same five randomly selected cobs at the end of harvest in each plot and expressed in cm.

Cob weight: the same five randomly selected cobs as for cob length were used to measure cob weight at the end of harvest using a sensitive balance.

1000 Seed weight (TSW): weight of 1000 seeds, randomly taken from the harvested bulk seeds per net plot, was measured at 12.5% moisture content (standard moisture content for maize after sun drying) using a sensitive balance.

Dry biomass yield per plant: - dry biomass, representing the shoot part excluding grains, was measured by sensitive balance after oven drying the above ground parts of five randomly selected plants per plot at 60 0C until a constant weight. Finally average biomass yield of the five plants was calculated and expressed in g plant^{-1}.

Above ground dry matter yield per ha: total above ground biomass yield of the net plot area was determined by harvesting at physiological maturity and sun-drying to a constant weight. Finally, the biomass yield of the net plot area was converted to biomass yield per hectare.

Grain yield per plant: - grain yield plant^{-1} was measured for five randomly selected plants in each plot. All cobs from the five plants were threshed and weighed at the end of harvest after adjusting grain moisture content to 12.5% using a digital moisture tester.

Grain yield per hectare: - grain yield of the net plot area was converted to yield in kg ha^{-1}.

All yield and yield components were measured using the procedure outlined by Yihenew (2004).

Harvest index (H.I): it was calculated as the ratio of economic yield (grain yield) to biological yield of harvestable rows multiplied by 100. It was calculated using the flowing equation:

$$\mathrm{H.I} = \frac{\mathrm{GY}}{\mathrm{BY}} * 100 \ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where, H.I = Harvest index, GY = Grain Yield (Kg), BY = Biological Yield (Kg) (CIMMYT, 1994)

3.6 Partial Budget Analysis

Partial budget analysis was done based on location average cost and benefit of each treatment (CIMMYT 1988). It was analyzed for all the treatments to determine their respective economic viabilities. In the study area crop residue has no economic value; therefore, partial budget analysis was done only depending on the benefits gained from grain yield. The values of residue and manure were not considered in the budget. Average mean grain yield was used to compare the interaction effect and the main effects of RM and MSS using discrete economic analysis as recommended by CIMMYT (1988) and given as follows:

Unadjusted grain yield (UGY) (kg ha^{-1}): the average grain yield~~s~~ of each treatment.

Adjusted grain yield (AGY) (kg ha^{-1}): average grain yield of the two districts adjusted downward by 10% to reflect the difference between the experimental yield and actual yield.

The yield was adjusted down by 10% to reflect actual production conditions (CIMMYT, 1988).

Gross field benefit (GFB) (ETB ha^{-1}): it was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield.

$\mathrm{GFB} = \mathrm{AGY} * \mathrm{FGP}$........... (3)

Where: FGP= field/farm gate price for the crop. Maize grain yield was valued at seasonal average open market price of ETB 7.5 kg^{-1} for the last 5 years.

Total variable cost (TVC) (ETB ha^{-1}):

I t was calculated by summing up the costs that vary, including costs of tin steel, wooden poll, grass, and labour for residue management, residue chopping, residue incorporation, manure storage and fence construction, manure transportation, and manure application. The costs of other inputs (starter inorganic fertilizer) and production practices such as labour cost for initial fertilizer application, land preparation, planting, and weeding were considered the same for all treatments or plots. Labour cost for field operation was 50 ETB man^{-1} day^{-1} for both locations. Accordingly gross return was calculated from the field gate price (seasonal average) of maize grain in the study area (7.5 Birr/kg seasonal averages). Variable cost was calculated from the costs involved for residue managements (chopping, removal and incorporation), and storage construction and manure application. A total of 1,100 Birr/ha was paid for residue removal from the field, considering that 69 laborers per hectare were needed (daily wage of one laborer is 50 Birr). For chopping and incorporation of the residue, 2450 Birr/ha was needed considering that 49 laborers per hectare were needed. For manure storage construction, steel sheet was bought for 150 birr per sheet (8 sheet X 150=1200 Birr), grass for roof was bought for 100 Birr load^{-1} (10 load X 50 Birr = 500 Birr) and wooden poll was bought for 25 Birr poll^{-1} (42 poll X 25 Birr =1050 Birr). For manure storage, transportation and application, 1350 Birr ha^{-1} was needed (daily wage of one laborer is 50 Birr). Plastic sheet for the manure storage floor was bought for 100 Birr per hectare.

Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) as:

MRR = $\frac{\Delta NB}{\Delta TVC} * \mathbf{100}$ ……………………….. (4)

MRR of 100% implies a return of one birr on every birr of expenditure in the given variable input.

Net benefit (NB) (ETB ha^{-1}): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment:

NB = GFB – TVC ……………………….. (5)

The treatment which gives the highest net return and a marginal rate of return greater than the minimum acceptable to farmers (100%) was considered for recommendation.

3.7 Statistical Data Analysis

Analyses of variance (ANOVA) for the measured parameters carried out using SAS (statistical analysis software) version 9.3 proc GLM procedure (SAS, 2012). Data were combined over the locations due to significance difference of all crop parameters over locations. Treatment differences were compared using the Least Significant Difference (LSD) procedure at 5% level of probability. Pearson correlation analysis was carried out for growth, yield and yield components of maize at each location and correlation coefficients (*r*) were established to determine magnitude and degree of their relation. Before the data was subjected to ANOVA, homogeneity and normality tests were done for the growth parameters, yield and yield components.

4. RESULT AND DISCUSSIONS

4.1. Crop Phenology and Vegetative Growth

4.1.1 Crop phenology

The maize phenological events were highly significantly influenced by location, residue management (RM) and manure storage system (MSS). In addition, interaction of RM by MSS not significantly affected only all phenological events. Location by RM significantly affected only days to 50% physiological maturity. Location by MSS and three way interaction of location, RM and MSS has no significant effect on all crop phenology. The results are further explained and discussed accordingly in light of available literature.

Days to 50% maturity was significantly ($P<0.05$) affected by interaction of location and manure (Appendix Table 3). It was delayed by 16.8 to 17.8 % as a result of this two way interaction. The longest duration (143 days) was recorded from 100% residue at Mana site and this result was statistically insignificant with the treatment of 75%, 50% and 25% residue at the same location, while the shortest maturity period (122 days) was recorded from control plot at Omonada site (Table 4). Therefore, delay in maturity time of maize was observed at higher rates of residue at all sites. The result might be attributed to the effects of environment on residue decomposition. In addition, location effect was also great in delaying maturity of maize with highest rate of residue at Mana site.

There was a highly significant difference ($p<0.01$) between locations for phenological parameters (Appendix Table 3). Mean maximum number of days (98.3, and 105.2 days, respectively) to attain 50% tasseling and 50% silking was recorded at Mana, while the shortest duration (80.8 and 84.0 days, respectively) for 50% tasseling and 50% silking was recorded at Omonada (Table 5). Furthermore, number of days to 50% maturity was lower at Omonada (125.1 days), while it took 142.4 days to reach 50% physiological maturity at Mana (Table 5). The variation between locations was most probably due to the effect of altitude. Maize tasseling or maturity was delayed with decreasing temperature mainly due to extended vegetative growth at Mana as compared to Omonada location. That means as altitude increases temperature decreases so plants in general and maize in particular has the probability to stay at vegetative stage longer than completing its life cycle.

The main effects of RM was highly significant (P<0.01) for all phenological parameters (Appendix Table 3). It was observed that there was an increment in number of days to 50% tasseling, silking and maturity with increased rates of residue application (Table 5). Increasing residue retention from 0 to 100% delayed the time required to attain 50% tessiling, silking and maturity stage from 87.8 to 90.8, 93.1 to 96.3 and 130.9 to 135.4 days, respectively. Nevertheless, the difference between 75% and 50% residue retention was statistically not significant for number of days to 50% silking. Similarly, there was no significant difference between 25% and 50% residue incorporation for number of days to 50% tasseling and maturity (Table 5). The result was in line with the findings of Thind *et al*., (2007) who reported longer period for 50% anthesis with application of organic manures. Furthermore, prolonged period for phenological events could probably be due to an increase in nutrient availability with application of more amount of plant residue, which favor crop vegitative growth with extended tasseling, silking and maturity period, which is similar with Thind *et al*., (2007) report.

The main effect of MSS was highly significant (P<0.01) for all phenological parameters (Appendix Table 3). There was significant difference in days to 50% tessiling, silking and maturity due to manure treatments. Application of manure delayed days to 50% tasseling, silking, and physiological maturity as compared to the control plot. Grass roofed (GR) manure storage system delayed days to 50% tasseling, silking and maturity (91.1, 96.4 and 135.7 days, respectively) as compared to the control (88.5, 93.6 and 132.2 days), open (89.2, 94.5 and 132.8) and steel roofed (SR) storage system (89.5, 95.4 and 134.2, respectively) (Table 5). In line with this, Djawu (2017) has reported that slight variations among treatments on days to 50% tasseling, silking and maturity are due to the synergistic effects of compost and N to improve soil fertility. Furthermore, prolonged period for phenological events with manure treatments could be due to an increase of nutrient availability, as nutrients are more and more available to plants there is a high probability for crops to stay in vegetative phase with extended tasseling, silking and maturity period.

4.1.2 Crop vegetative growth

Accordingly, the growth of maize was highly significantly influenced by residue management (RM) and manure storage system (MSS). Location was only significantly affected plant height from growth parameters. Location by RM significantly affected only plant height. Interaction of RM by MSS, Location by MSS and their three way interaction were not significantly affected crop growth.

***Plant height*:**

The interaction of location by RM was significantly ($p<0.05$) affected the plant height (Appendix Table 3). The taller plant (368.8 cm) was recorded from the treatment treated with 100% residue incorporation at Omonada, while the shorter (278.9 cm) plant height was obtained from the control plot at Mana site (Table 4), which was might be attributed effects environment on residue decomposition rate and nutrient mineralization. The data recorded from the plot treated with 100 % residue at Mana has no statistical difference with 100%, 75% and 50% residue at Omonada site (Table 4).

The main effect of location proved highly significant difference ($P<0.01$) for plant height at physiological maturity (Appendix table 3). The tallest (352.3 cm) plant was recorded at Omonada (Table 5), which could probably be due to higher availability of plant nutrient at this location. In line with this, Tahir *et al*., (2008) have reported that plant height is genetically as well as environmentally controlled factor; however selection of proper crop cultivar manages the influence of environment.

The result revealed statistically significant ($P=<0.05$) difference between RM treatments for plant height (Appendix Table 3). The highest mean value of plant height was obtained from the treatments that received 100% residue (341.7cm), followed by 75% residue (338.3 cm), while the shortest (296.6 cm) plant was recorded for the control plot. Hence, Plant height consistently increased with increasing rate of residue application (Table 5**).** The probable reason for this increment could be increases in macro and micro nutrient content of the soil, which was recycled from the residue. In addition, residue management improves the physical conditions of the soil by improving soil structure, increasing the water holding capacity, modulating soil aeration and adjusting the soil temperature (Sidhu and Beri, 1989**,** Karmakar *et al*., 2013).

Plant height was highly significantly ($p<0.01$) affected by MSS (Appendix Table 3) with the highest (339.8 cm) mean value recorded for GR manure and the lowest (311.0 cm) for the control plot. Plot treated with SR manure and open manure storage systems did not show significant difference for plant height (Table 5). The longest plant was obtained from the treatments that received the application of GR manure (339.8 cm) followed by the treatments of SR manure (326.8 cm)**,** whereas the shortest (311.0 cm) plant was obtained from the control plot (Table 5). The current result was in agreement with the findings of Tanimu *et al., (*2016) who reported that maize plant height was affected by the various cow dung storage techniques and surface heaped and covered dung treatment resulted in taller plants as compared to pit and open surface heaped dung. On the other hand, it has been reported that application of poultry manure produced the tallest plants when compared with the unfertilized plot (Khan *et al*., 2016). The probable reason for the increment in plant height with application of manure could be associated with increased availability of macro and micro nutrients recycled from the manure maintained under best storage condition. In addition, organic manure improves the physical conditions of the soil by improving soil structure, increasing the water holding capacity, modulating soil aeration and adjusting the soil temperature (Sidhu and Beri, 1989; Karmakar *et al*., 2013).

Total leaf area per plant:

Total leaf area per plant was highly significantly ($p<0.01$) affected by the RM treatments (Appendix Table 4). The highest (6,916.5 cm^2) leaf area per plant was recorded for the plot that received 100% residue, while the lowest (5920.6 cm^2) mean value was recorded for the plot that received zero residues (Table 5). However, there was no significant difference between 50% and 75% or 75% and 100% residue application. Increasing residue rate from 0% to 100% did show consistent increment of leaf area. The higher leaf area per plant could be related with number of leaf per plant due to increased source of plant available nutrients, probably due to increased soil organic matter, increased water and nutrient retention in the soil, and decreased soil density (Stubbs, 2016)**.** The current study was in agreement with the findings of Swanson and Wilhelm., (1996), who reported that leaf area increased with increased residue application.

Total leaf area per plant was highly significantly ($p<0.01$) affected by MSS (Appendix Table 3). The highest (7,058.5 cm^2) leaf area per plant was recorded for the plot that received GR manure, while the lowest (5,931.0 cm^2) mean value was recorded for the plot with no manure

(Table 5). The current study was in agreement with the finding of Khan *et al*., (2016) who reported that application of poultry manure produced higher leaf area per plant when compared with the unfertilized plot. This can be attributed to the higher availability and crop uptake of N with manure treatment (Shah *et al*., 2016). The higher leaf area per plant could also be related with increased number of leaves per plant due to enhanced source of plant available nutrients as a result of increased soil organic matter content and water and nutrient retention in the soil, and decreased soil density (Stubbs, 2016).

Table 4. Mean days to 50% maturity and plant height as influenced by the interaction effects of location and RM at Jimma Southwestern Ethiopia (2019 cropping season).

Location	Residue management (%)	Parameters DM	PHt(cm)
Omonada	0	122.1^{e}	314.3^{c}
	25	123.5^{ed}	344.5^{b}
	50	125.1^{d}	361.4^{a}
	75	127.6^{c}	372.4^{a}
	100	127.3^{c}	368.8^{a}
Mana	0	139.7^{b}	278.9^{e}
	25	143.1^{a}	292.8^{de}
	50	142.7^{a}	297.1^{d}
	75	142.8^{a}	304.1^{cd}
	100	143.4^{a}	314.5^{a}
LSD (5%)		1.9338	16.31

Where, DM= days to 50% maturity; PHt= plant height, NKPR = number of kernels per row, TSW= thousand seed weight, GYPP= grain yield per plan, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level.

Table 5. Mean phonological and growth parameters of maize as influenced by MSS in Jimma area, Southwestern Ethiopia, (2019 cropping season).

	Phenological Parameters			Growth Parameters	
Location	DT	DS	DM	PHt (cm)	LAPP (cm^{2})
Omonada	80.8^{b}	84.0^{b}	125.1^{b}	352.3^{a}	6537.2^{a}
Mana	98.3^{a}	105.2^{a}	142.4^{a}	297.4^{b}	6472.1^{a}
LSD (5%)	0.638	0.699	0.714	6.597	Ns
Residue management (%)					
0	87.8^{c}	93.1^{d}	130.9^{c}	296.6^{d}	5920.6^{d}
25	88.9^{b}	94.5^{c}	133.3^{b}	318.6^{c}	6279.1^{c}
50	89.4^{b}	95.0^{bc}	133.9^{b}	329.3^{b}	6618.2^{b}
75	90.8^{a}	95.9^{ab}	135.2^{a}	338.3^{ab}	6788.9^{ab}
100	90.8^{a}	96.3^{a}	135.4^{a}	341.7^{a}	6916.5^{a}
LSD (5%)	1.001	1.1053	1.12	10.4	206.36
Manure storage system					
Control	88.46^{c}	93.6^{c}	132.2^{c}	311.0^{c}	5930.9^{d}
Open	89.20^{bc}	94.5^{bc}	132.8^{c}	321.9^{b}	6340.5^{c}
SR	89.56^{b}	95.4^{ab}	134.2^{b}	326.8^{b}	6688.6^{b}
GR	91.13^{a}	96.3^{a}	135.7^{a}	339.8^{a}	7058.5^{a}
LSD (5%)	0.9023	0.9886	1.0093	9.3304	184.57

Where, GR= grass roofed, SR=steel roofed, DT= days to 50% tasseling, DS = days to 50%, silking, DM=days to 50% physiological maturity, PHt=plant height, LAPP= leaf area per plant, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level.

4.2. Above Ground Dry Matter Yield

Accordingly, the above ground dry matter yield per plant and per hectare was highly significantly influenced by location, residue management (RM) and manure storage system (MSS). In addition, interaction of RM by MSS significantly affected only dry matter yield per plant. Location by RM, Location by MSS and three way interactions has no significant effect on dry matter yield.

Dry biomass yield per plant:

It was also significantly ($P<0.05$) affected by residue and manure interaction (Appendix Table 4). The higher (292.5 g/plant) dry biomass yield per plant was recorded from the plot received the combined application of 100% residue and GR manure, while the lower (202.4 g) yield recorded from the control plot. The combination of 75% with GR manure, 100% residue with

GR manure and 50% residue with GR manure were statistically not significantly different from each other (Table 6).

Highly significant (P<0.01) differences was observed between the locations for dry biomass yield per plant (Appendix Table 4). The higher value for dry biomass yield per plant was recorded in Omonada district (Table 7).

Statistical analysis of the data revealed that the main effect of RM was highly significant (P<0.01) for dry biomass yield per plant (Appendix Table 4). The treatments which received 100% residue gave higher (293.6 g/plant) dry biomass yield with an increase of 36.0% over the control treatment (215.9 g/plant), and 7.5 % over the 75% residue incorporation (Table 7). This result was in agreement with the findings of Swanson and Wilhelm, (1996) who reported that crop residue application rate had a significant effect on dry aboveground biomass yields of maize**.** The same article reported that dry above ground yield showed a significant increase up to the rate of 100 % residue application. Furthermore, Kouyate *et al*., (2000); Shafi *et al*., (2007); Bakht *et al*., (2009) and Arif *et al*., (2011), have reported that higher maize biomass yields were recorded for the plots applied with residues. According to Arif *et al*., (2011), plots in which no residues were incorporated performed poorly and resulted in least values of these parameters.

The main effect of MSS was highly significant (P<0.01) for dry biomass yield per plant (Appendix Table 4). The result showed that the plot which received GR manure gave higher (292.5 g/plant) dry biomass than the control (222.7g/plant), open (241.7 g/plant) and SR manure (264.7 g/plant) (Table 7). This could be attributed to the higher availability and crop uptake of N in the GR treatment that had probably enhanced the leaf area of maize (Shah *et al*., 2016). This result was in line with the findings of Shah *et al*., (2016) who reported that maize dry matter yield increased with manure application as compared to the unfertilized control. Tanimu *et al.* (2016) concluded, as surface heaped and covered animal manure gave the higher stover yield over than did pit and surface heaped but uncovered manure.

Dry matter yield per hectare:

Highly significant (P<0.01) differences were observed between the locations for above ground dry matter yield per hectare (Appendix Table 4). The highest values for above ground dry matter yield per hectare were recorded in Omonada district (Table 7).

Maize dry matter yield was highly significantly (P<0.01) affected by application of crop residue (Appendix Table 4). The highest biological yield (12,192.5 kg/ha) was produced from the plot that was treated with 100 % residue, whereas, the lowest value (10,653.2 kg/ha) was recorded for the control plot (Table 7). The result showed that there were statistically no significance differences between 75% and 50% as well as between 25% residue application and the control plot. Generally, substantial increases in above ground biological yield with an increase in rate of residue application could be due to significant increases in the amount of N, P and OM in the soil and improvements in other soil chemical and physical properties. This result was in lined with the findings of Swanson and Wilhelm, (1996); Bakht *et al*., (2009) and Raghavendra *et al.,* (2017) who reported that residue application rate has a significant effect on dry aboveground biomass yields of maize**.** The Arif *et al*., (2011) has also reported that above ground dry biomass yield showed a significant increase up to 100 % residue application.

Dry matter yield per hectare highly significantly (P<0.01) affected by application of manure (Appendix Table 4). The results showed that all manure treatments significantly increased above ground dry matter yield of maize. The maximum yield (11,848.6 kg/ha) was obtained from the treatment receiving GR manure, while the lowest (10,761.0 kg/ha) value was recorded for the control plot (Table 7). Manure stored without shade gave the lowest biological yields next to the control plot. This result was in line with the findings of Shah *et al*., (2016) who reported that maize stover yield was affected by the various cow dung storage techniques. Tanimu *et al.,* (2016) have also reported that surface heaped and covered animal manure gave higher maize stover yield over pit and surface heaped but uncovered manure.

Table 6. Dry matter yield per plant as influenced RM by MSS interaction in Jimma area, Southwestern Ethiopia, (2019 cropping season).

Residue management (%)	DBYPP				
	Manure storage systems				
	Control	Open	SR	GR	Mean
0	202.4^{gh}	215.6^{gh}	216.63^{gh}	228.8^{gh}	215.9^{d}
25	219.5^{gh}	221.9^{gh}	229.8^{gh}	274.9^{cde}	236.5^{c}
50	222.5^{gh}	239.6^{fg}	264.2^{def}	305.1^{abc}	257.8^{b}
75	225.6^{gh}	245.02^{efg}	301.03^{abc}	321.1^{a}	273.2^{b}
100	243.5^{efg}	286.2^{bcd}	311.9^{ab}	332.6^{a}	293.6^{a}
Mean	222.7d	241.7c	264.7b	292.5a	
LSD(0.05)	33.846				

Where, MSS= manure storage systems; SR= steel roofed, GR = grass roofed, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level.

Table 7: Dry matter yield of maize as influenced by RM practice in Jimma area, Southwestern Ethiopia, (2019 cropping season).

Location	DBMPP (g)	DMPH (kg)
Omonada	27.0^{a}	11311.5^{a}
Mana	240.8^{b}	11269.2^{b}
LSD (5%)	9.8139	270.7
Residue management (%)		
0	215.9^{d}	10653.2^{c}
25	236.5^{c}	10772.6^{c}
50	257.8^{b}	11208.4^{b}
75	273.2^{b}	11625.2^{b}
100	293.6^{a}	12192.5^{a}
LSD (5%)	15.517	428.05
Manure storage system		
Control	222.7^{d}	10761.0^{b}
Open	241.7^{c}	10761.0^{b}
SR	264.7^{b}	11505.7^{a}
GR	292.5^{a}	11848.6^{a}
LSD (5%)	13.87	282.86

Where, GR= grass roofed, SR=Steel roof, DBMPP=dry matter yield per plant, DMPH= above ground dry matter yield per hectare, LSD: Least significance difference; Means followed by same letter within a column are not significantly different at 5% P level.

4.3. Grain Yield and Yield Components

The yield of a crop is influenced by many factors interacting together and independently. Accordingly, the yield and yield components of maize were highly significantly influenced by location, residue management (RM) and manure storage system (MSS). In addition, Location by RM significantly affected number of kernels per row, thousand seed weight, and yield per plant. Interaction of RM by MSS, Location by MSS and their three way interaction has no significant effect on all the measured response varies. The results are further explained and discussed accordingly in light of available literature.

4.3.1 Yield components

Locations showed highly significant ($P<0.01$) difference for number of ears per plant, cob weight, cob length, number of kernels per cob, number of kernels per row, number of kernel rows per cob, and 1000-seed weight (Appendix Table 3). Higher values of all parameters were recorded at Omonada site (Table 9). This might be attributed to a more conducive environment for maize production in Omonada as compared to Mana district. In general, the variation in number of ears per plant, cob weight, cob length, number of kernels per cob, number of kernels per row, number of kernel rows per cob, and 1000-seed weight could be due to soil fertility differences among the locations. It might be attributed to edaphic factors like soil type and soil pH, and environmental factors like light, temperature and humidity, which are responsible for the variation between locations (Prodhan *et al.*, 2018)**.** It could also be attributed to the higher pre soil available P (22.3%), total N (79.1%), K (1.8%) OM (83.3%) and OC (77.7%) at Omonada over Mana site (Table 15).

Number of ears per plant:

The result showed that number of ears per pant was highly significantly ($P<0.01$) affected by RM (Appendix Table 3). The greater value (1.16) was recorded for application of 100% residue, followed by the plot in which 75% residue (1.1) was applied, whereas the lowest number of ears per plant was recorded for the control plot (Table 9). This result was in agreement with the findings of Sadeghi *et al.*, (2015) who indicated that number of wheat spike per plant significantly increased with increased residue rates. Besides, it has also been reported that crop residue incorporation significantly increased number of maize ears per plant as compared with the residues removed treatment (Arif and Al, 2011). The increase in number of ears per plant with increased of residue application rate which might be due to better vegetative growth of the plants as reflected by increased plant height and higher leaf area per plant. Nevertheless, there was no significant difference between 75% and 50%, as well as between the control and 25% residue application (Table 9).

Number of ears per plant was highly significantly ($P<0.01$) affected by MSS (Appendix Table 3). Higher number of ears per plant (1.16) was recorded for the plot applied with GR manure, followed by SR manure storage system (1.09), while the lowest (1.02) value was recorded for the control plot (Table 9). However, there was no significant difference between open and SR manure storage systems, indicating that loss of nutrients increases as the storage temperature increase due to the steel roof. This finding was in agreement with the results of other studies, indicating that application of cattle manure (Alhrout *et al.*, 2017) and poultry manure (Akongwubel *et al.*, 2012) resulted in a higher ear number per plant than with no fertilizer.

***Cob length*:**

It was highly significantly ($p<0.01$) affected by RM (Appendix Table 3). Cob length is an important yield contributing parameter of maize. It substantially contributes to grain yield of maize by influencing both numbers of grains per cob and grain size. Highest values of (21.7cm) cob length were recorded for the application of 100% residue, while the least (18.7cm) was for the control plot. The mean values of 25% RM and the control were not significantly different (Table 9). This result was in agreement with the findings of Arif *et al.*, (2011) who had reported that plots in which no residues were incorporated performed poorly and resulted in least values of these parameters. The increase in cob length with application of crop residue may be attributed to more photosynthetic activities with increased total leaf area of the plant due to adequate supply of nitrogen which was recycled from residue.

The current study revealed that cob length was highly significantly ($p<0.01$) affected by MSS (Appendix Table 3) with the highest value (22.1 cm) recorded for GR manure, followed by SR manure (20.9 cm), while the least (18.8 cm) was for the control treatment (Table 9). On the other hand, the difference between open manure and the control plot was not significant. The reason for increased cob length with application of manure may be attributed to more photosynthetic activities of the plant on account of adequate supply of nitrogen which was recycled from the manure. This finding was in agreement with the results of some other studies, indicating that ear length was significantly increased by application of cattle manure (Alhrout *et al*., 2017).

Cob weight:

RM practice highly significantly ($p<0.01$) affected cob weight (Appendix Table 4). Cob weight consistently increased with increased rate of application of crop residues. The highest cob weight was recorded for 100% residue (297.7g), which was statistically similar with the value, resulted from 75% residue application, while the lowest (234.9 g) value was recorded for the control plot (Table 9). In agreement with the results of this study, Arif *et al*., (2011) have found poorly performed and least values of cob weight for residues untreated plot. This may be due to the effect of residue recycling that showed improvements in physical, chemical and biological health of the soil with significant increases in the quantity and availability of plant nutrients (Bisen and Rahangdale, 2017).

Cob weight was highly significantly ($p<0.01$) affected by MSS (Appendix Table 3), where GR manure storage method gave the highest value (295.8 g), while the lowest (242.4 g) was recorded for the control plot. However, the difference between the control plot and open manure storage system or between SR manure and open manure was not significant (Table 9).

Number of kernel rows per cob:

The main effect of RM practice was high significant ($P<0.01$) for number of kernel rows per cob (Appendix Table 4). The highest (14.05) number of rows per cob was recorded for incorporation of 100% residue, which was not statistically different from 75% residue, whereas, the lowest (12.4) value was recorded for the control plot. On the other hand, the difference between 50% and 75% or between 25% and 50% residue incorporation was not significant (Table 9). The increase in number of kernel rows per cob could probably be due to improved soil health and physico-chemical properties of the soil, leading to an increase in both microbial activity and availability of macro and micro nutrients (Seenan *et al*., 2018).

It was highly significantly ($P<0.01$) affected by MSS (Appendix Table 4). The highest (14.1) number of rows per cob was recorded for application of GR manure, whereas the lowest

(12.4) value was recorded for the control plot (Table 9). There was no statistically significant difference between the mean values of kernel rows per cob for open manure and the control plot. The increase in number of kernel rows per cob could be due to improved soil health and physico-chemical properties of the soil and, thus, enhanced microbial activity and availability of macro and micro nutrients (Seenan *et al.*, 2018)**.**

Number of kernels per row:

Number of kernels per row was significantly ($p<0.05$) affected by the interaction of locations by residue (Appendix Table 4). The higher (36.8 g) number of kernels per row was recorded from the plot that treated with 100% residue at Omonada site, while the smallest (24.9) number of kernels per row was recorded from control plot at Mana site (Table 8). The result that obtained from 100%, 75% and 50% residue at Omonada was at par with the result for the 100% residue at Mana site. This might be attributed to the effects of temperature on residue decomposition process and nutrient release from it. Increase in soil temperature increases the soil nitrogen mineralization rates through the increase in microbial activity and increase in the decomposition of organic matter in the soil (Yan and Hangwen, 2014).

The main effects of RM practice was highly significant ($P<0.01$) for number of kernels per row (Appendix Table 4). Retaining 100% residue gave the maximum (36.02) numbers of grains per row, while the minimum (27.6) value was recorded for 0% residue retention (Table 9). On the other hand, there was no statistical difference between 50% and 75% residue treatments.

Number of kernels per row was highly significantly affected by MSS (Appendix Table 3). The maximum (32.8) number of grains per row was obtained from the plot treated with GR manure, while the lowest value (28.3) was from the control plot (Table 9). The increase in number of grains per row with GR manure may be due to more photosynthetic activities with increased supply of plant nutrients saved from volatilization and leaching.

Number of kernels per cob:

RM practice was highly significantly ($P<0.01$) affected number of kernels per cob (Appendix Table 4). The number of grains per cob has a direct influence on the grain yield of maize (Begam *et al.*, 2018). The highest (342.3) mean kernel number per cob was counted for plots treated with 100% residue, followed by 324.1 for plot treated with 75% residue incorporation; whereas, the lowest value (272.8) was recorded for the control plot. However, there was no significant difference between 100% and 75% residue, as well as 75% and 50% residue retention (Table 9). The increase in number of grains per cob with increasing rate of crop residue application might be due to increased availability of N, which is required for better growth and development of plants. In line with this, Sadeghi *et al.,* (2015) reported that number of spikes per plant significantly increased with increased residue application rates. Similarly, Arif *et al*., (2011) have reported that plots in which no residues were incorporated performed poorly and resulted in least values of grain per ears.

Number of kernels per cob of maize was highly significantly ($P<0.01$) affected by MSS (Appendix Table 3). It was observed that maximum (336.6) number of grains per cob was obtained from GR manure application, followed by SR (317.0) manure. Whereas, the lowest (280.9) value was recorded for the control plot. The difference between open and SR manure storage system was not significant for number of kernels per cob (Table 9). This result was in line with the findings of Shah *et al*., (2015) who reported that application of cow dung produced the highest number of kernels per cob, while the lowest number of grains per cob was resulted from the plots with no treatment. The increase in number of grains per cob with manure application might be due to increased availability of N at proper time, which is required for better growth and development of plants.

Thousand Seed weight:

The thousand seed weight was significantly ($p<0.05$) affected by interaction of location by residue (Appendix Table 4). The highest thousand seed weight (334.1 g) was recorded for the 100% residue at Omonada site, while the lowest was recorded for the control plot at Mana site. The result obtained from 100% and 75% residue has statistically no significance difference at Omonada, however they (100% and 75%) were showed significance difference at Mana site (Table 8). This might be also attributed to the effects of environment on residue decomposition process. Soils with low temperature have low availability of phosphorus because the release of phosphorus from organic material is hindered by low temperature (Gahoonia *et al*., 2003).

The result of the present study showed that variations among the RM treatments were highly significant (P<0.01) for thousand seed weight (Appendix Table 4). This variation might have occurred due to the presence of differences in seed size as a result of different treatments, as thousand seed weight increases with increasing seed size. The highest 1000 seed weight (288.2 g) was recorded for application of 100% residue, while the lowest value (239.2g) was recorded for the control plot. On the other hands, 50% and 25% residue application did not show significant difference for 1000 seed weight (Table 9). This result was in agreement with the findings of Sadeghi *et al.,* (2015) who reported that 1000-seed weight of wheat significantly increased with increasing application rates of crop residue. Similarly, Kamkar *et al.,* (2014) have reported that maize residue applications resulted in the highest 1000-seed weight compared with the control treatments. This might be due to the fact that crop residues contain significant quantities of plant nutrients and, thus, their judicious application will have a positive effect on soil nutrient management (Minz, 2018).

Thousand seed weights was found to be highly significantly (P<0.01) affected by the main effect of MSS (Appendix Table 4), where the highest (287.4 g) value was recorded for GR manure, which may be attributed to higher N supply while the lowest (240.2 g) was recorded for the control plot (Table 9). The current result was in agreement with the findings of Alhrout *et al*., (2017) who reported that seed weight was higher when manure was added to the soil compared with the control plot. It has also been reported that thousand seed weight of maize significantly increased with poultry manure application as compared to the unfertilized plot (Akongwubel *et al*., 2012). Since N has considerable effects on grain filling, it can be concluded that the release of N from animal manure has prolonged the supply of N during grain filling period and resulted in an increase in thousand seed weight. The maximum thousand seed weight with manure application might be due to increased availability of N and other nutrients while the minimum value for the untreated plots could be attributed to deficiency of macro- nutrients throughout the plant life especially at the time of flowering and seed setting (Amos *et al*., 2015).

Table 8. Kernel number per row, 100-seed weight and grain yield per plant as influenced by the interaction effects of location and RM at Jimma Southwestern Ethiopia, (2019 cropping season).

		Parameters	
Location	Residue management (%)	NKPR	TSW (g)
Omonada	0	30.2^{c}	270.6^{c}
	25	31.3^{bc}	296.5^{b}
	50	34.1^{ab}	314.2^{ab}
	75	35.5^{a}	325.2^{a}
	100	36.8^{a}	334.1^{a}
Mana	0	24.9^{d}	207.8^{e}
	25	28.3^{cd}	218.4^{e}
	50	30.1^{c}	221.3^{de}
	75	30.9^{bc}	222.8^{de}
	100	35.2^{a}	242.1^{d}
LSD (5%)		3.7429	23.344

Where, DM= days to 50% maturity; PHt= plant height, NKPR = number of kernels per row, TSW= thousand seed weight, GYPP= grain yield per plan, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level.

Table 9. Mean yield and yield components of maize as influenced by Location, Residue and RM in Jimma area, Southwestern Ethiopia, (2019 cropping season).

Location	Yield components						
	EPP	CL (cm)	CW (g)	NKRPC	NKPC	NKPR	TSW (g)
Omonada	1.11^{a}	22.19^{a}	309.7^{a}	13.8^{a}	320.02^{a}	33.6^{a}	308.1^{a}
Mana	1.05^{b}	18.5^{b}	229.2^{b}	12.6^{b}	297.6^{b}	29.89^{b}	222.5^{b}
LSD (5%)	0.0339	0.7832	13.2	0.4801	12.325	1.256	8.52
Residue management (%)							
0	1.02^{c}	18.7^{d}	234.9^{d}	12.4^{c}	272.8^{d}	27.6^{d}	239.2^{d}
25	1.06^{bc}	19.6^{cd}	253.4^{cd}	13.0^{bc}	399.0^{c}	29.8^{c}	257.45^{c}
50	1.07^{b}	20.3^{bc}	273.4^{bc}	13.2^{b}	306.1^{bc}	32.1^{b}	267.75^{bc}
75	1.10^{b}	21.4^{ab}	287.8^{ab}	13.5^{ab}	324.1^{ab}	33.2^{b}	274.02^{b}
100	1.16^{a}	21.7^{a}	297.7^{a}	14.1^{a}	342.3^{a}	36.0^{a}	288.17^{a}
LSD (5%)	0.0536	1.24	20.927	0.7592	19.488	1.986	13.471
Manure storage system							
Control	1.02^{c}	18.7^{c}	242.3^{c}	12.3^{c}	280.9^{c}	28.3^{d}	240.2^{d}
Open	1.04^{c}	19.6^{c}	262.8^{b}	12.9^{bc}	300.9^{b}	30.6^{c}	260.4^{c}
SR	1.09^{b}	20.8^{b}	276.8^{b}	13.5^{ab}	316.9^{b}	32.7^{b}	273.2^{b}
GR	1.16^{a}	22.1^{a}	295.8^{a}	14.1^{a}	336.6^{a}	35.2^{a}	287.4^{a}
LSD (5%)	0.0479	1.108	18.72	0.6479	17.43	1.776	12.049

Where, GR= grass roofed, SR=steel roofed, EPP = ear per plant**,** CL= cob length, CW = cob weight, NKRPC= number of kernel rows per cob, NKPC= number of kernels per cob, NKPR=number of kernels per row, TSW = thousand seed weight, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level.

4.3.2 Grain yield

Highly significant (P<0.01) differences were observed between the treatments for grain yield per plant and grain yield per hectare due to main effects of location (Appendix Table 4). The highest values for grain yield per plant and grain yield per hectare were recorded from Omonada district (Table 11). The result might be due to more acidic soil and less available phosphorus, total N and OMC at Mana when compared to Omonada location. At pH below 5, aluminum is soluble in water and becomes the dominant ion in the soil solution. In acid soils, excess aluminum primarily injures the root apex and inhibits root elongation. The poor root growth leads to reduced water and nutrient uptake, and consequently crops grown on acid soils are confronted with poor nutrients and water availability. The net effect of which is reduced growth and yield of crops (Wang *et al*., 2006).

Grain yield per plant:
It was significantly (p<0.05) affected by the interaction of location by residue (Appendix Table 4). The highest (267.1 g/plant) grain yield per plant was recorded for 100% residue at Omonada location, while the smallest grain yield per plant was recorded for the control plot at Mana site. The result that obtained for 50%, 25% and control plot has no significance difference at Mana, but the same treatment (50%, 25% and Control) has statistically not the same at Omonada site (Table 10). This might be attributed to the effects of location on residue decomposition rate, which can determine the amounts of available nutrient. Crop residue removal can increase, decrease, or have no effect on crop yields depending on site-specific conditions (Taylor, 2009).

RM practice was highly significantly (P<0.01) affected the grain yield per plant (Appendix Table 4). Yield per plant increased considerably as the rate of residue application increased. The maximum grain yield (235.8 g) was obtained from the plot treated with 100 % residue, while the minimum 187.0 g was recorded for the control plot (Table 11). In lined with this, Wilhelm *et al*., (2004); Mupangwa *et al*., (2015) and Sadeghi *et al*., (2015) have concluded that grain yield increased with an increase in residue level. Arif *et al*., (2011) have also reported that grain yield had shown a significant increase with increasing residue application rate of up to 100 %. This may be due to increased total N and organic carbon levels in the soil which contribute to improvement in soil quality and productivity, and increased efficiency of carbon sequestration into the soil (Halvorson *et al*., 1999).

It was observed that MSS highly significantly ($P<0.01$) affected grain yield per plant (Appendix Table 4), where application of GR manure produced the maximum (235.1g/plant); while the minimum (194.0 g/plant) value was recorded for the control plot (Table 11). The increase in grain yield with manure application could be due to extension in the growth period of maize, and increases in weight of individual grains and number of grains per cob (Taylor, 2010). In line with this, Lekasi *et al.,* (2012) reported that maize grain yields were greater for manure generated from improved management practices compared with that generated from farmer's extensive manure management practices. This may be due to timely availability of more net N relative to plant N demand with GR manure application.

Grain yield per hectare:

Crop RM practice was highly significantly ($P<0.01$) affected grain yield per hectare (Appendix Table 4). Yield increased considerably as the rate of residue application increased. Among the residue treatments, 100 % incorporation gave the maximum grain yield (6,703.2 kg ha^{-1}), while the minimum (5,790.0 kg ha^{-1}) was recorded for the control plot. The data recorded for 100% residue was statistically at par with 75% residue incorporation. Similarly, 25% residue retention was statistically at par with the control plot. In general, grain yield per hectare increased by 2.02%, 11.01%, 14.7% and 15.7% over the control for 25%, 50%, 75% and 100% RM practice, respectively (Table 11). The present findings were in agreement with the results obtained by Mbah and Nneji (2011); Shittu and Fasina (2006) and Raghavendra *et al.,* (2016), who reported that crop yield was significantly influenced by residue management. The result of the present study was also in line with the findings of Taylora, (2009) who revealed that corn grain yield was reduced by 20% with 50% of stover removal and by 30% with 100% stover removal. According to Srivastava *et al*., (2019), where residue was not incorporated in the field, maize yield declined by 21.9%. Furthermore, it has been reported that grain yield showed a significant increase up to a residue rate of 100 % (Arif *et al.,* 2011). Wilhelm, *et.al.,* (1986) have also reported that residue removal reduces grain yields by amounts equal to 10% of the quantity of residue removed.

The effect of MSS was highly significant (P<0.01) for grain yield per hectare (Appendix Table 4). The result showed that the highest (6,887 kg/ha) maize grain yield per hectare was produced by the plot that received GR manure; whereas the minimum value (5,738.5 kg/ha) was recorded for the control plot (Table 11). It was observed that grain yield of maize consistently increased as the leaf area per plant and plant height increased and, open, SR and GR manure treatments increased mean grain yield per hectare by 6.4%, 12.3%, and 20.0%, respectively, over the control plot. The increase in grain yield due to application of manure might be attributed to extension in the growth period of maize, and increases in individual grain weight and number of grains per cob as a result of increased availability of both macro and micro nutrients recycled from the manure treatments (Rufino *et al*., 2007; Markewich *et al*., 2010; Tittonell *et al*., 2010; FAO 2018). The present findings were in agreement with the results obtained by Lekasi *et al*., (2012) who concluded that manures stored under improved management conditions gave 18% higher maize grain yields over the grain yield for farmer's manure management practices (Shah et al., 2016).

Improvement in maize yield and related attributes due to incorporation of different organic nutrient sources can be attributed to balanced carbon nitrogen ratio, more organic matter buildup, better root proliferation, sustainable nutrient availability, and accelerated transport and higher concentration of plant nutrients, leading to better assimilation of photosynthetates and their efficient translocation from source to sink, and an improvement in overall yield performance (Lone *et al*., 2013).

Table 10. Grain yield per plant as influenced by the interaction effects of location and RM at Jimma Southwestern Ethiopia, (2019 cropping season).

Location	Residue management (%)	Parameters
		GYPP(g)
Omonada	0	196.9^{de}
	25	225.4^{bc}
	50	231.7^{b}
	75	254.2^{a}
	100	267.1^{a}
Mana	0	177.0^{e}
	25	183.1^{de}
	50	191.2^{de}
	75	200.4^{d}
	100	204.6^{cd}
LSD (5%)		21.61

Where, GYPP= grain yield per plan, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level.

Table 11. Yield and yield components of maize as influenced by Location, RM and MSS at Jimma Southwestern Ethiopia, (2019 cropping season).

Location	Parameters	
	GYPP (g)	GYPH (kg)
Omonada	235.1^{a}	6975.8^{a}
Mana	191.3^{b}	5621.5^{b}
LSD(%)	8.073	156.52
Residue management (%)		
0	187.0^{c}	5790.0c
25	204..2^{b}	5906.8c
50	211.5^{b}	6427.2^{b}
75	227.3^{a}	6643.7^{ab}
100	235.8^{a}	6703.2^{a}
LSD (5%)	12.765	247.48
Manure storage system		
Control	194.0^{d}	5738.5^{d}
Open	205.8^{c}	6105.4^{c}
SR	217.8^{b}	6445.5^{b}
GR	235.1^{a}	6887.0^{a}
LSD (5%)	11.418	221.35

Where, GR= grass roofed,SR=Steel roof, GYPP= grain yield per plant, GYPH = grain yield per hectare, LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level

4.4 Harvest Index (HI)

Harvest index was not significantly ($p>0.05$) affected by any interactions of location, residue and MSS. As well as it was also not affected ($p>0.05$) by the main effects of RM. It was highly significantly ($P<0.01$) affected by location and MSS (Appendix Table 4) with respective values of 53.3%, 55.3%, 56.1% and 58.5% for control, open, SR and GR manure application (Table 12). The result was in line with the findings of Alhrout *et al*., (2017) who reported that addition of poultry and farmyard manures increased HI over the control plot. Harvest index was low when total biomass (grain plus stover) yield was low, which was similar to the findings of Wilhelm *et al*., (2004).

Table 12. Yield and yield components of maize as influenced by MSS at Jimma Southwestern Ethiopia, (2019 cropping season).

Location	Parameters HI (%)
Omonada	61.73^{a}
Mana	49.9^{b}
LSD (5%)	1.9236
Manure storage system	
Control	53.3^{c}
Open	55.3^{bc}
SR	56.1^{ab}
GR	58.5^{a}
LSD (5%)	2.7204

Where, GR= grass roofed,SR=Steel roof, HI= Harvest index LSD: Least significance difference; Means followed by same letter(s) within a column are not significantly different at 5% P level

4.5 Correlation of Some Yield and Yield Related Parameters

Pair wise correlation analysis indicated strong and positive relationship between parameters. Accordingly, there was a positive and significant ($p=<0.05$) correlation between plant height and leaf area per plant (0.48** and 0.62**), cob length (0.60** and 0.42*), cob weight (0.29* and 0.50**), number of ears per plant (0.48** and 0.37*), number of kernels row cob^{-1} (0.49** and 0.37*), kernel number per cob (0.59** and 0.37*), kernel number row^{-1} (65** and 0.43*), thousand seed weight (0.58** and 0.44*), grain yield per plant (0.59** and 0.34**), grain yield per hectare (0.68** and 0.45*), dry biomass yield per plant (0.62** and 0.38*), and above ground dry biomass yield per hectare (0.56** and 0.38*) at Omonada and

Mana sites, respectively, indicating that as plant height increases most parameters also increase (Table 13 and 14). The current result was in agreement with the findings of Kareem *et al., (*2017) who reported the presence of strong and significant relationship between the final yield and growth parameters. Therefore, it can inferred that there was a positive relationship between leaf area and grain yield, indicating that leaf area (photosynthetic area) determines the level of assimilate production and accumulation.

Maize grain yield was significantly ($P=<0.05$) and positively correlated with various yield attributes. The r^2 values of yield attributes like ear per plant (0.62** and 0.53**), number of kernels per cob (0.56** and 0.48*), number of kernel rows per cob (0.50** and 0.41*), number of kernels per row (0.67** and 0.60**), cob length (0.48** and 0.55**), TSW (0.61** and 0.40*), yield per plant (0.57** and 0.53**) and cob weight (0.56** and 0.35*) in Mana and Omonada districts, respectively, indicated the existence of close association between these parameters and grain yield per ha. Generally, yield components were highly correlated with grain yield of maize (Table 13 and 14). Similar results have been reported by Milander, (2015) and Raghavendra *et al.* (2017)

Table 13: Pearson correlation analysis for growth, yield and yield components of Maize in Mana District, Jimma Zone, Southwestern Ethiopia

	PHt	LAPP	CL	CW	EPP	KRPC	KNPC	KNPR	TSW	GYPP	GYPH	HI	DBMPP	ABYPH
PHt	1.000													
LAPP	0.48**	1.000												
CL	0.60**	0.57**	1.000											
CW	0.29*	0.55**	0.41*	1.000										
EPP	0.37*	0.55*	0.28*	0.35*	1.000									
KRPC	0.37*	0.55**	0.40*	0.47**	0.38**	1.000								
KNPC	0.37*	0.60**	0.47*	0.45*	0.47*	0.44*	1.000							
KNPR	0.43*	0.64**	0.48**	0.58**	0.50**	0.51**	0.62**	1.000						
TSW	0.44*	0.57**	0.42*	0.33*	0.44*	0.28*	0.55**	0.37*	1.000					
GYPP	0.34*	0.68**	0.55**	0.64**	0.41*	0.54	0.61**	0.56**	0.58**	1.000				
GYPH	0.45*	0.56**	0.41*	0.35*	0.62**	0.41*	0.48*	0.60**	0.40*	0.53**	1.000			
HI	0.24^{ns}	0.15^{ns}	0.15^{ns}	0.13^{ns}	0.34*	0.15^{ns}	0.24^{ns}	0.27^{ns}	0.08^{ns}	0.13^{ns}	0.56**	1.000		
DBMPP	0.38*	0.61**	0.43*	0.39*	0.51**	0.48**	0.38*	0.59*	0.42**	0.66**	0.64**	0.05^{ns}	1.000	
ABYPH	0.38*	0.68**	0.45*	0.36*	0.52**	0.41*	0.43*	0.57**	0.51**	0.64**	0.58**	-0.090^{ns}	0.90**	1.000

(**)= highly significant, (*)= significant, (ns)= none significant, PHt= plant height, LAPP= leaf area plant^{-1}, CL= Cob length, CW = Cob weight, EPP= Ear plant^{-1}, KRPC= Kernel row cob^{-1}, KNPC= kernel numbers cob^{-1}, KNPR= Kernels numbers row^{-1}, TSW= Thousand seed weight , GYPP= Grain yield plant^{-1}, GYPH= Grain yield hectare^{-1}, HI= Harvest index, DBMYPP = Dry biomass yield plant^{-1}, ABYPH= Above ground biomass yield hectare^{-1}.

Table 14: Pearson correlation analysis for growth, yield and yield components of Maize in Omonada District, Jimma Zone, Southwestern Ethiopia

	PHt	LAPP	CL	CW	EPP	KRPC	KNPC	KNPR	TSW	GYPP	GYPH	HI	DBMPP	ABYPH
PHt	1.000													
LAPP	0.62**	1.000												
CL	0.42*	0.53**	1.000											
CW	0.50**	0.546**	0.50**	1.000										
EPP	0.48**	0.42*	0.22^{ns}	0.44*	1.000									
KRPC	0.49**	0.53**	0.36*	0.47*	0.40*	1.000								
KNPC	0.59**	0.57**	0.47**	0.31*	0.37*	0.36*	1.000							
KNPR	0.65**	0.63**	0.53**	0.61**	0.49**	0.49**	0.46*	1.000						
TSW	0.58**	0.61**	0.47**	0.60**	0.34*	0.54**	0.45*	0.54**	1.000					
GYPP	0.59**	0.55**	0.56**	0.48*	0.39*	0.45*	0.57**	0.41*	0.65**	1.000				
GYPH	0.68**	0.67**	0.48**	0.56**	0.53**	0.50**	0.56**	0.67**	0.61**	0.57**	1.000			
HI	0.30*	0.25^{ns}	0.15^{ns}	0.36*	0.46*	0.26*	0.13^{ns}	0.38*	0.22^{ns}	0.071^{ns}	0.59**	1.000		
DBMPP	0.62**	0.62**	0.48**	0.51**	0.55**	0.45*	0.66*	0.67*	0.66**	0.53**	0.65**	0.24^{ns}	1.000	
ABYPH	0.56**	0.59**	0.46*	0.34*	0.22^{ns}	0.37*	0.57**	0.47*	0.54**	0.64**	0.67**	-0.19^{ns}	0.77**	1.000

(**)= highly significant, (*)= significant, (ns)= none significant, PHt= plant height, LAPP= leaf area plant^{-1}, CL= Cob length, CW = Cob weight, EPP= Ear plant^{-1}, KRPC= Kernel row cob^{-1}, KNPC= kernel numbers cob^{-1}, KNPR= Kernels numbers row^{-1}, TSW= Thousand seed weight , GYPP= Grain yield plant^{-1}, GYPH= Grain yield hectare^{-1}, HI= Harvest index, DBMYPP = Dry biomass yield plant^{-1}, ABYPH= Above ground biomass yield hectare^{-1}.

4.6 Post Harvest Soil Analysis

The analysis of soil samples after harvest showed an increased level of P availability, soil pH, CEC, total nitrogen, K, EC, OM and OC as compared to the pre-sowing results (Table 15). In line with this, it has been reported that recycling crop residue (CR) and animal manure sustains and restores soil fertility in terms of available nutrients and major physical and chemical characteristics of the soil (Patra and Anwar, 2000).

4.6.1 Soil pH

The soil pH slightly increased with application of RM and MSS probably due to release of different organic acids and CO_2 during decomposition. Similar results have been reported by Bulluck *et al*., (2002). Among the different treatments, combination of 100% residue with GR manure showed higher pH values (5.93 at Omonada and 5.66 at Mana site) and brought about a positive effect on the availability of plant nutrients (Appendix Table 1). In general, soil pH after harvest increased by 12.7 % and 15.5% at Omonada and Mana sites, respectively, as compared to the pre-sowing results (Table 15). In contrary, Butterly *et al*., (2011) have demonstrated that the retention of organic manure can affect soil pH since the direction of change in soil pH is related to the chemical composition of the residue and soil properties. Moreover, soil properties that affect rate of residue decomposition such as texture, moisture content, temperature, available N, SOC and initial pH control the effect of residue on soil pH (Jarvis *et al*., 1996). Changes in pH from crop residue addition are correlated with the concentration of organic anions in the residue and the nitrogen content of the residue (Tang and Yu, 1999; Butterly *et al*., 2011). The major causes of soil pH increase when plant residues are returned to soil are (1) decarboxylation of organic anions causing consumption of protons and release of OH^-, (2) specific adsorption of organic molecules produced during decomposition onto Al and Fe hydrous oxides with the consequent release of OH^- ions, and (3) high concentration of excess base cations such as Ca, Mg, Na (or ash alkalinity) in plants (Haynes and Mokolobate 2001).

4.6.2 Soil total nitrogen

There was an increasing trend in soil N content (from 0.12 to 0.23% at Omonada and from 0.067 to 0.12% at Mana site) with application of crop residue and manure as compared to the initial value. Maximum total N (0.29%) content after harvest was observed for application of 100% and 75% CR in combination with GR manure, followed by 50% crop residue with GR manure (Appendix Table 2). According to Minase *et al.*, (2015), N values were higher for open stored manure than for covered treatments. The average soil N content after harvest increased by 91.6 % and 79.1 % at Omonada and Mana sites, respectively, as compared to the pre-sowing results (Table 15). In agreement with this result, it has been reported that total nitrogen in soil increased by 86% with the incorporation of sunflower residues at a rate of 6 ton ha^{-1} as compared with the control (Ullah *et al.*, 2018). Sylvester-Bradley, (1993) has also reported that organic materials improved soil fertility status and other properties depending upon the nature of added material and, thus, produced different effects on soil N status depending upon their composition, stage of decomposition and environmental factors (Hadas and Portnoy, 1997; Cooperband *et al.*, 2002). It has also been reported that soils which received organic matter inputs on a regular basis generally had greater labile carbon pools and greater N supplying ability than soils which received only mineral amendments (Gunapala and Scow, 1998).

4.6.3 Available soil phosphorus

The amount of available phosphorus (P) in the soil was relatively higher for 100% residue and GR manure applied plots compared to the control ones (Appendix Table 2) and its average value after harvest increased by 20% and 26.8% at Omonada and Mana, respectively, as compared to the pre-sowing results (Table 15). The probable reason for the increase in available P might be the binding of P-fixing agents (Ca, Fe and Al) by OM that ultimately decreased P precipitation and increased P availability (Braschi et *al.,* 2003).

4.6.4 Available soil potassium

Available potassium (K) content of the soil in the residue and manure amended plots slightly increased (from 8.4 to10.3 cmol (+) kg^{-1} at Omonada and from 8.25 to 8.7 cmol (+) kg^{-1} at Mana sites) compared to the pre-sowing results (Table 15). Among the different treatments, 100%

residue and GR manure treatment showed the highest values (Appendix Table 2). Similar results have been reported by Bulluck *et al.* (2002) and Edmeades (2003), indicating that increased K availability with organic amendments could be due to the release of K from organic materials and lower fixation and leaching losses (Chen *et al*., 1996; Barker 1997; Eklind *et al.,* 1998).

4.6.5 Organic matter content

Soil organic matter content in the plots treated with residue and animal manure was relatively higher compared with the pre-sowing result. Moreover, among different treatments, 100% residue and GR manure treatment showed the highest (5.7% and 3.6% Omonada and Mana, respectively) increase in soil organic matter content (Appendix Table 2). The average value after harvest increased by 102.2 % and 132.5 % at Omonada and Mana, respectively, as compared to the pre-sowing results (Table 15). Similar results have been reported by Ayoola and Makinde (2009).

4.6.6 Organic carbon

Organic carbon content of the experimental soil increased from 1.28 and 0.72 to 2.6 and 1.67 at Omonada and Mana, respectively, which is also still categorized in the low range at Mana (Jones, 2003). The average value after harvest increased by 103.1 % and 132.0 % at Omonada and Mana, respectively, as compared to pre-sowing results (Table 15). An increase in organic carbon content due to incorporation of residues has also been reported by Dormaar *et al*. (1979) and Biederbeck *et al*., (1980).

5.6.7 Cation exchange capacity

The RM and MSS treatments increased cation exchange capacity of the experimental soil from 17.94 to 22.32 cmol (+) kg^{-1} and 17.98 to 21.2 cmol (+) kg^{-1} compared to pre-sowing results at Omonada and Mana, respectively. The average value of CEC after harvest increased by 24.4 % and 18.0 % at Omonada and Mana, respectively, as compared to the pre-sowing results (Table 15).

Table 15. Pre-sowing and Post-harvest soil chemical properties (Av. Phosphorus (Av.P), soil pH, % organic carbon (OC), % total nitrogen (TN), potassium (K), organic matter (OM) and Cation Exchange Capacity (CEC)) of the experimental sites in 2019 cropping season.

Soil Parameters	Omonada		
	Pre-sowing analysis results	Post-harvest soil analysis	Descriptions
Av.P (ppm)	10.5	12.6	from moderate to moderate
pH	5.26	5.93	from strongly acidic to moderately acidic
% OC	1.28	2.6	From low to moderate
% TN	0.13	0.22	from moderate to moderate
K (mg/kg)	8.40	10.3	
OM(%)	2.2	4.45	From low to moderate
CEC (cmol (+) kg1)	17.94	22.32	from moderate to high
	Mana		
Av.P (ppm)	8.58	10.88	from low to moderate
pH	4.9	5.66	from strongly acidic to moderately acidic
% OC	0.72	1.67	From very low to low
% TN	0.065	0.12	From moderate to moderate
K (mg/kg)	8.25	8.70	
OM (%)	1.2	2.79	From very low to moderate
CEC (cmol (+) kg1)	17.98	21.2	from moderate to moderate

4.7. Partial Budget Analysis

Economic analysis for the main RM effect indicated that the highest (42,796.9 Birr/ha) net benefit was recorded for 100% residue with MRR of 19.0%, followed by 75% residue and 50% residue which gave net benefits of 42,732.81 Birr/ha and 40,765.19 Birr/ha with MRR of 583.0% and 690.8%, respectively (Table 17). More or less similar net benefits were recorded for 100% and 75% residue, despite the higher (583.0%) MRR with higher (42,732.81 Birr/ha) net benefit was obtained from the 75% residue application. Economic analysis for the main MSS effect showed that the highest (42,319.19 Birr/ha) net benefit was recorded for GR with MRR of 549.2%, followed by SR which gave net benefits of 41,587.44 Birr/ha with negative MRR (Table 18).

Combined application of RM and MSS, as indicated in Table 16, gave the highest average net benefit (44,882.1 Birr $ha^{-1)}$ with the highest marginal rate of return (MRR) (721.6 %), which was obtained from the combined application of 75% residue with GR manure. However, the lowest net benefit (35,110.8 Birr per hectare) was obtained from the control treatment maintained without application of both residue and manures (Table 16). The costs in the combined application of residue and manure were around 50.0 % to 458.7% higher than for the control treatment.

Generally, application of both RM and GR manure for the production of maize in was economically feasible in Omonada and Mana districts of Southwestern Ethiopia. Conversely, those combinations which showed negative MRR are not recommended for use by the farming communities in the study areas. In general, application of 75% RM with GR manure gave the highest (44,882.1 Birr/ha) net benefit with MRR of 721.6 % which was economically sound/feasible and could be recommended for maize production in the study areas as well as in similar agro-ecologies

Table 16: Economic analysis for effects of combined application of residue management (RM) and manure storage systems (MSS)

Residue	Manure	AY (KG/ha)	TVC (ETB/ha)	GFB (ETB/ha)	NB (ETB/ha)	MRR (%)
0%	Control	4,828.1	1,100.0	36,210.8	35,110.8	0.0
0%	Open	5,244.2	2,550.0	39,331.4	36,781.4	115.2
0%	SR	5,206.6	4,230.0	39,049.4	34,819.4	-116.8
0%	GR	5,564.7	3,950.0	41,735.4	37,785.4	-1059.3
25%	Control	4,989.1	1,649.0	37,418.0	35,769.0	119.9
25%	Open	5,251.7	3,099.0	39,387.9	36,288.9	-89.7
25%	SR	5,351.4	4,779.0	40,135.5	35,356.5	97.8
25%	GR	5,672.5	4,499.0	42,543.5	38,044.5	47.2
50%	Control	5,257.8	2,198.0	39,433.4	37,235.4	267.1
50%	Open	5,519.9	3,648.0	41,399.3	37,751.3	266.4
50%	SR	5,781.2	5,328.0	43,359.3	38,031.3	487.2
50%	GR	6,129.1	5,048.0	45,968.4	40,920.4	523.9
75%	Control	5,283.0	2,747.0	39,622.2	36,875.2	-65.6
75%	Open	5,618.3	4,197.0	42,137.6	37,940.6	34.5
75%	SR	6,285.6	5,877.0	47,142.2	41,265.2	589.1
75%	GR	6,730.5	5,597.0	50,479.1	44,882.1	721.6
100%	Control	5,525.5	3,296.0	41,441.3	38,145.3	231.4
100%	Open	5,840.1	4,746.0	43,800.4	39,054.4	202.9
100%	SR	6,139.8	6,426.0	46,048.6	39,622.6	-299.2
100%	GR	6,626.3	6,146.0	49,697.3	43,551.3	-242.4

Where, AY: adjusted yield, TVC: total variable cost, GFB: gross field benefit, NB: net benefit and MRR: marginal rate of return

Table 17: Economic analysis for effects of residue management (RM)

Residue treatments	Residue management/Removal cost (Birr/ha)	Residue chopping and incorporation cost (Birr/ha)	TVC (Birr/ha)	AGY (kg/ha)	GFB (Birr/ha)	NB (birr/ha)	MRR (%)
Control	1,100.0	0.0	1,100.00	5,210.91	39,081.83	37,981.83	
25%	825.0	612.5	1,437.50	5,316.165	39,871.24	38,433.74	133.90
50%	550.0	1,225.0	1,775.00	5,672.025	42,540.19	40,765.19	690.80
75%	275.0	1,837.5	2,112.50	5,979.375	44,845.31	42,732.81	583.00
100%	0.0	2,450.0	2,450.00	6,032.925	45,246.94	42,796.94	19.00

Where, AGY: adjusted yield, TVC: total variable cost, GFB: gross field benefit, NB: net benefit and MRR: marginal rate of return

Table 18: Economic analysis for effects of manure storage systems (MSS)

Manure	Manure storage Construction cost (Birr/ha)	Manure storage, transportation and application cost (Birr/ha)	TVC (Birr/ha)	AGY (kg/ha)	GFB (Birr/ha)	NB (birr/ha)	MRR (%)
Control	0	1,350.00	1,350.00	5,164.56	38,734.20	37,384.20	
Open	425	1,350.00	1,775.00	5,494.815	41,211.11	39,436.11	482.80
GR	950	1,350.00	2,300.00	5,949.225	44,619.19	42,319.19	549.16
SR	1675	1,350.00	3,025.00	5,948.325	44,612.44	41,587.44	-100.93

Where, AGY: adjusted yield, TVC: total variable cost, GFB: gross field benefit, NB: net benefit and MRR: marginal rate of return

5. SUMMARY AND CONCLUSION

Results of post-harvest soil analysis showed that almost all soil parameters, (available phosphorous, pH, organic carbon, organic matter, total nitrogen, and cation exchange capacity) considerably increased as a result of residue and manure treatments.

Yield and yield components of maize were highly significantly influenced by location, residue management (RM) and manure storage system (MSS). In addition, interaction of RM by MSS significantly affected only dry biomass yield per plant. Location by RM interaction significantly affected days to 50% physiological maturity, plant height, number of kernels per row, thousand seed weight, and yield per plant. Location by MSS interaction has no significant effect on all the measured plant parameters, which were also not significantly influenced by three way interaction of location, RM and MSS.

The highest (6,975.8 kg ha^{-1}) grain yield per hectare was recorded at Omonada site, while the lowest (56213.5 kg ha^{-1}) was recorded at Mana location, indicating that Omonada has a better environment for maize production, as growing maize in Omonada area has 24.1% yield advantage over maize grain yield in Mana district.

In generally, there were significant differences among RM and MSS treatments for number of days to phonological events, plant height, leaf area per plant, ear per plant, cob length, cob weight, number of kernels row per cob, kernels per row, kernels per cob, TSW, grain and biological yield. The highest (6,703.2 kg ha^{-1}) grain yield per hectare was recorded for 100 % residue followed by 75% residue incorporation. Grain yield increased by 15.7% and 14.7% over the control plot with 100% and 75% residue incorporation, respectively. Similarly, GR manure gave maximum grain yield per hectare (6,887.0 kg ha^{-1}) and maximum values of all maize parameters.

There was a positive and significant correlation between phenological events, plant height and total leaf area per plant. As well as maize vegetative growth was positively and significantly correlated with yield attributes like ear number per plant, number of kernels per cob, cob weight, number of kernel rows per cob, number of kernels per row, cob length, TSW and grain yield per plant, and with above ground dry matter yield. Generally, all maize parameters were positively and significantly correlated with its grain yield.

The result of partial budget analysis showed that 75% residue incorporation and GR manure storage system either alone or in combination gave greater economic benefit with higher MRR. The partial budget analysis revealed that combined applications of 75% residue and GR manure gave the best economic benefit of 44,882.1Birr ha^{-1} with MRR of 721.6%. Therefore, combined application of 75% residue and GR manure can be tentatively recommended for production of maize in the study area and in areas with similar agro-ecological conditions. However, since the experiment was conducted for one season at only two locations, it is suggested that it has to be repeated over seasons and locations using the same and other improved maize varieties to come up with a conclusive recommendation.

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7. APPENDIX

Apendix Table 1: Post-harvest soil results of the two locations for power of hydrogen(pH), percent of organic carbon (%OC), Electrical conductivity (EC) and cation exchange capacity (CEC) in Jimma in 2019.

Treatment		PH (mV/L)		%OC		CEC (cmol (+) kg-1)	
		Location					
RM (%)	MSS	Omonada	Mana	Omonada	Mana	Omonada	Mana
0	Contol	5.26	4.90	1.28	0.72	17.94	17.98
25	Contol	5.57	4.95	1.58	1.13	18.42	23.26
50	Contol	5.92	5.30	2.03	1.67	22.10	20.25
75	Contol	5.99	5.40	2.79	2.25	20.48	21.95
100	Contol	6.02	5.65	3.19	2.34	23.38	13.78
0	Open	5.67	5.15	1.76	1.26	24.32	17.33
25	Open	6.00	5.37	2.12	1.53	22.30	21.05
50	Open	6.03	5.56	2.70	1.62	21.80	16.77
75	Open	6.24	6.05	2.85	1.98	17.54	20.58
100	Open	6.03	5.50	3.02	2.16	24.68	21.74
0	SR	5.68	5.09	2.48	0.90	23.52	18.63
25	SR	5.72	5.25	2.34	1.13	23.56	20.80
50	SR	5.78	5.25	2.48	1.22	20.56	15.60
75	SR	5.90	5.38	2.43	1.40	19.86	17.50
100	SR	6.30	5.43	3.83	1.80	28.62	20.20
0	GR	5.77	5.10	2.07	1.40	23.58	21.12
25	GR	5.81	5.20	2.52	1.49	20.22	22.28
50	GR	5.98	5.42	2.93	1.58	24.30	24.98
75	GR	6.00	5.43	2.93	2.03	24.68	21.93
100	GR	6.35	6.07	3.33	2.12	20.18	24.80

Where: pH (power of hydrogen), %OC (Organic Carbon), CEC (Cation Exchange Capacity).

Apendix Table 2: Post-harvest soil results of the two locations for percent of Organic matter, percent of Total nitrogen, and Available phosphorous at Jimma, 2019.

Treatment		TN (%)		Av.P (ppm or mg/kg)		OM (%)		K (mg/kg)	
		Location							
RM (%)	MSS	Omonada	Mana	Omonada	Mana	Omonada	Mana	Omonada	Mana
0	Contol	0.11	0.03	10.50	8.58	2.2	1.2	8.40	8.25
25	Contol	0.17	0.06	11.00	8.40	2.7	1.9	8.88	7.53
50	Contol	0.24	0.13	11.62	8.70	3.5	2.9	9.20	6.97
75	Contol	0.24	0.14	12.11	10.30	4.8	3.9	9.69	6.86
100	Contol	0.27	0.14	13.50	9.42	5.5	4.0	10.81	6.70
0	Open	0.15	0.17	11.49	8.58	3.0	1.5	9.19	6.83
25	Open	0.18	0.19	11.97	8.11	3.6	2.6	10.42	6.49
50	Open	0.25	0.08	11.89	8.52	4.7	2.8	9.60	6.80
75	Open	0.23	0.10	12.08	10.26	4.9	3.4	9.57	10.80
100	Open	0.26	0.10	13.03	13.52	5.2	3.7	9.51	8.21
0	SR	0.21	0.12	11.92	8.99	4.0	1.6	9.53	7.19
25	SR	0.20	0.13	10.48	9.69	4.2	1.9	9.38	7.75
50	SR	0.22	0.16	13.05	11.23	4.3	2.1	10.44	8.98
75	SR	0.21	0.19	14.60	12.70	4.3	2.4	12.93	10.16
100	SR	0.33	0.12	16.16	17.20	6.6	3.1	11.71	13.76
0	GR	0.18	0.14	12.44	7.67	3.6	2.4	9.95	7.82
25	GR	0.25	0.17	12.04	7.08	4.3	2.6	11.32	6.13
50	GR	0.27	0.18	12.70	11.70	5.0	2.7	9.63	5.66
75	GR	0.29	0.20	14.15	9.78	5.1	3.5	10.16	9.36
100	GR	0.29	0.22	13.15	16.30	5.7	3.6	10.52	13.04

Where: %OM (Percent of Organic Carbon), %TN (percent of total nitrogen), Ava. P (Available Phosphorous).

Appendix Table 3: Pooled p-values of ANOVA for phonological events, growth and yield parameters of maize at Jimma, Southwest Ethiopia in 2019.

S.V	Pr>F								
	Parameters								
	DT	DS	DPM	PHt	LAPP	CL	CW	EPP	KRC^{-1}
Rep	0.4995	0.7486	0.8488	0.8489	0.8011	0.8774	0.7193	0.7432	0.4995
Location (L)	<.0001	<.0001	<.0001	<.0001	0.3235	<.0001	<.0001	0.0006	<.0001
Residue (R)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Manure (M)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
R*M	0.6697	0.9545	0.3078	0.6388	0.9150	0.6825	0.9988	0.1493	0.6697
L*R	0.3248	0.5900	0.0032	0.0234	0.1388	0.6716	0.9899	0.9863	0.3248
L*M	0.8779	0.9430	0.0596	0.7349	0.8971	0.2388	0.9946	0.6260	0.8779
L*R *M	0.4991	0.9026	0.9287	0.8300	0.5528	0.9545	0.9980	0.9882	0.4991
CV	2.0	2.0	1.5	5.6	5.5	10.6	13.5	8.601	1.32

Where, DT=days to 50% tassiling, DS=days to 50% silking , DPM=days to 50% physiological maturity, PHt=Plant height, LAPP = Total Leaf area per plant ,CL= cob length, CW=cob weight, EPP=Number of ears per plant and KRPC= Number of kernels rows per cob

Apendix Table 4: Pooled p-values of ANOVA for yield and yield parameters of maize at Jimma, Southwest Ethiopia in 2019.

Source of variation	**Pr>F**							
	Maize parameters							
	KC^{-1}	KR^{-1}	TSW	GYP^{-1}	$GYha^{-1}$	HI	$DBYP^{-1}$	$ABYha^{-1}$
Rep	0.7486	0.8488	0.0474	0.3997	0.4003	0.5001	0.2929	0.5185
Location (L)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.7569
Residue (R)	<.0001	<.0001	<.0001	<.0001	<.0001	0.2048	<.0001	<.0001
Manure (M)	<.0001	<.0001	<.0001	<.0001	<.0001	0.0038	<.0001	<.0001
R*M	0.9545	0.3078	0.8121	0.3771	0.2578	0.9706	0.0210	0.5788
L*R	0.5900	0.0032	0.0426	0.0195	0.7734	0.9465	0.9497	0.9372
L*M	0.9430	0.0596	0.5053	0.0777	0.7976	0.7888	0.8568	0.7538
L*R *M	0.9026	0.9287	0.8715	0.9966	0.8449	0.9857	0.9961	1.0000
CV	11	10.88	8.8	10.4	6.8	9.5	10.6	6.6

Where; KC^{-1}=kernels per cob, KR^{-1}=kernels per row, TSW=1000 seed weight, GYP^{-1} = grain yield per plant, $GYPha^{-1}$= grain yield per hectare, HI=harvest index, $DBMYP^{-1}$ = dry biomass yield per plant and $ABYha^{-1}$= above ground biological yield per hectare