Effect of Integrated Use of Lime AND Manure Fertilizer Rates on Soil Physicochemical Properties, Yield AND Yield Components of Maize(*Zea mays l.)* In Acidic Soil AT Meket District, Northwollo Ethiopia

MSc THESIS

YIRBEB WORETAW TSEGAYE

MAY 2024

WOLDIAUNIVERSITY, ETHIOPIA

Effect of Integrated Use of Lime AND Manure Fertilizer Rates on Soil Physicochemical Properties, Yield AND Yield Components of Maize(*Zea mays l.)* In Acidic Soil AT Meket District, Northwollo Ethiopia

A Thesis Submitted to Graduate Studies of Soil Resource and watershed managment, Woldia University

In Partial Fulfillment of the Requirements for the Degree of Master of Science (MSc.) In Soil Science

By

YIRBEB WORETAW TSEGAYE

Advisor: Endalkachew Fekadu (PhD)

MAY 2024

WoldiaUniversity, Ethiopia

WOLDIA UNIVERSITY

Post Graduate Program Directorate

I hereby certify that I have read and evaluated this Thesis entitled "Effect of Integrated Use of Lime and Manure Fertilizer Rates on Soil Physico-Chemical Properties, Yield and Yield Components of Maize (*Zea mays l.)* In Acidic Soil at Meket District, Northwollo Ethiopia" prepared under my guidance, by Yirbeb Woretaw Tsegaye. I recommend that it be submitted as fulfilling the Thesis requirement.

Endalkachew Fekadu (PhD)	_____	_____
Name of Major Advisor	Signature	Date

As member of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read, evaluated the Thesis prepared by Yirbeb Woretaw Tsegaye and examined the candidate. We recommended that the thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Soil science.

_____	_____	_____
Chairperson	Signature	Date
_____	_____	_____
Internal Examiner	Signature	Date
_____	_____	_____
External Examiner	Signature	Date

Approval and acceptance of the thesis is contingent upon the submission of its final copy of the thesis to Council of Graduate Studies (CGS) through the departmental or School Graduate committee (DGC or SGC) of the candidate.

DEDICATION

This thesis is dedicated to my beloved mother Tsega Miretu and my father Woretaw Tsegaye, whom I lost before the study period.

STATEMENT OF THE AUTHOR

I here by declare that the work contained in this thesis is entirely original and that all sources consulted in its creation have been properly acknowledged. This Thesis has been deposited at the Woldia University Library and will be madeaccessible to borrowers in accordance with the Library's guide lines after it has been submitted in partial fulfillment of the requirements for an MSc degree at Woldia University. I here by sincerely declare that this thesis has never been submitted to any university for the purpose of receiving a diploma, certificate, or academic degree from any other organization.

This thesis may be briefly quoted with out requesting special permission so long as the source is correctly acknowledged. The head of the major department may agree to requests for extensive quotations from or reproductions of this work in whole or in part. However, in all other cases, consent from the thesis's author and supervisors is required.

Name: Yirbeb Woretaw Signature: _____

Date: _____

Place: College of Agriculture, Soil Resource and Watershed Management, WoldiaUniversity.
Date of Submission: ----------

AUTHOR'S BIOGRAPHY

The author, Yirbeb Woretaw Tsegaye was born on 16 December 1976 E.C in Meket District, North wollo Administrative Zone, Amhara Regional State, Ethiopia. She attended elementary education (grade 1-8) at Geregera Elementary School from 1985 -1991 E.C. After completing elementary education, she was enrolled at Filakit Secondary School from 1992-1993E.C (grade 9-10) and then she was joined Mertolemariam Agricultural TVET college in september 1994-1996 E.C and graduated with Diplloma on Natural Resource in July 1996 E. C. Following her graduation, she was a Soil and water conservation expert at Meket District in Meket Woreda Agricultural Development office from 1997-2000 E.C and then She joined Bahirdar University college of Agriculture and Environmental science in October 2001-2003 E.C and graduated with Bachelor of Science degree on Natural Resource Management in July 2003 E. C. Still now she is employed by Meket woreda Agriculture office in Natural resources Department. Then after, in 2012 E.C the author joined the school of graduate studies of Woldia University, College of soil Resource and watershed managment, Department of Soil science in regular program as a candidate for Master of Science degree in soil science.

TABLEOF CONTENTS

Contents pages

DEDICATION IV
STATEMENT OF THE AUTHOR V
TABLEOF CONTENTS VII
ACKNOWLEDGMENT IX
ACRONYMS AND ABBREVIATIONS X
LIST OF TABLES XI
LIST OF FIGURES XII
LIST OF APPENDIX TABLES XIII
LIST OF APPENDIX FIGURES XIV
ABSTRACT XIV
1. INTRODUCTION 1
1.1. Background and Justification 1
1.2. Statement of the Problem 3
1.3. Objectives of the Study 4
1.3.1. General objective 4
1.3.2. Specific objectives 4
1.4. Research Questions 4
2. LITERATUREREVIEW 5
2.1. Soil Fertility 5
2.1.1. Soil fertility determining factors 5
2.1.2. Nutrient critical value 7
2.1.3. Application of lime and its effect in acidic soil 8
2.2. Soil Fertility Status in Ethiopia 10
2.3. Agroecology and Production of Maize 11
3. MATERIALS AND METHODS 13
3.1. Description of the Study Area 13
3.1.1. Altitude, climate and soils 13
3.1.2. Farming system 14
3.2. Experimental Material and Treatments 15
3.2.1. Plant material 15
3.2.2. Fertilizer materials 15
3.3. Methods 16
3.3.1. Evaluation of the changes in soil physicochemical properties 16
3.3.2. Soil analysis 16
3.4. Treatments and Experimental Design 17

3.4.1. Application of treatments and field management 18
3.5. Experimental Procedure 19
3.5.1. Fertilizer application and field activities 19
3.6. Collected Data for Yield and Yield Components of Maize 20
3.8. Economic Analysis 21
3.9. Agronomic Efficiency 22
4 RESULT AND DISCUSSION 23
4.1. Inherent soil Physicochemical Properties of the Experimental site 23
4.2. Effect of Integrated use of Lime and Manure on soil Physico-chemical Properties 25
4.2.1. Change in soil bulk density (BD) afterharvest 25
4.2.2. pH change of soil after harvest 26
4.2.3. Change in soil organic carbon (OC) 27
4.2.4. Total Nitrogen (TN) content after harvest 28
4.2.5. Change in available phosphorus after harvest 29
4.2.6. Change in Cation exchange capacity after harvest 30
4.2.7. Electrical conductivity content of soil after harvest 31
4.3. Effect of Integrated use of Manure and Lime on Yield and Yield Components of Maize .. 33
4.3.1. Effect of Manure fertilizer and lime on moropho-phenological parameters 33
4.3.3. Effect of urea fertilizer and lime rates on yield components 44
4.3.3.4. Grain yield of maize 52
4.3.3.5. Aboveground dry biomass (AGDB) 53
4.3.3.6. Harvest index of maize 55
4.3.3.7. Straw yield of maize 56
4.4. Correlation of Maize Yield and Yield Components 58
4.5. Economic Feasibility Analysis 60
4.6. Agronomic Use efficiency 63
5.1. Conclusions 65
5.2. Recommendations 65
6. REFERENCES 66
7. APPENDICES 84
APPENDEX FIGURES 91

ACKNOWLEDGMENT

First, I would like to offer lots of thanks to my God, the savor, and the Saint Virgin Mary for their compassionate help in all aspects of my life.

I sincerely thank my supervisors Dr. Endalkachew Fekadu for his professional guidance and tireless efforts to assist me during this work. I acknowledge the contribution received from all academic staff at Woldia University and particularly the Department of Soil Resource and watershed managment, during my stay at Woldia.

I would like also to express my gratitude to Mekit Agriculture Office for providing me the chance for this study. I am also grateful to Mr. Eyeberu Abere, Mr. Daniel Asnake and Muhabaw Shiferaw for their financial support, moral and encouragement.

Moreover, I am indebted to my lovely hasband Mekuanint Setegn for his encouragement and sharing experience and skills during data collection periods and all stage of research. I would like to express my sincere gratitude to my sister Yeshiye Setegn, my best friend Mekuanint Getachew and my family for their dedication and strong support.

ACRONYMS AND ABBREVIATIONS

ATA	Agriculture Transformation Agency
AMH	Amhara Hybrid
BH	Bako Hybrid
EARS	Ethiopian Agricultural Research System
EIAR	Ethiopian Institute of Agricultural Research
ESE	Ethiopian Seed Enterprise
GB	Gross Benefit
IAR	Institute of Agricultural Research
IFPRI	International Food Policy Research Institute
MoARD	Minister of Agriculture and Rural Development
MoU	Minister of Universities
NPS	Nitrogen Phosphorus Sulfur
MRR	Marginal Rate of Return
SARI	South Agricultural Research Institute
SNNP	Southern Nation, Nationality and Peoples
TVC	Total Variable Costs
MWAO	Meket Woreda Agriculture Office

LIST OF TABLES

Table Page

Table4.1. Soil physicochemical property status before improvement 25
Table4. 4. Moropho-phenological parameters influenced by as main effect of lime and Manure 35
Table4. 5. Mean moropho-phenological parameters as influenced by the interaction effect of lime and Manure 36
Table4.6. Effect of Manure and lime rates on vegetative parameters as influenced by the main effect 42
Table4.7. Mean vegetative parameters as influenced by the interaction effect of lime and Manure fertilizer 43
Table4. 8. Mean yield components of maize as influenced by main effect of Manure and lime 49
Table4. 9. Mean yield components of maize as influenced by the interaction effect of lime and Manure fertilizer 50
Table4. 10. Pearson's simple correlation coefficient among yield and yield components of maize .. 59
Table4. 11. Dominances analysis of Maize 61
Table4. 12. Marginal analysis of Maize 62
Table4.13. Agronomic use efficiency for maize 64

LIST OF FIGURES

Figure Page

Figure3.1. Location map of the study area 13

Figure 3. 2. Field layout for maize trial 19

LIST OF APPENDIX TABLES

Appendix Table Page

Appendix Table1.Critical level used for classifying soil fertility parameters analysis result (Ethiosis team analysis, 2014) ----------84
Appendix Table2.ANOVA table for days to 50% tasseling----------85
Appendix Table 3 ANOVA table for days to 50% silking----------85
Appendix Table 4.ANOVA table for Days to 90% physiological maturity----------85
Appendix Table 5.ANOVA table for plant height----------86
Appendix Table 6.ANOVA table for the Number of leaves per plant----------86
Appendix Table 7.ANOVA table for the number of cobs per plant----------86
Appendix Table 8.ANOVA table for the number of grains per cobs----------87
Appendix Table 9 ANOVA table for1000 seed weight of maize----------87
Appendix Table 10.ANOVA table for Grain yield of maize----------87
Appendix Table11.ANOVA table for above ground dry biomass of maize----------88
Appendix Table 12.ANOVA table for harvest index of maize----------88
Appendix Table 13.ANOVA table for the Straw yield of maize----------88
Appendix Table 14.Partial budget analysis of lime and manure fertilizer rates applied for maize in Meket District----------89
Appendix Table 15.Summary of 10 years (2012-2021) mean rain fall and temperature data of study area----------90

LIST OF APPENDIX FIGURES

Appendix Figure Page

Appendix Figure 1. Partial view of ten treatments with three replication and yield 91

\

ABSTRACT

Soil fertility problem is the limiting factor for agricultural productivity in the mid and highlands of Ethiopia. High soil acidity coupled with soil nutrient depletion negatively affect the performance and yield of maize in the Amhara region. This study was therefore carried out at Meket District in one cropping season to determine the effect of integrated use of lime and manure fertilizer rates on soil physicochemical properties, yield and, yield components of Maize. The treatments include lime (0 and 0.5 t ha^{-1}), Manure (0, 4, 8, 12 and 16 tone ha^{-1}). The maize variety BH-661 was used as a test crop. The experiment was laid out in a randomized complete block design (RCBD) with ten treatments replicated three times. Nine representative soil samples were collected and one composite sample was taken for analysis of soil physicochemical properties. After harvesting, disturbed soil samples were collected for soil chemical properties analysis. While a total of thirty undisturbed soil samples were collected from three blocks for bulk density determination. Soil texture and bulk density were analyzed before and after harvest. The change in chemical properties of soil including pH, SOC, CEC, Available P, and EC were also analysed following the standard laboratory procedure.The Morpho-phenological parameters (50% tasselling, 50% silking, days to 90% maturity, plant height, number of leaves per plant, number of cobs per plant, number of grain per cob, 1000 grain weight, grain yield, above ground dry biomass yield, harvest index, straw yield were collected. Analysis of variance (ANOVA) was carried out using the SAS statistical package program version 9.0 (SAS, 2004). Soil physicochemical properties were changed due to lime and Urea or manure. Field experiments revealed that individual, as well as combined application of lime and Manure, improved yield and yield components of maize. The maximum grain yield of maize harvested was 7122.44 kg ha^{-1} with the net benefit of 58891.47ETB ha^{-1}. The economic analysis result indicated that the application of lime and organic fertilizer was found economically feasible for maize production. Plots treated with organic fertilizer were the best in nutrient use efficiency (5.88%). In the study area, the recommended treatments are T2, T7, T8 and T9.But based on the highest net benfit, combined application of 0.5 t ha^{-1} lime and 12t ha^{-1} Manure is economically feasible and recommended to the farmers. Therefore, farmers should use 0.5 t ha^{-1} lime and 12t ha^{-1} Manure.

Keywords: Optimum, liming, maize, soil acidity, manure, yield, Ethiopia.

1. INTRODUCTION

1.1. Background and Justification

Declining soil fertility is a fundamental impediment to crop production and a major reason for slow growth of food production in Sub-Saharan Africa (SSA). In Ethiopia, soil degradation and nutrient depletion have gradually increased in area and magnitude and have become serious threats to agricultural productivity (Fasil and Charles, 2009).

Soil fertility management for food and livelihood security is a major concern in the face of persistent poverty and widespread environmental degradation in Sub-Saharan Africa (SSA) including Ethiopia. About 97% of agricultural land in SSA is under rain fed system (Bello *et al*., 2010) which remains dominant source of food production shortly. Due to the widespread nutrient depletion in the agricultural soils exacerbated by improper land use, yield and water productivity in the rain fed systems is decreasing or stagnating in many SSA countries (Bello *et al*., 2010). In addition Mosisa *et al*. (2012) explained that, nutrient depletion is the chief biophysical factor limiting small-scale production in Africa.

Soil acidity is one of the limiting factors to acid-sensitive crop production in the Northestern highlands of Ethiopia. Its effects on crop growth are those related to the deficiency of major nutrients and the toxicity of aluminum (Al), manganese (Mn) and hydrogen (H) ions in the soil to plant physiological processes (Mesfin, 2009). To secure sustainable crop production and reasonable yield, acidic soils have to be corrected by the addition of agricultural lime to a pH range which is suitable for better yield of crop production (Mesfin, 2009).

Agricultural liming material is the most common soil management practices whose addition to agricultural soil in moderate amounts may be beneficial as plant nutrients, minimize soil acidification (Kebede and Dereje, 2017). The beneficial effects of liming soil are neutralization of exchangeable Al, increase Ca, Mg, P and Mo, availability, stimulate microbiological activity in the soil, and improve the physical structure of soil (Woubshet *et al*., 2017).

Ethiopia is the fifth largest producer of maize in Africa and smallholder farmers make up 94% of the crop production (Miteku and Asnakech, 2016). Maize is cultivated in a wide range of

altitudes, moisture regimes, soil types, and terrains, mainly by smallholder crop producers. It is mainly produced in southern, western, central, and eastern regions of Ethiopia (MoARD, 2009). But specifically, the mid-altitude, sub-humid agro-ecology (1,000-1,800 meter above sea level) is the most important maize producing environment in Ethiopia (Wende, 2013).

The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the straw as animal fodder and source of fuel for rural families (Tsedeke *et al*., 2015). Maize is used as human food (accounting for 62% of all household cereal consumption), as a source of cash income (accounting for about 54% of cash income), as fuel (about 25%), feed for livestock and industrial purposes (Mosisa *et al*., 2002). Farmers consume maize by preparing different dishes, including bread, *injera*, thick porridge, boiled maize, roasted maize and local beer. Green cobs are also sold in big cities and towns (Berhanu *et al*., 2007). The smallholder farmers' of Ethiopia owning 97% of the total maize land contribute 95% of the national maize production (CSA, 2011).On the other hand, commercial farms owning only 3% of land contribute 5% of the total production. In the Amhara region, maize production accounts 519,495.71 ha^{-1} with productivity of 37.79 qt ha^{-1}, while in south Gonder and west Gojam it accounts 212,556.78 ha^{-1} with a productivity of 42.28 qt ha^{-1} (CSA, 2017).

The low productivity of maize is mainly attributed to many factors including frequent occurrence of drought, declining soil fertility (IFPRI, 2010), poor agronomic practice, limited use of inputs, poor seed quality, disease, and pests (Wende, 2013). Among these, declining soil fertility (due to continuous cultivation with low input) is a major limitation to crop production and productivity in smallholder farms in Ethiopia (Mosisa *et al*., 2012).

Manure is an important source of nutrients for many smallholder farmers in East Africa who can't afford or those only using limited amounts of chemical fertilizers (Elias, 1998; *Elias et al*., 2002; Walaga *et al*., 2003; De Jager *et al*., 2007; Onduru *et al*., 2008). Integrated soil fertility management through application of both organic and inorganic fertilizers is highly recommended to attain sustainable crop productivity (Elias *et al*., 2002; Walaga *et al*., 2003; De Jager *et al*., 2007 and Onduru *et al*., 2008). Unlike chemical fertilizers, organic fertilizers including manure and compost improve the physical, chemical and biological properties of soils. Indeed, farmers identified insufficient manure, labor and/or knowledge as important constraints to using manure

in East Africa (Elias *et al*., 2002; Walaga *et al*., 2003). As being a new crop to the country, response of maize to chemical and/or organic fertilizer application has not yet been studied well in the country. To harness its maximum production potential, it is necessary to optimize the requirement of inorganic and organic fertilizers including cattle manure for maize.

Although, the Amhara region especially Burie District is a potential area for maize production the productivity is generally low, which is attributed to several factors one of which is poor soil fertility and nutrient management. Thus, identifying effective Integrated Nutrient Management (INM) ways is needed to replenish the soil nutrients and increase the maize grain productivity in the study area. Therefore, this study was initiated to investigate the effect of integrated use of lime and manure fertilizer on soil physicochemicalproperties, maize yield and yield components on the Nitisols of Meket District, Northestern Ethiopia.

1.2. Statement of the Problem

In the mid and highlands area of Ethiopia the soil is acidic and deficient in nitrogen and phosphorus due to soil erosion, leaching of basic cations, intensive and continuous cultivation of land with poor soil fertility management practices (Kebede and Dereje, 2017)

Efforts to ameliorate the harmful effects of soil acidity must therefore be accompanied by measures to replenish soil N and P. Use of organic fertilizers is recognized as an effective way for overcoming nitrogen and phosphorus deficiencies. However, in acid soils, response to fertilizers may not occur because of constraints imposed by soil acidity. Therefore; liming is the most effective practice to control soil acidity (Peter *et al.,* 2018).

Moreover, farmers of the study area are not well familiar in applying lime on acidic soil and the knowledge concerning integrated use of lime with mineral fertilizer. Similarly, fertilizer rate recommendations for the integrated application of lime and manure fertilizers are not available in the study area. Therefore, conducting research on the integrated application of lime and manure fertilizer and evaluating their combined effect on soil physicochemical properties and maize crop productivity is crucial.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study was to investigate the effect of integrated use of lime and manure fertilizer rates on soil physicochemical property, yield and components of maize (*Zea mays l.)* in the Nitisols of Meket District, North wollo Ethiopia.

1.3.2. Specific objectives

The specific objective of this study was

- To evaluate the effect of integrated use of lime and manure on selected soil properties
- To determine the optimum dose of manure fertilizer and lime that increase maize productivity on the Nitislos of the study area.
- To determine yied and yield components of maize in the study area.

1.4. Research Questions

In line with the specific objectives the research was attempted to address the following significant questions:

1. What is the inherent soil physicochemical properties condition of the study area?
2. What is the effect of lime and manure on soil physicochemical properties and yield and yield components of maize?

2. LITERATUREREVIEW

2.1. Soil Fertility

Soil fertility refers to the ability of the soil to supply the nutrients needed by the plants (Orkaido, 2004*)*. According to Martin (1993), the study of soil fertility involves examining the forms in which plant nutrients occur in the soil, how these become available to the plant, and factors that influence their uptake. This is usually done by adding fertilizers, manures and amendments to the soil but sometimes by supplying nutrients directly to the plant parts using sprays (Orkaido, 2004*).*

Importance of soil fertility and plant nutrition to health and survival of all life cannot be understated as the human population continues to increase, human disturbance of earth's ecosystem to produce food and fiber will place a greater demand on soils to supply essential nutrients. Therefore, we must increase our understanding of the chemical, biological and physical properties and relationships in the soil-plant-atmosphere continuum that control nutrient availability (Tisdale *et al.,* 1995). If we do not improve and/or sustain the productive capacity of our fragile soil, we cannot continue to support the food and fiber demand of our growing population (Orkaido, 2004*).*Soil nutrient status of most farming systems is widely constrained by the limited use of inorganic and organic fertilizers and by nutrient loss mainly due to erosion and leaching (Balesh *et al*., 2007).

2.1.1. Soil fertility determining factors

Several factors contribute to reducing the fertility status and quality of soil in Ethiopia.The major ones being land degradation because of massive deforestation, human and livestock population pressure, limited use of crop residue and animal dung and little or no use of modern technologies to restore soil fertility, the high price of mineral fertilizer, and low use of organic nutrient sources (Taye and Yifru, 2010). The physical and chemical properties of soil are the major determinant factors of soil fertility status. Different physical and chemical properties of the soil relate to one another and hence, the presence of one can indicate the status of the other (Brady and Weil, 2004).

2.1.1.1. Soil physical properties

Physical properties of soils determine theiradaptability tocultivation and the levelof biological activity that can be supported by the soil. Many soil physical properties change with changes in land usesystem and its management practices such as intensity of cultivation,the instrument used and the nature of the land under cultivation, rendering the soil less permeable, and more susceptible to runoff and erosion losses (Sahrawat *et al.,* 2010).

White (1997) found that Bd ranges from lessthan 1 g/cm^3 for soils high in OM, 1.0 to 1.40 g/cm^3 for well- aggregated loamy soils, and 1.4 to 1.8 g/cm^3 for sands and compacted horizons in clay soils. Soils having low and high Bd exhibit favorable and poor physical conditions respectively (Mitiku *et al.,* 2006). Bulk density normally decreases as mineral soils become finer in texture. Bulk densities of soil horizons are inversely related to the amount of pore-space and soil OM (Brady and Weil, 2002).

2.1.1.2. Soil chemical properties

Soil chemical properties are the most important among the factors that determine thenutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build-up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil (Wang *et al.,* 2007).

Soil reaction (pH) value is the degree of soil acidity or alkalinity, which is caused by a particular chemical, mineralogical, and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth.Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment (Troeh and Thompson, 1993).

Descriptive terms commonly associated with certain ranges in pH are extremely acidic (pH< 4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately

alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0) and very strongly alkaline (pH > 9.1) (Rowell, 2014).

Soil organic matter (SOM) is the organic fraction of soil derived from the decayed tissue of plants, animals and from animal excreta (Teklu,2005).Soil OM helps to bind soil particles together that improve the physical properties of the soil making it easier for roots to penetrate. Organic matter forms complexes with micro-nutrients and prevents them from being lost through leaching. During the anaerobic fermentation process, about 25 to 30% of the OM from the manure is converted into biogas while the rest becomes available as residual manure (Chendu, 2006).

Dense populations of micro-organisms inhabit the upper soil surface and have access to the soil N sources. If the ratio of the substrate is high there will be no net mineralization and accumulation of N.They further noted that as decomposition proceeds, carbon is released as CO_2 and the C: N ratio of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients (Lee, 2005).

The ability of a soil to retain cations such as potassium (K^+), ammonium (NH_4^+), hydrogen (H^+), calcium $Ca^{2+)}$ and magnesium (Mg^{2+}) in a form that is available to plants is known as cation exchange capacity.The Cation exchange capacity (CEC) of soils also is the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002).There is a fairly constant equilibrium between adsorbed cations and those moving freely in the soil moisture.When the equilibrium is disturbed, ion exchange between the solid and liquid soil phases occur,resulting in either adsorption or release of cations (Samuel *et al.*, 2000).

In general, CEC is a crucial factor in the determination of soil fertility for two fundamental reasons. First, the total quantities of nutrients available to plants as exchangeable cations depend on it, and second are it can influence the degree to which hydrogen and aluminum ions occupy the exchange complex and thus, affect the pH of soils (Sahlemedhin Sertsu and Taye, 2000).

2.1.2. Nutrient critical value

Several elements take part of the growth and development of plants, and those absorbed from the

soil are generally known as plant nutrients. Besides these, the plant takes up carbon, oxygen, and hydrogen, either from the air or from the water absorbed by roots. In all, 16 elements have been identified and are established to be essential for plant growth (Ethio SIS, 2014). There are carbon (C), hydrogen (H), Oxygen (O), nitrogen (N), phosphorus(P), potassium(K),calcium (Ca), magnesium (Mg), iron (Fe), sulfur (S), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and chlorine(Cl) (Ethio SIS, 2013). These elements serve as raw materials for the growth and development of plants, and the formation of fruits and seeds. Most of the essential elements are found in abundant quantities in the mineral soils. Even though these are available inadeuately, they may not be available to the plants, as they are tied up in mineral and chemical compounds (Taylor and Francis, 2006). The roots cannot absorb and deliver them to the growing plants for synthesis, and hence, the need for assessing the plant available amounts of nutrients in the soil and meeting deficiency by application of manures and fertilizers to such soils for optimum crop production (Taylor and Francis, 2006).

The proper rates of plant nutrients can be determined by knowledge about the nutrient requirement of the crop and supplying power of the soil. However, Ethiopian farmers used to apply only chemical fertilizers Di-ammonium phosphate (DAP) and urea to increase crop yields for about five decades and this did not consider soil fertility status and crop nutrient requirement (Tilahun, 2007).

Critical levels may vary with crop, soil type, and climate and they are also specific to the soil test method used. Optimally critical values should be calibrated for each crop and for conditions that are as similar as possible to the conditions under which the fertilizer recommendations are applied (Ethio SIS, 2013).

Generally, critical nutrient level for different nutrients was given as follow as; Nitrogen (0.2%), Phosphorous (15mgkg^{-1}), Potassium (190mgkg^{-1}), Calcium (50mgkg^{-1}), Magnesium (10mgkg^{-1}), Sulphur (20mgkg^{-1}), Zinc (1.5mgkg^{-1}), Boron (0.8mgkg^{-1}) (Ethio SIS, 2014).

2.1.3. Application of lime and its effect in acidic soil

Acidic soils are made less acidic by adding a liming material. Agricultural lime is a material containing calcium (Ca) and/or magnesium (Mg) compounds capable of neutralizing soil acidity.

A liming material with a higher CCE value will have greater effectiveness than one with a lower CCE value. Impurities, such as clay and organic matter that naturally occur in liming materials, produce variations in CCE among various liming materials (Mark, 2009). The common liming materials used to ameliorate acidity are Calcium Oxide (CaO) and Calcium Carbonate ($CaCO_3$) in powdery formulations (Peter *et al.,* 2018).

Factors to consider in selecting a liming material include available lime sources in the area, the length of time between application of lime and planting of the crop, degree of soil acidity, the need for magnesium, value of the crop, and the intensity of cropping (Nagle, 1983).

According to Nagle (1983) use a slow or a quick-acting liming material can be a difficult and confusing decision. If lime can be applied three to six months ahead of planting, then more coarsely ground limestone can be used. Agricultural lime works best when applied in this manner. However, the fine particles (percent passing 100-mesh) in Agricultural lime will react very quickly and yield benefits will be seen even if lime is applied at the time of planting.

As Bertsch (1981) stated that extractable soil calcium and magnesium increased more rapidly with suspension limestone applications as compared to conventional Agricultural lime. However, after 16 weeks, pH and exchangeable calcium and magnesium levels were nearly the same for the two liming materials. Moreover, corn yields responded equally to suspension and conventional ground Agricultural lime. Agricultural lime immediately reacts with soil acidity and does produce a crop response even when lime is applied at the time of planting (Bertsch, 1981).

In strongly acid soils, it may be desirable to use crushed lime or one of the burnt or hydrated limes (Bertsch, 1981).These liming materials will benefit crops and reduce the level of soil acidity more quickly. Though the cost per area may be somewhat greater, improved crop performance may result in higher net income. The value of the crop should be considered in determining what lime source to use, especially for those crops that are acid-sensitive or have a critical pH requirement (Bertsch, 1981).

On the other hand application of ammonium and urea types of nitrogen fertilizers increases the

need for lime. The natural nitrification process of these fertilizers produces acid and tends to speed the acidification of soils. A soil test every two or three years will reveal the need for lime. As reported by Bertsch (1981) the maximum increase in soil pH occurred within approximately two years after the lime application. Sandy soils generally require less lime at any one time than silt or clay soils to increase pH by a given amount. Sandy soils, however, usually need to be lime more frequently (Bertsch, 1981). Lime should be mixed to tillage depth.

According to Bertsch (1981) the best time to lime is any time that a lime need has been determined. Agricultural lime can be applied anytime between the harvest of a crop and the planting of the next. Lime is usually broadcast on the soil surface and then incorporated into the soil during tillage operations. Spring applications are excellent for fall crops since there will be adequate time for significant soil pH adjustment. Application of good quality agricultural lime can adjust soil pH adequately in 45 to 60 days (Bertsch, 1981). Broadcasting lime by hand followed by incorporation is recommended on smallholder farms to enhance their effectiveness but this is laborious (Peter *et al.,* 2018).

2.2. Soil Fertility Status in Ethiopia

Agriculture in Ethiopia has long been a priority and focus of national policy such as Agricultural Development Led Industrialization (ADLI) and various large scale programs such as the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (Alemayehu Seyum, 2008). However, the sector is characterized by low productivity and the prevalence of a fragmented smallholder and subsistence farmer population that is relegated to highly degraded/marginal land due to loss of soil fertility. Low productivity can be attributed to limited access by small farmers to agricultural inputs such as inorganic fertilizer, poor attitude on organic fertilizer, financial services, improved production technologies, irrigationand agricultural outputmarket and, more importantly, to poor land management practices that have led to severe land degradation in some areas (MoARD, 2010).

Ethiopia faces a wider set of soil fertility issues beyond inorganic fertilizer use which has historically been the major focus for extension workers, researchers, policymakers and donors. These issues interact and include loss of soil organic matter, macronutrient (N, P and K) and

micronutrient (Fe, Mn, Zn, Cu, B, Mo and Cl) depletion, topsoil erosion, acidity, salinity and deterioration of other physical soil properties (Zeleke *et al*., 2010).

2.3. Agroecology and Production of Maize

Maize (*Zea mays* L.) is a member of *Gramineae* family, and it was originated in America and first cultivated in the area of Mexico more than 7,000 years ago (Hilaire, 2000). In world production, maize is ranked as the third major cereal crop after wheat and rice (Zamir *et al.*, 2013). It is one of the most important food crops worldwide. It has the highest average yield per hectare and it is grown in most parts of the world over a wide range of environmental conditions (Geremew, 2009).

Maize is generally less suited to semi-arid or equatorial climates, although drought-tolerant cultivars adapted to semi-arid conditions are now available. The crop requires an average daily temperature of at least 20^{o}C for adequate growth and development; the optimum temperature for growth and development ranges between 25 to 30^{o}C; temperature above 35^{o}C reduces yields (Brink and Belay, 2006). Frost can damage maize at all growth stages and a frost-free period of 120 to 140 days is required to prevent damage. Leaves of mature plants are easily damaged by frost and grain filling can be adversely affected. Currently, maize is widely grown in most parts of the world over a wide range of environmental conditions ranging between 50^{o} latitude north and south of the equator. It is also grown from sea level to over 3000 meters above sea level (m.a.s.l) elevation. In the tropics; maize does best with 600-900 mm well-distributed rainfall during the growing season (Brink and Belay, 2006).

The most appropriate soil for maize is one with good effective depth, favorable morphological properties, good internal drainage, and an optimal moisture regime, sufficient and balanced quantities of plant nutrients, and chemical properties that are favorable specifically for maize production. Although large-scale maize production takes place on soils with a clay content of less than 10% (sandy soils) or over 30% (clay and clay loam soils), the textural classes between 10 and 30% (clay) have air and moisture regimes that are optimal for healthy maize production and productivity (Kena Kelbesa, 2015). The accessibility of quality seed with required inputs at the right time and place with a reasonable price is vital. The maize productivity gap between

stressed and high potential areas is not only an issue of technology but also differences in climatic factors. The non-availability of suitable maize varieties is also responsible for such a significant yield reduction. Wise utilization and conservation of natural resources will also have a considerable impact on maize grain production (Mosisa *et al*., 2001).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted in Meket District, Northwollo Zone of Amhara National Regional State (ANRS) during the 2022/2023 rainy season. The district is a highland area. Meket District has a total of 41216 ha productivity area from this 10.8% is covered by maize crop in the 2021/2022crop production year (Meket Woreda Agriculture Office, 2021).The mean yield of maize was 4.5 t ha^{-1} by using recommended N, NPS and Manure fertilizer (100 kg urea, 100 kg NPS, and 12000 kg Manure ha^{-1}) inorganic and Organic fertilizer (Meket Woreda Agriculture Office, 2021).

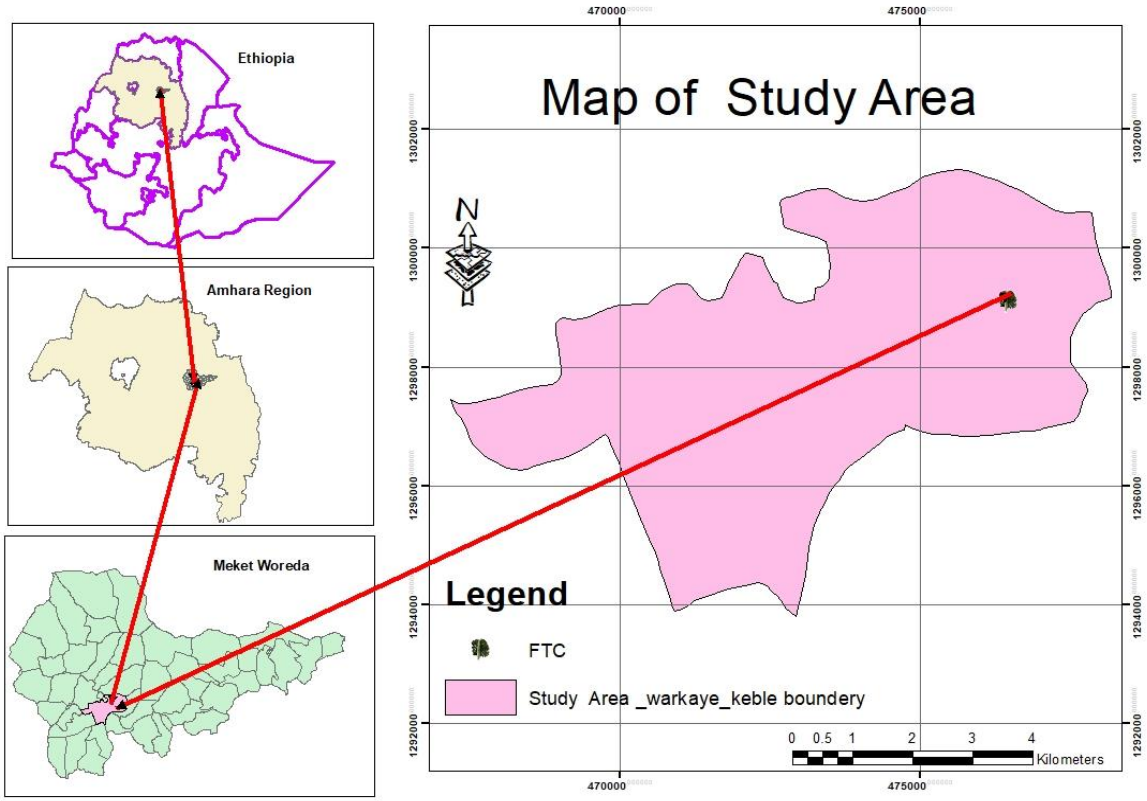


Figure3.1. Location map of the study area

3.1.1. Altitude, climate and soils

The altitude of Meket district ranges from 2007to 2924 m.a.s.l. Geographically, the testing site is

located at 11° 72′ 28"-11° 75′ 30"N latitude and 38° 44′ 20" -40° 27′ 10" E longitude. Having an altitude of 2924 meters above sea level.Metrological data obtained from Ethiopiain Meteorological Service (2021), during 2010-2019 indicates that mean annual rainfall of the district was 1375.8mm (Appendix Table 15). The mean minimum, mean maximum and average air temperature of ten years (2010-2019) in the study area were 12.31^{o}C, 25.93^{o}C and 19.12^{o}C, respectively (Fig 3.2).The soil of the area is characteristically netosols and eutric vertisols, relatively fine in texture (Meket Woreda Agriculture Office, 2021).

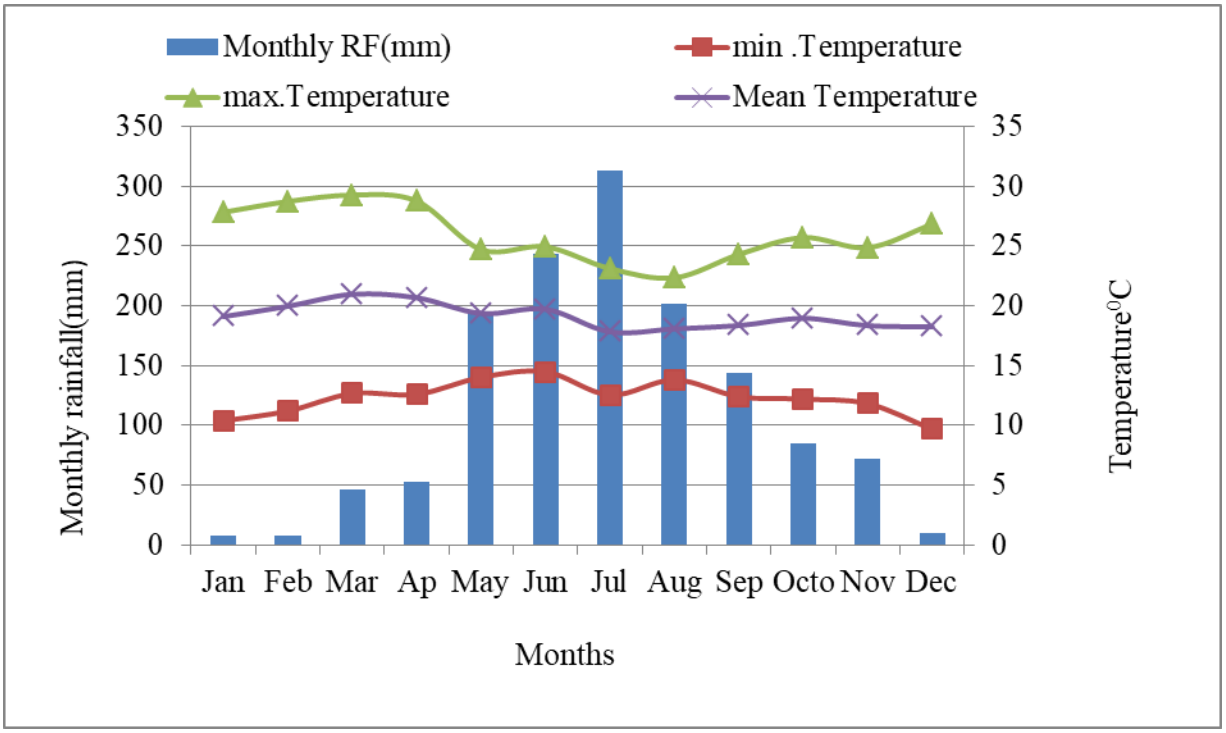


Figure 3.2.Monthly rainfall (mm), minimum, maximum and average air temperature (ºC) of the study area during 2010/2019

3.1.2. Farming system

According to MWAO (2021), the main crops grown in the districtare maize (*Zea mays*), Barley (*Hordeumvulagre*), wheat (*Triticum aestivumL*) ,field pea (*Pisumsativum*), chickpeas (*Cicer arietinum*), common beans (*Phaseolus vulgaris*), nug (*Niger seed)*, telba (*flex seed*), onion (*Allium cepa*), garlic (*Allium sativum*),cabbage (*Brassica oleracea var. capitata*), carrot (*Daucus carota subsp. Sativus*), finger millet (*Eleusinecoracana*), potato(*Solanumtuberosum*), pepper (*Capsicum annuum*) and teff (*Eragrostis tef*).The experiment was conducted at Warkaye Peasant

Administration, Sisye rural village.

3.2. Experimental Material and Treatments

3.2.1. Plant material

The maize variety H-661 (Bako Hybrid-661) which is adapted to the agroecology and registered at the national level was collected from Amhara Seed Enterprise and used as a test crop. This variety was released by Bako research center and has one of the most successful hybrid varieties. It is a three-way cross-hybrid and the most prominent throughout Ethiopia due to high productivity and coverage. It gives an average 7 t ha^{-1} in farmer's trial (Esayas Eyasu *et al.*, 2018).

3.2.2. Fertilizer materials

Manure from different cattle was used as a source of different nutrient. It was applied at five different rates (0, 4, 8, 12 and 16 tone ha^{-1}). The blanket recommended rate of manure is 8 tone ha^{-1}.This fertilizer was applied at the specified rate and timing by banding before 2 weeks and immediately incorporated with soil.

Lime material in the form of calcium carbonate ($CaCO_{3)}$) which has present passing100-mesh was applied.According to Meket District Woreda Agricultural Office Manual (2022) there are two way of lime application. Those are during seed sowing (i.e row application) when the lime type is powder and broad casting application when the lime type is granular. It is recommended to apply before one or two month before seed sowing. In order to apply during seed sowing use $1/4^{th}$of the recommended rate of broad casting application. Lime was added based on soil pH of the experimental site. If the pH (H_2O) value of soil is between5.14 to 5.32, the recommended lime is 0.2t ha^{-1} for broad casting application (MWAO, 2021). Thus based on the district recommendation and the experimental site soil pH (that was 5.2), the amount of lime rate added during maize sowing was 0.5 t ha^{-1}.

3.3. Methods

3.3.1. Evaluation of the changes in soil physicochemical properties

Before the sowing of the seed, soil samples were taken at a depth of 0 to 20cm at different points by vertical insertion of a shovel and mixed to get one composite sample. The composite soil sample from surface soil was properly labeled and placed both inside and outside the plastic bags.

Similarly, soil sample collection was done after treatment application from each plot within a block. The composite surface soil and individual soil samples from each plot after treatment was properly labelled and placed both inside and outside the plastic bags and was transported to soil laboratory.

3.3.2. Soil analysis

3.3.2.1. Analysis of soil physical properties

Soil bulk density was measured from undisturbed soil samples collected using a core sampler (which was weighed at field moisture) after drying the pre-weighed soil core samples to constant weight in an oven at 105 ^{0}C as per the procedures described by Blake (1965). Then soil samples were dried in an oven at 105 ^{0}C to constant weights. Then soil bulk density was calculated by dividing the masses of the oven dried soils by their respective total volume of the core sampler. BD (g/cm3) =Weight of oven dried soil (g)/core volume of the soil (cm^3).

3.3.2.2. Analysis of soil chemical properties

The composite soils samples were air-dried, mixed well and passed through a 2 mm sieve for the analysis of selected chemical properties. The soil pH was determined in pH-H_2O with soil to solution ratio of 1:2.5 by using pH meter as outlined by Van Reeuwijk, (1993). Soil organic carbon was determined by the Walkley and Black wet digestion method (Walkley and Black,

1934) and the soil organic matter (OM) was calculated by multiplying the percent organic carbon by a factor of 1.724. Total nitrogen (N) was determined using the micro-Kjeldahl digestion, distillation and titration procedure as described by Bremner and Mulvaney (1982). Available P was determined using the standard Olsen extraction method (Olsen et al., 1954). To determine the cation exchange capacity (CEC), the soil samples were first leached with 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by Na. Then, the CEC was measured titrimetrically by distillation of the ammonia that was displaced by sodium (Chapman, 1965).

3.4. Treatments and Experimental Design

This experiment was laid out as a randomized complete block design (RCBD) with three replications and ten treatments.Two factors were involved in the study, namely five levels of Manure (0, 4, 8, 12 and 16 tone ha^{-1}) and two-level of lime (0 and 0.5 t ha^{-1}) to have a total of ten (10) treatments that were arranged in 5*2 factorial combinations.

Table3.1. Factorial combination of Manure and lime

		Manure				
		M0	M1	M2	M3	M4
Lime	L0	L0M0	L0M1	L0M2	L0M3	L0M4
	L1	L1M0	L1M1	L1M2	L1M3	L1M4

Note:

- L0M0 was the control without lime and Manure fertilizer
- L0M1was treatment without lime and 4 tone ha^{-1} Manure fertilizer
- L0M2 was treatment without lime and 8 tone ha^{-1} Manure fertilizer
- L0M3 was treatment without lime and12 tone ha^{-1} Manure fertilizer
- L0M4 was treatment without lime and 16 tone ha^{-1} Manure fertilizer
- L1M0 was treatment with 0.5 t ha^{-1} lime and 0 tone ha^{-1} Manure fertilizer
- L1M1 was treatment with 0.5 t ha^{-1} lime and 4 tone ha^{-1} Manure fertilizer
- L1M2 was treatment with 0.5 t ha^{-1} lime and 8 tone ha^{-1} Manure fertilizer
- L1M3 was treatment with 0.5 t ha^{-1} lime and 12 tone ha^{-1} Manure fertilizer
- L1M4 was treatment with 0.5 t ha^{-1} lime and 16 tone ha^{-1} Manure fertilizer

3.4.1. Application of treatments and field management

The field was leveled and divided into three blocks which were lastly divided into 30 plots. The plots were leveled and ridges were prepared manually. Each gross plot had an area of 3.75 m × 3.5 m (13.125m^2) and consists of 5 rows of 3.5 m length. The spacing between rows and between plants was 0.75m and 0.25m, respectively and the spacing between plots and blocks was 0.5m and 1m respectively. The treatments were assigned to each plot randomly. The one which was the outer most rows from each side 12.5cm and 37.5cm length from both ends of each row was considered as a border. Thus, the net plot was 3 rows of 2.25m width and 2.5m length (2.25m× 2.5m = 5.625m^2). The total area used for this research was 39.5m by 13.25m (523.375m^2). Seeds of maize variety BH661 were sown by hand at a rate of 100 kg ha^{-1} on May 30, 2021 and lime was applied in row with 0.5 t ha^{-1} rate. The experimental field was hand weeded twice at 25 and 45 days after planting to control weeds. At physiological maturity maize

crop was harvested on December 26, 2021, sun dried and threshed on January 6 and 7, 2021 to determine grain yield.

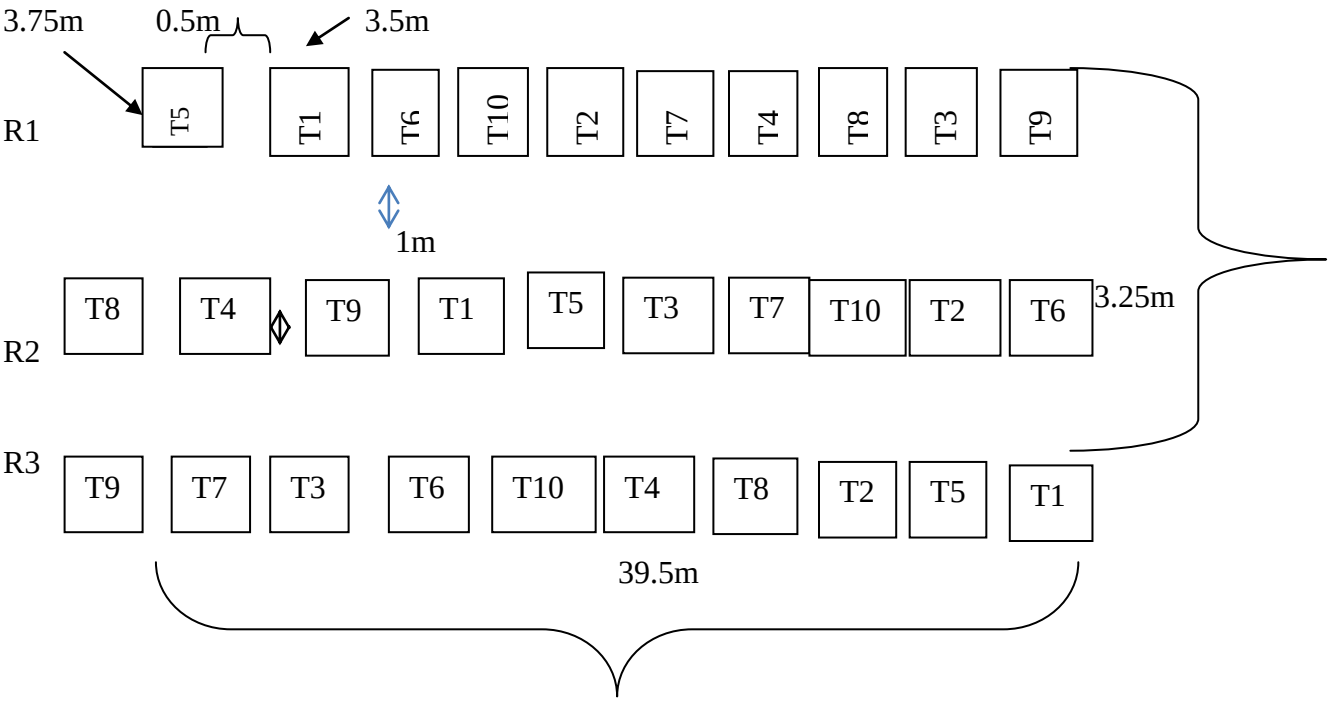


Figure3. 2. Field layout for maize trial

3.5. Experimental Procedure

3.5.1. Fertilizer application and field activities

Weed was managed by hand weeding after weed emergence. A late emerging weed was removed by hoeing to avoid interference with the maize plants for the N applied from 100kgNPS source. All other agronomic practices such as fertilization, hoeing, disease, insects and weeds management was as per the recommendation. Finally, maize plants in the central net plot area were harvested.

3.6. Collected Data for Yield and Yield Components of Maize

The following phonological, yield and yield components of maize crop data were collected.

Days to 50% tasseling was recorded when more than 50 percent of the plants produced tassels in each plot.

Days to 50% silking was recorded when more than 50 percent of the plants produced silks in each plot.

Days to 90% maturity was recorded as the number of days from emergence to the date on which about 90 percent of the plants in a plot matured (ninety percent plants showed drying of cobs husk).

Plant height (cm): five plants were selected randomly from each net plot. Plant height was measured as the distance from the base of the plant to the height of the first tassel branch and average height was calculated.

Number of leaves per plant: Five plants were randomly selected from three central row of each net plot and counted and their average was worked out.

Number of cob per plant: Five plants were selected randomly and the total numbers of cobs were divided by the total number of plants harvested.

Number of grains per cob: five cobs in each net plot were randomly selected, and then number of grains in each cob were counted and averaged.

Thousands grain weight (g): Two samples of thousand grains had taken at random from each treatment then weighed by digital balance and average was recorded. The 1000 grain weights was weighed after testing seed moisture content by using seed moisture tester instrument at Ethiopia commodity exchange (ECX) office, Burie branch. The final dry weight of 1000 grains was computed using 12.5% as market standard seed moisture content of maize.

Grain yield (kg ha^{-1}): After sun drying, the cobs were threshed manually and yield was recorded on per plot basis, with moisture content 12.5 %, and then converted into kg ha^{-1}.

Above ground dry biomass yield (kg/ha): Plants from the net plot area were harvested at physiological maturity and weighed after sun drying.

Harvest index: The harvest index (HI) was computed as the ratio of grain yield (GY) to the total above ground Dry-mass (DM) yield.

Straw yield: was determined by subtracting grain yield from above ground dry biomass.

3.7. Data Analysis

The collected data were computed by Analysis of variance (ANOVA) using SAS statistical package program version 9.0 (SAS, 2004). All significant treatment means were compared using the least significant difference (LSD) test at 5% probability level Pearson correlation analysis was used to determine the relationship between major soil properties and yield and yield components of maize crop.

3.8. Economic Analysis

The mean grain data was adjusted down by 90% (to reduce the grain gap between experimental plots and farmers field) partial budget analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988).

The gross benefit was calculated as grain yield (kg ha^{-1}) multiplied by field price that farmers receive for the sale of the crop. Total variable cost is the sum of cost that has variable or specific to a treatment against the control. Net benefit was calculated by subtracting total variable cost from the gross benefit.

Analysis of marginal rate of return (MRR) was carried out for non- dominated treatments, and MRR were compared to a minimum acceptable rate of return (MARR) of 100% in order to select the optimum treatments to recommend for farmers. Marginal rate of return was calculated using the procedures described by CIMMYT (1988).

Marginal rate of return (MRR) = the change in NB dividing by change in TVC and multiply by hundred. Calculation of MRR is used to show acceptable rang. MRR below hundred is not acceptable range for developing countries like Ethiopia. A treatment having acceptable MRR and highest NB is said to be economically profitable and will be recommended for farmers (CIMMYT, 1988).

3.9. Agronomic Efficiency

The NPS, urea and lime fertilizer agronomic efficiency was calculated using the procedure described by Craswell and Godwin (1984) as: $AE\ \left(\frac{Kg}{kg}\right) = \frac{Gf\,(kg) - Gu\,(kg)}{Na\,(kg)}$, where; AE stands for agronomic efficiency, Gf and Gu for grain yield in fertilized and unfertilized plots, respectively, and Na for quantity of lime, Manure and NPS fertilizer applied.

4. RESULT AND DISCUSSION

4.1. Inherent soil Physicochemical Properties of the Experimental site

The results of soil analysis before planting maize are presented in Table 4.1. Before harvest bulk density (BD) of the soil was 1.42 g/cm^3 with clay texture (Figure 4.1 and Table 4.1). The highest BD value might be due to compactness of the soil, and lower organic matter content that resulted from continuous cultivation and removal of plant root and residues.This is supported by Assefa Derebe (2009) found that Compaction increases bulk density by decreasing soil pore space. It is an increase in bulk density and soil strength and a decrease in soil porosity by the application of mechanical forces to the soil. Based on this soil of the study area has higher BD as per the critical value rated by Ethiosis team analysis (2014) (Table 4.1). Bulk densities of soils are inversely related to the amount of pore space and soil OM (Brady and Weil, 2002 and Gupta, 2004).Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in a decrease of total porosity (Brady and Weil, 2002).

The soil reaction (pH H2O was highly acidic with value of 5.2 (Table 4.1). According to EthioSIS (2014) pH was classified as< 4.5: strongly acidic, 4.5-5.5: highly acidic, 5.6-6.5: moderately acidic, 6.6-7.3: neutral, 7.4-8.4: moderately alkaline,>8.5: strongly alkaline. Therefore, soils of the study area were strongly acidic, that are deficient in basic cations, which needs the application of lime for amendment.

The soil OC contents was 1.32% (Table 4.1), which is rated as very low (< 1.7%) to low (2-4%) based on the rating of soil test values interpretation by Landon (1991). Based on this result soil OC of the study area rated as very low as compared with critical value (3%). This might due to the removal of plant tissues and root residue from soil. For a soil to be productive, it needs to have organic carbon content in the range of 1.8-3.0% to achieve a good soil structural condition and structural stability (Charman and Roper, 2007).

The content of Total Nitrogen (TN) calso followed the trend of soil OCwhich had the content of 0.12% (Table4.1). According to EthioSIS (2014), TN rated as very low (< 0.1%), low (0.1-0.15%) and optimum (0.15-0.3%) Based on this ratings therefore, the study area had lower TN content. This minimum soil OC and TN values are expected in the maize-growing fields of the study area where there is complete removal of biomass from the field, lower application rate of fertilizers and continuous cultivation that favors rapid rate of mineralization (Abera Girma and Endalkachew, 2013).That is why it was treated with N source fertilizers to improve maize yield.

Available phosphorus before the application of lime and Manure fertilizer was very low (8.86 mg kg^{-1}) in the clay textured Nitisols of the study area (Table 4.1). The value is below the critical level of available P for maize (i.e 30 mg kg^{-1}) as per the rate suggested by EthioSIS (2014).This might be attributed to P fixation due to the acidic nature of the soil. The low application rates of P-containing fertilizers, continuous crop uptake, losses due to erosion and fixation by acidic soils in this maize-growing field of the study area might be linked to the inadequate P levels recorded in the studied soils.

The CEC value of Nitisols of the study area was 19.57 $cmol_c\ kg^{-1}$ which was rated as medium as per the ratings of Landon (1991). According to this author, soils having CEC of >40, 25-40, 15-25, 5-15, < 5 $cmol_c\ kg^{-1}$ categorized as very high, high, medium, low and very low, respectively Landon. (1991).The level of CEC could be associated with the texture of the soil which is clay. Clay soils have more cations as they have the caracterstics of increasing negative surface charges of a soil.

The laboratory result showed that the EC content of the study area before harvest was low (0.145%) (Table 4.1) Soils having EC of >15, 8-15, 4-8, <4dS/m categorized as very high, high, medium, low, respectively (Landon *et al*., 1991). Therefore, the study area soil was non-saline.

Table4.1. Soil physicochemical property status before improvement

Soil properties	Values	Critical values	Reference
Sand (%)	22		
Silt (%)	31		
Clay (%)	47		
Classes	Clay		
BD g/ cm^3	1.42	1.2 g/cm^3	ETosis,2014
pH (H_2O)	5.20	7.3	ETosis,2014
TN %	0.12	0.2%	ETosis,2014
Available P mg kg^{-1}	8.86	30 mg kg^{-1}	ETosis,2014
Organic carbon (%)	1.32	3%	ETosis,2014
Organic matter (%)	2.27	0.3%	ETosis,2014
CEC $cmol_c\, kg^{-1}$	19.57	15 $cmol_c\, kg^{-1}$	Landon ,1991
EC (dS/m)	0.145	4(dS/m)	ETosis,2014

4.2. Effect of Integrated use of Lime and Manure on soil Physico-chemical Properties

4.2.1. Change in soil bulk density (BD) afterharvest

Application of lime and organic fertilizer solely or in combination affected soil bulk density. Due to the application of lime, bulk density was reduced in all plots (Table 4.1, Table 4.2 and Table 4.3). However, the highest reduction (from 1.42 to 1.21 g/cm^3) was recorded in plots treated with 0.5 t ha^{-1} lime with 16 tone ha^{-1} Mnure. This might be due to the increasing effect soil organic matter (SOM) after harvest which makes the soil less compact and reduces the BD.

The result was in line with Tesfaye (2017) at Yilmana Densa district north western Ethiopia in maize.The result was similar also with Muhammad et al. (2013) who found lower bulk density as a result of nutrient and crop management on crops sugarcane, maize, sorghum, and cotton residues at Gatton, southern Queensland Australia. However, as Wondimu *et al*. (2006) reported the application of inorganic fertilizers alone had no significant effect on bulk density of the soil. The result was in agreement with Shirani *et al*. (2002) that reported significant decrease in soil

bulk density just after harvesting a maize field supplied with integrated use of soil fertilizers. Similarly, Onwonga *et al.* (2010) reported the positive effect of integrated use of lime, manure and mineral fertilizers on soil physical and chemical properties on maize production at the Kenya Agricultural Research Institute field station located 5 km from Molo Town in Molo District.

4.2.2. PH Change of soil after harvest

This experiment indicated that pH was affected by integrated nutrient management which was increased with the application of lime and Manure fertilizer as compared to the control (Table 4.1, Table 4.2 and Table 4.3).

In the sole application of Manure fertilizer, the highest (5.79) and lowest pH (5.55) was recorded in plots treated with 16 tone ha^{-1} and 4 tone ha^{-1} Manure, respectively (Table 4.2).This might be due to effect of nitrification on Manure fertilizers.Though Manure fertilizers increase crop yield, at the same time they also increase soil acidity.This is because when the nitrification process converts ammonium to nitrate, hydrogen-ions are released which is one the contributing factors leading to acidification. Hence, the application of inorganic fertilizers containing NH_4^+ or even adding large quantities of organic matter to a soil can ultimately increase soil acidity and lower the pH (Guo *et al.*, 2010). Similarly, Peter *et al.* (2018) found that pH of soil treated with Manure fertilizer was 5.21 as compared with control pH (4.92) in acidic soils of Western Kenya on the Maize crop.

On the otherhand, the sole application of lime effectively increased the soil pH from 5.2 to 6.45 (Table 4.2). This rise in pH of soil is associated with the presence of basic cations (Ca^{2+}) and anions (CO_3^{2-}) in lime that are able to exchange H^+ -ions from exchangeable sites to form (H_2O + CO_3^{2-}). The increase in soil pH resulting from the application of lime provides a more favorable environment for soil microbiological activity which increases the rate of release of plant nutrients, particularly Manure. Reduced acidity due to liming increased the availability of other plant nutrients mostly phosphorus (Kebede Dinkecha and Dereje Tsegaye, 2017).The result was in line with Peter *et al. (*2018) that reported increased soil pH (5.26) after the application lime as compared to the control that had a pH value of 4.92 in acid soils of Western Kenya Similarly, Woubshet Demissie (2017) found increased soil pH after the application of lime,

where it was changed from extremely acidic pH of 3.8 to medium and neutral pH of 6.63-6.86 in acid Soils of Wolmera District, West Showa, Ethiopia. Ethiopia.

This result was also supported by Waluchio *et al.* (2015) who reported the effect of lime in raising the soil pH and increase the availability of soil P by unlocking the soil fixed P into available P for crop use. Lime increases availability of other nutrient elements mostly basic cations essential to crop use especially calcium which forms plant structure (Kebede Dinkecha and Dereje , 2017).

Combined application of lime and Organic fertilizer improve soil pH. The highest pH (6.85) was recorded from plots treated with 0.5 t ha^{-1} lime with 4 tone ha^{-1} Manure (Table 4.2). This is due to the dissociation of Manure which releases NH_4^+, so plants take NH_4^+ and release HCO_3^- which reacts with H^+ and form H_2CO_3 acid. This acid is a weak acid and dissociates into H_2O and CO_2. So, CO_2 released to atmosphere water stays in the soil increasing pH by decreasing H^+ ion concentration in the soil solution.On the other hand, dissolution of minerals as ($CaCO_3$) dissolved with H_2O into Ca^{2+} which can be taken by the plant from the soil solution and release CO_3^{2-} to the soil. Then after plant release equivalent OH^- to the soil. The increase in OM also increases pH since it can minimize the H^+ from soil solution by forming an organic complex. (Dereje, 2017).

This result is supported by Peter *et al.* (2018) that indicated the integrated effect of lime and Manure fertilizer in increasing soil pH in acid soils of Western Kenya. Similar increases in pH using integrated soil fertility management have been reported by Whalen *et al.*, (2002); Moreira and Fageria, (2010) and Buni, (2014). This was due to the application of lime integrated with Organic fertilizers.

4.2.3. Change in soil organic carbon (OC)

The highest OC content (2.45%) was recorded in plots treated with 0.5 t ha^{-1} limes with 8 tone ha^{-1} Manure which was an increase by 54.69% from the initial soil OC analysis result (1.32%) (Table4.1, Table 4.2 and Table 4.3).The increase in SOC could be associated with decomposition of dead plant tissue like root and leaves the addition of plant biomass after the addition of lime.
The finding was similar with Antill *et al*. (2001) whofound higher OC after crop harvest after the

application lime integrated with Organic and inorganic fertilizers. Besides, Sharma and Subehia (2003) also reported greater levels of soil organic carbon under integrated treatments of lime with inorganic fertilizerin acidic soil in the western Himalayas on maize crop. In a similar study Tadesse Moges *et al.* (2018) reported increased amounts of OC from 2.23 %, to 2.49 % after the application of lime with integrated inorganic feretilizers in the malt barley crop in Angolela Tera district.On the other hand the combined use of lime and P fertilizer increased SOC to 2.27 after harvesting of malt barley in one growing season in Angolela Tera district (Tadesse *et al.*, 2018). However, the sole application of lime reduced SOC from 1.32% to 1.29%. This is supported by Tadesse Moges *et al.* (2018) found in sole application of lime 4 t ha^{-1} and 6 t ha^{-1} SOC was 2.12% and 2.07%.

4.2.4. Total Nitrogen (TN) content after harvest

The maximum TN (0.225%) was recorded in treatment eight, i.e in plots treated with 0.5 t ha^{-1} of lime and 12tone ha^{-1}Manure. The lowest TN (0.124%) was recorded in the control plots. (Table 4.1, Table 4. 2 and Table 4.3).

After the integrated application of lime with Organic fertilizers, the highest and the lowest values of TN was 0.225% and 0.205%, respectively.This highest TN was seen in treatment T8 i.e 0.5 t ha^{-1} of lime and 8tone ha^{-1} Manure. Hence, it is clear that the application lime with Organic and inorganicfertilizers increased TN, which may be attributed to mineralization of N from OM during decomposition of organic matter. Generally, the combined application of lime and mineral fertilizers at different rates affects the contents of total nitrogen in the study area.

The result was supported by Fassil and Yamoah (2009) who reported an increased amount of TN in the Vertisols of the Central highlands after the application of lime with Organic fertilizers. An increase in TN after the application of organic integrated with inorganic fertilizers has also been reported by different authors elsewhere in Ethiopia (Getachew Agegnehu and Taye Bekele, 2005; Muhammad *et al*., 2013).

4.2.5. Change in available phosphorus after harvest

In the sole application of Organic fertilizer, the highest and the lowest available phosphorous was 26.04 mg $kg^{-1}$and 15.28 mg kg^{-1} recorded in treatments T5 and T2 respectively, (Table 4.1, Table 4.2 and Table 4.3).

After the combined application of lime and Manure, the maximum and the minimum values of available phosphorous content was 30.43 mg kg^{-1} and 22.84 mg kg^{-1} in treatments T10 and T7 respectively.Thus the combined use of lime and Organic fertilizers increased the available P content in the soil by mineralization or solubilizing of the native P reserves in clay soil. As a result, soil available P after harvest was much higher than initial levels in the lime treated plots. Therefore the major benefits of liming acid soils are the increased utilization of residual fertilizer phosphorus by crops.

Table4.2. Soil physico-chemical properties change after improvement

Soil properties	Values before treatment	Mean Values after treatment	Change	Change Percentage (%)
BD g/ cm^3	1.42	1.29	-0.13	-9.15
pH (H_2O)	5.20	6.15	0.95	15.45
TN %	0.12	0.186	0.066	35.48
Available P mg kg^{-1}	8.86	21.87	13.01	59.48
Organic carbon (%)	1.32	1.84	0.52	28.26
Organic matter (%)	2.27	3.15	0.88	72.06
CEC $cmol_c\ kg^{-1}$	19.57	27.07	7.5	27.7
EC(ds/m)	0.145	0.14	-0.005	-3.57

The incorporation of lime has been shown to increase the amount of soluble organic matter which were mainly organic acids that increase the rate of desorption of phosphate and thus improves the available Phosphorous content in the soil (Zsolnay and Gorlitz, 1994) Similarly, Kimiti (2018) showed an increase in soil available P after the application of lime, combined

with manure and P fertilizer. Generally, the application of lime and Organic fertilizer gave increased P content.

The result was inline with Gawai (2003) and Tesfaye Bayu (2017) who showed that Combination of compost with Organic fertilizer helped in increasing the available P in the soil by mineralization or solubilising the native P reserves in Yilmana Desnsa district, Northwestern Ethiopia.

4.2.6. Change in Cation exchange capacity after harvest

In the sole application of Organic fertilizer, the highest CEC was 23.36 $Cmol_c\ kg^{-1}$ and the lowest 22.19 $Cmol_c\ kg^{-1}$ in treatments T5 and T2 respectively (Table 4.1, Table 4.2).This might be due to increased pH, so do the number of negative charges on the clay or organic matter particles, and thus increase CEC. Similarly, Tesfaye Bayu (2017) found an increase in CEC value after the application of Organic fertilizers in the soils of Yilmana Desnsa district.

Similarly after the application of lime alone, CEC was increased from 22.17 cmolc kg^{-1} to 27.25 cmolc kg^{-1} in treatments T1 and T6 respectively .This increase in CEC may be due to an increase in pH that increase the negative surface charges on the soil colloids which subsequently increase the cation holding capacity or CEC of the soil. Similarly, Buni (2014) higher values of CEC after lime treatment. Likewise, Getachew Agegnehu et *al.* (2019) found the highest (values of CEC in soils treated with the highest lime rate (3.75 t ha^{-1}).

Besides, in the combined application of lime and Organic fertilizer, the highest and lowest CEC value was 35.38 $cmol_c\ kg^{-1}$ and 31.43 $cmol_c\ kg^{-1}$ recorded in treatments T10 and T7 respectively. (Table 4.2) with mean value of 27.07 cmolc kg^{-1}.This indicates that the combined application of lime and Organic fertilizer increased CEC so as to hold higher amount of nutrients and that readily available to plants. This change was the result of addition of cations from Organic fertilizer and lime.

The result was in compliment with Fassil Kebede and Yamoah (2009) who found high CEC due to an increase in OC and OM after treatment of lime and Organic fertilizer. The result was

similar to Getachew Agegnehu *et al*. (2014) who found higher CEC value due to integrated nutrient management.

4.2.7. Electrical conductivity content of soil after harvest

The application of lime, Manure and their interaction does not affect EC value (Table 4.1, Table 4.2 and Table 4.3).

In the sole application of lime, EC was 0.138 dS/m. In the combined application of lime and Organic fertilizer, the highest and lowest EC value was 0.136 ds/m and 0.131 dS/m (Table 4.2).Similarly, Woubshet Demssie *et al.* (2017) found that integrated use of lime and Organic fertilizer (0.611t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl +36 kg N ha^{-1}) reduce EC of soil from 0.14dS/m lime alone to 0.11dS/m than the control plot (0.07dS/m). This result was in line with Yuli *et al.* (2016) the effects of lime; Manure fertilizers and their interaction on soil EC were not significantly different.

Table4.3. Effect of lime and Manure on soil physicochemical properties after nine months of lime incorporation

	Soil physicochemical properties							
Treatment	BD (g/cm^3)	pH (H_2O)	SOC (%)	OM (%)	TN (%)	Available P (mg/kg)	CEC ($cmol_c\ kg^{-1}$)	EC (ds/m)
T1	1.4	5.54	1.33	2.29	0.124	12.24	22.17	0.140
T2	1.39	5.55	1.36	2.34	0.169	15.28	22.19	0.142
T3	1.37	5.57	1.39	2.39	0.147	16.30	22.64	0.144
T4	1.35	5.65	1.59	2.73	0.130	17.78	22.68	0.143
T5	1.32	5.79	1.86	3.18	0.126	26.04	23.36	0.143
T6	1.26	6.45	1.29	2.22	0.172	18.60	27.25	0.138
T7	1.24	6.59	2.23	3.84	0.205	22.84	31.43	0.136
T8	1.23	6.71	2.45	4.21	0.225	24.73	33.21	0.134
T9	1.22	6.76	2.41	4.15	0.222	25.62	34.46	0.132
T10	1.21	6.85	2.39	4.11	0.221	30.43	35.38	0.131
Mean	1.29	6.15	1.84	3.15	0.186	21.87	27.07	0.14

*T1-control (*100 kg ha^{-1} NPS)*; T2- NPS (100 kg ha^{-1}) + Manure (4 toneha^{-1}); T3- NPS (100 kg ha^{-1}) + Manure (100 kg $ha^{-1)}$; T4- NPS (100 kg ha^{-1} + Manure (12tone ha^{-1});T5- NPS (100 kg ha^{-1}) + Manure (16 tone ha^{-1}) ;T6-Lime (500 kg ha^{-1}) +NPS (100 kg ha^{-1});T7- Lime (500 kg ha^{-1}) + NPS (100 kg ha^{-1})+ Manure (4 tone ha^{-1});T8- Lime (500 kg ha^{-1}) + NPS (100 kg ha^{-1})+ Manure (4 tone ha^{-1});T9- Lime (500 kg ha^{-1}) + NPS (100 kg ha^{-1})+ Manure(12tone ha^{-1});T10- Lime (500 kg ha^{-1}) + NPS (100 kg ha^{-1})+ Manure 16 tone ha^{-1})*

4.3. Effect of Integrated use of Manure and Lime on Yield and Yield Components of Maize

4.3.1. Effect of Manure fertilizer and lime on moropho-phenological parameters

4.3.1.1. Days to 50% tasselling

The ANOVA revealed that the application of lime and Manure ($P \leq 0.01$) and the interaction effect ($P \leq 0.05$) significantly affected days to 50% tasselling of maize (Apendix Table1).

The tasseling period increased as the Manure level decreased and the maximum days to 50% tasseling was 91 days that was recorded under 0 tone Manure ha^{-1}. Whereas, the minimum 50% tasseling was 85 days that was recorded in the plot treated with 16tone Manure ha^{-1} (Table 4.4). This might be due the uptake more Manure by the maize plant for growth as tasseling time is affected by the amont of Manure in the soil.Thus with an increase in Manure rate the availability of nutrients in the soil increased. This condition might lead to uniform flowering.

These results were inline with Begizew Golla (2018) that reported a decrease in days of 50% tasseling from 82.44 to 80.89 days in the maize crop when the nitrogen rate was increased from 0 kg N ha^{-1} to 115 kg ha^{-1}.This result is also in consistent with the finding of Shrestha (2013) who observed the earlier days to tasseling in the maize crop treated with increased rates of nitrogen.

The delaying of flowering date in response N deficiency has been previously acknowledged by different researchers (Tollenaa *et al.,* 1997; Gozubenli, 2010; Shrestha, 2013; Jassal *et al.,* 2017). Brady and Nyle (1984) also explained that, in addition the direct nutritional role to the plant, the deficiency of nitrogen affects the optimum and efficient utilization of other elements in the soil if. However, the result of this study disagreed to Imran *et al.* (2015) that reported a consistent increase in days to 50% tasselling due to the prolonging vegetative growth period, when the rate of nitrogen applied increased.

Similarly the Sole application of lime ($CaCO_3$) had a significant ($P \leq 0.01$) effect on days to 50% tasselling between treatments. The minimum tasselling period was 87 days as compared with the control (i.e 89 days) (Table 4.4).

The analysis also showed that, the maximum and minimum tasselling period was 88 days from plots treated with 0.5 t ha^{-1} lime and 4 tone ha^{-1} Manure (i.e treatment T7), and 85 days was recorded in 0.5 t ha^{-1} lime and 6 tone ha^{-1} Manure (i.e treatment T10) (Table 4.5). This might be due the uptake of most of the calcium by plants that come from the exchangeable Ca and nitrogen from Manure.

This result was agreed with Negash Teshome (2018) who reported the significant ($P \leq 0.001$) influence of the interaction of lime and potassium on the number of days required for 50% flowering on the soybean crop on acidic soil in Gobu sayo district, western Ethiopia.furthermore, Woubshet Demissie *et al.* (2017) found synergistic effect of applied lime and Organic plant nutrient sources and highly influenced phonological parameters of Barely on acid soils of Wolmera District, West Showa, Ethiopia.

Table4. 2. Moropho-phenological parameters influenced by as main effect of lime and Manure

Main effect	DT (day)	DS(day)	DM(day)
Manure levels (tone ha^{-1})			
0	91.16[a]	95.17[a]	143[c]
4	88.50[b]	93[b]	146.33b
8	87.50[c]	91[c]	146.50[b]
12	86.33[d]	89.67[d]	147.67[a]
16	85.66[e]	89[d]	148.33[a]
Mean	87.83	91.5	146.36
LSD (0.05)	0.506	0.484	0.672
CV	0.539	0.564	0.304
SE±	0.26	0.26	0.508
P	**	**	**
Lime (kg ha^{-1})			
0	88.53[a]	92.86[a]	146.2[a]
500	87.13[b]	90.26[b]	146.533[a]
LSD	0.32	0.306	0.42
CV	0.539	0.564	0.304
SE±	0.09	0.092	0.508
P	**	**	*

DT=Days to 50% tasseling, DS=days to 50% silking, DM=Days to 90%maturity, CV: Coefficient variation and LSD=least significance difference, Means within column followed the same letter are not significantly different at 5% probability level,, significantly different at $p<0.05$, **highly significantly different at $p<0.05$*

Table4. 3. Mean moropho-phenological parameters as influenced by the interaction effect of lime and Manure

Interaction effect			Growth parameters		
Lime	Manure fertilizer rate	Treatments	DT(day)	DS(day)	DM(day)
	M0	T1	92.33[a]	96.33[a]	143.67[e]
L0	M1	T2	89[c]	95[b]	146[d]
	M2	T3	88[d]	92[d]	146[d]
	M3	T4	87[e]	91[e]	147.66[b]
	M4	T5	86.33[ef]	90[f]	147.67[b]
L1	M0	T6	90[b]	94[c]	142.33[f]
	M1	T7	88[d]	91[e]	146.66[cd]
	M2	T8	87[e]	90[f]	147[cb]
	M3	T9	85.66[fg]	88.33[g]	147.66[b]
	M4	T10	85[g]	88[g]	149[a]
Mean			87.83	91.56	146.36
LSD			0.7157	0.68	0.95
SE±			0.21	0.252	0.333
CV			0.475	0.43	0.37
P			*	**	**

*DT=Days to 50% tasseling,DS=days to 50% silking, DM=Days to 90% maturity, LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letters in a column are not statically different at p<0.05.*

4.3.1.2. Days to 50% silking (DS)

The ANOVA revealed that the main effect of Manure, lime, and their interaction effect significantly (P≤0.01) affected days to 50% silking (Appendix Table 2). Similar to days to tasselling, days to silking were delayed with nitrogen deficiency.

In the sole application of Manure, the early DS (89 days) was recorded in the 16 tone ha^{-1} Manure treated plots (Table 4.4). Days to 50% silking were decreased with an increase in Manure rates. This decrease in the silking period in response to the increase in the Manure rate might be associated with hastiness in growth period and promoting silk extrusion. Time of silking is the critical stage of plant growth next to tasselling for effective fertilization and kernels development after flowering (Reference). Thus, the factors that affect silking and duration of silking may affect the period of physiological maturity as well as grain production of maize.

The result was agreed with Begizew Golla (2018) that reported decreased days to 50% silking when rate of nitrogen added increased from 0 kg N ha^{-1} to 115 kg ha^{-1} maize crop at Bako, Western Ethiopia. Similarly, Dawadi and Sah (2012) and Jassal *et al.* (2017) reported an increase in the earliness of tasselling and silking stages after an increase application of Manure fertlizers on mize crop in Nepal, Tropical Agricultural Research.

However, there has been some controversy regarding the phenological parameters of maize. According to Imran *et al.* (2015) and Sharifi, and Namvar (2016) maize took more time to tasselling and silking in plots that received the highest rate of nitrogen fertilizer in on maize in acidic soils.This is also agreed with Raouf and Ali Namvar (2016) that found the maximum days to 50% silking (68.2 days) after the application of 225 kg N ha^{-1}, after three split applications of N fertilizer.

With regarding to the effect lime, the maximum days to 50% silking (92 days) was recorded in the control and early DS (90 days) was recorded in plots treated with 0.5 t ha^{-1} lime. This might be due to the delaying effect of tasselling.

The statistical analysis also indicated that the maximum (91 days) and minimum (88 days) DS was recorded in plots treated with 0.5 t ha^{-1} lime and 4 tone ha^{-1} Manure as compared with control DS (94 days) (Table 4.5).

This result was agreed with Kumar *et al.* (2018) and Habtamu Yigermal *et al.* (2019) that showed the significant influence of fertility management on days to silking on maize crop in central plain zone of Uttar Pradesh, India and Ethiopia respectively. Based on Abdissa Bekele *et al.* (2018) works days to silking were also hastened with the application of 5 t vermicompost ha-

1 and 20 kg P ha^{-1} with lime. Likewise, Amanullah Khalid (2015) also recorded delayed (68 days) of silking was after the application of cattle manure (5 t ha^{-1}) with phosphorus (160 kg P ha^{-1}) and with or without NPSB.

4.3.1.3. Day to 90% maturity

The effect of Manure had significantly ($p \leq 0.01$) affected days to 90% maturity while lime rate had significant ($p \leq 0.05$) effect on days to 90% maturity but their interaction had highly significantly ($p \leq 0.01$) affected days to 90% maturity (Appendix Table 3).This indicates that increasing the Manure rate significantly increased the number of days to physiological maturity.

The maximum days to attained 90% physiological maturity were recorded under maximum Manure rate (16tone ha^{-1}) which was 148.33 days, but statistically similar days (147.66) to 90% maturity were recorded under application 12 tone ha^{-1}.The shortest day to attained 90% physiological maturity was obtained in control plots (143) days (Table 4.4). As the Manure rates increased, the days to physiological maturity was also numerically increased. This might be higher nitrogenous fertilizer delays the senescence of leaves and plant remained more prolong as green stage this could increase the days required to attained physiological maturity.

This result agreed with Shrestha (2013); Sharifi and Namvar (2016); Anwar *et al.* (2017) and (Begizew Golla, 2018) who reported the delay in the process of physiological maturity with the increasing rate of N application in the maize crop. Similarly, Dawadi and Sah (2012) reported that increasing the nitrogen level from 120 kg ha^{-1} to 200 kg ha^{-1} decreased the tasselling, silking, and anthesis-silk interval but increased the physiological maturity and seed fill duration of maize crop. This result is also agreed with Rosan *et al.* (1997) who explained that the application of N has hastened early germination in maize.

In the sole application of lime, the maximum (147 days) to maturity was recorded from plots treated with 0.5 t ha^{-1} lime while the shortest (146 days) from the control.

The analysis showed that, days to 90% maturity was affected by the interaction effect of lime and Manure. The shortest (144) days to maturity was recorded from the control and the longest (149) days to 90% maturity was recorded from plots treated with 0.5 t ha^{-1} lime and 16 tone ha^{-1}

Manure(Table 4.5). This is due to the availability of nitrogen in the soil from Manure fertilizer.This might be to increase shoot growth, leave to be green, and maximizes the number of days required to be matured.This might be because of increasing nitrogen from Manure and Ca^{2+} from lime enhances days to maturity (Brady and Weil, 2002). As the rate of Organic fertilizer and lime increased days to 90% maturity was decreased.The result also inline with Rahman *et al.* (2012) who reported maximum maturity by combining compost and mineral fertilizer.According Abdissa Bekele *et al.* (2018), physiological maturity was significantly extended by applications of lime, vermicompost and chemical P fertilizeron the maize crop in Ebantu District, Western highlands of Ethiopia.

4.3.2. Effect of manure fertilizer and lime rates on vegetative growth parameters

4.3.2.1. Plant height

The analysis of variance showed that the plant height of maize was highly significantly ($p \leq 0.01$) affected by the application of Manure and lime but significantly affected by by the interaction of the two ($p \leq 0.05$) (Appendix Table 4).

The maximum mean plant height was recorded from plots treated with 16 tone manure ha-1 (349.33cm) and the minimum mean plant height was recorded from control plots (250cm) (Table 4.6). The mean plant height of maze maize was significantly increased with an increased of Manure fertilizer rates. This was due to increased soil organic matter as well as the plant can take nitrogen nutrient from Manure.

The result agreed with Yihenew G.Selassie (2015) that reported that the variance invaration in plant in plant height in the later stages of plant growth than in the earlier stages. Due to the application of higher accounted by the applied N fertilizer nitrogen fertilizers was higher in the maize crop on Alfisols of North-western Ethiopia later stages of plant growth than in the earlier stages. Similarly, Alam *et al.* (2003); Ghafoor (2016) and (Tolcha Tufa, 2018) reported the significant increase of that thethe maize plant height significantly increased with rising an increase of nitrogen fertilizer application rates. The result was also coincide coincides with Adekayode and Ogunkoya (2010) who explained that there was a very high significant

difference in maize plant height in plots treated with high fertilizers compared with the control. A similar result was reported by Ghafoor and Akhtar (1991) who stated that the application of high N rates had a significant effect on plant height of maize.

Likewise, Abera Kechi (2013) reported that an increase in N ratesrates extended vegetative growth period of maize that and increases photosynthetic assimilate production and its partitioning to stems that might have favorable impacts on heights of maize.

Plant height was affected bylime rate. The highest mean plant height (306cm) was recorded from plots treated with 0.5 t ha^{-1} lime and the lowest (291.4cm) was from the control. The result is agreed with Woubshet Demissie (2017) that reported increased plant height of barley that after application of lime with balanced fertilization increased plant height by 24cm compared to balanced fertilizer sole application (68 cm) of Barley. Similarly, Getachew Agegnehu (2009) reported that, the use of organic manures in combination with mineral fertilizers maximized the plant height of Faba Bean and Wheat crop in Nitosols than the application of Organic fertilizers alone.

In the combined application, the maximum (352.3cm) plant height was recorded from plots treated with 0.5 t ha^{-1} lime with 16 tone ha^{-1} Manure, and minimum (287cm) was recorded from plots treated with 0.5 t ha^{-1} with 4 tone ha^{-1} Manure (Table 4.7). This might be a synergetic effect of Manure and lime. Increased plant height with the increasing rate of lime and Manure fertilizer rate might be due to the addition of Ca^{2+} nutrient and reduce P fixation and, reduce Al^{3+} and H^{+} ion from the soil, improve CEC, aeration, root penetration, water storage capacity of the soil (Rehman *et al.,* 2012).This is in line with the finding of Mitiku Weldesenbet *et al.* (2014) who found a significant effect of the combined application of organic and inorganic fertilizers on plant height. Likewise, Woubshet Demissie (2017) reported that the integrated application of lime with inorganic fertilizer and compost had a significant effect on Barley plant height.

4.3.2.2. Number of leaves per plant (NLPP)

The analysis of variance revealed that Number of leaves per plant (NLPP) was highly significantly ($p \leq 0.01$) affected by the application of Manure and lime as well as the interaction of

the two (Appendix Table 5).

The maximum mean number of leaves (14) were recorded in plots treated with 16 tone ha^{-1} while the smallest mean number (9.5) of leaves were observed from the control (Table 4.6). The photosynthetic activity of a plant which influences growth and yield of the crop is also determined by the number of leaves on a plant. Therefore, the increase in the number of leaves with an increasing rate of Manure application could be due to the positive effect of N on vigorous vegetative growth and inter-nodal extension.

This result was in line with Adekayode and Ogunkoya (2010) who explained a significant difference in height and number of leaves per plant in maize crop as in plots treated with higher fertilizer ratess as compared with control. This increase in number of leaves in response to higher rates of nitrogen has been confirmed in the findings of Wajid *et al.* (2007), Gokmen *et al.* (2001),Woldesenbet and Haileyesus (2016) and Tesfaye Bayu (2017), that reported increased height and number of leaves of maize plant with increasing nitrogen fertilizer rates .

Regarding to the effect of lime, the highest NLPP was 12.7 recorded from plots treated with lime and the lowest was from the control. The resut was in line with Hassan *et al.* (2007) that reported increased growth and development of maize plants after the application of 0.25 t ha^{-1} lime; since lime increased the uptake of nutrient elements especially phosphorus,leaf production increased linearly from absolute control to application of 0.25 t ha^{-1} lime and diminished. Hassan *et al.* (2007) shows that production of maize forage for livestock production can be achieved at this optimum level (0.25 t ha^{-1}).

Similarly, the analysis indicated that there was a significant increasing in the number of leave per plant ($P \leq 0.01$) (Table 4.7). The maximum (14.67) NLPP was recorded from plots treated with 0.5 t ha^{-1} lime and 16 tone ha^{-1} Manure while the minimum (11.33) mean NLPP was recorded from plots treated with 0.5 t ha^{-1} lime and 4 tone ha^{-1} Manure (Table 4.7). This result also agreed with Woubshet Demissie (2017) that recorded higher number of effective tillers of Barley and NPKS due to the synergetic effect of lime, organic and inorganic fertilizers on acidic soils of Wolmera district West Showa.

Table4.4. Effect of Manure and lime rates on vegetative parameters as influenced by the main effect

Treatments	PH(cm)	NLPP
Manure levels (tone ha^{-1})		
0	250^{e}	9.50^{e}
4	275.83^{d}	10.83^{d}
8	290.33^{c}	12.17^{c}
12	328.33^{b}	13.5^{b}
16	349.33^{a}	14^{a}
Mean	298	12
LSD (0.05)	0.077	0.411
SE±	0.035	0.173
CV	2.89	3.52
P	**	**
R value	0.981	0.962
Lime (kg ha^{-1})		
0	291.46^{b}	11.27^{b}
500 kg ha^{-1}	306.06^{a}	12.73^{a}
Mean	298.77	12.00
LSD (0.05)	0.049	0.259
SE±	0.022	0.109
CV	2.89	3.52
P	**	**
R value	0.981	0.962

*PH=plant height, NLPP=number of leaves per plant, CV= Coefficient of Variation, p=probability level; ** significantly different at p<0.05. Means followed by the same letter in a column are not significantly different at 5 % probability level by DMRT*

Table4.5. Mean vegetative parameters as influenced by the interaction effect of lime and Manure fertilizer

Interaction		Growth parameters		
Lime	Manurefertilizer rate	Treatments	PH (cm)	NLPP
	M0	T1	251^{g}	9f
L0	M1	T2	264.66^{f}	10.33^{e}
	M2	T3	276.33^{e}	11.33^{d}
	M3	T4	319^{c}	12.33^{c}
	M4	T5	346.33^{ba}	13.33^{b}
L1	M0	T6	249^{g}	10^{e}
	M1	T7	287^{e}	11.33^{d}
	M2	T8	304.33^{d}	13^{b}
	M3	T9	337.66^{b}	14.67^{a}
	M4	T10	352.33^{a}	14.67^{a}
Mean			298.00	12
LSD (0.05)			0.109	0.58
SE±			0.039	0.189
CV			2.14	2.823
P			*	**
R- value			0.983	0.9805

*PH=plant height, NLPP=number of leaves per plant, CV= Coefficient of Variation, p=probability level; ** =highly significantly different at p<0.01, * = significantly different at p<0.05. Means followed by the same letter in a column are not significantly different at 5 % probability level by DMRT*

4.3.3. Effect of urea fertilizer and lime rates on yield components

4.3.3.1. Number of cobs per plant (NCPP)

Numberof cobs perplant were significantly affected ($p \leq 0.01$) by the main effect of Manure and lime. The interaction of Manure fertilizer and lime rate had also a significant effect on the number of cobs ($p \leq 0.01$) (Appendix Table 6).

The maximum (2.87) mean number of cobs was recorded from plots treated with 16 tone ha^{-1} Manure and the minimum (1.37) observed from control (Table 4.8). The improvement of soil conditions through lime and Manure fertilizer might be responsible for better cob production.

These results were in line with the findings of Malaiya *et al.* (2004) who concluded that N fertilizer treatments produced higher cobs. Similar result was also reported by Raisi and Nejad (2012); Shahid *et al.* (2016) and Tesfaye Bayu (2017) who found, higher number of cobs per plant from plots treated with increased Manure fertilizer rate. Similarly, Yihenew G.Selassie, (2015) indicated increased number of ears per plant of Maize on Alfisols of Northwestern Ethiopia (from 0.993 to 1.077) as N rate increased from 0 kg ha^{-1} to 200 kg ha^{-1}. Inaddition he reported a significant increase in yield parameters as the rate of application increased to 90 kg N ha-1 in Northwestern Ethiopia.

In the sole application of lime, the maximum numbers of cobs (2.327) were recorded from plots treated with 0.5 t ha^{-1} (Table 4.8). This might be due to the involvement Ca supplied in the form of lime in cell growth and division, membrane permeability, enzyme activation protection of cells against toxicity from other elements.

This result agreed with Kisinyo *et al.* (2005) who explained about the effect of lime application in the soil acidity neutralization, reduction of toxicity levels of Al, Fe and Mn, and its role in the improvement of physiological, chemical and biological properties of soils;. Moreover, the application of lime improves soil productivity by providing Ca, Mg and availability of P which in turn improve crop performance. Meaningless! Rewrite or removeThe interaction effect indicated thatthe maximum (2.93) NCPP was recorded from plots treated with 0.5 t ha^{-1} lime and 16 tone ha^{-1} Manure while the minimum (1.96) from plots treated with 0.5 t ha-1 lime with 4 tone ha^{-1} Manure (Table 4.9).

This might be the result of the synergetic effect of nitrogen and Ca. This result was in line with Kimiti Winnie (2018) who found improved crop yield of Maize after the combined application of lime, manure and mineral fertilizers as compared with the sole application of mineral fertilizers, lime, and manure. Similarly, Wagh (2002) reported significantly higher cobs of sweet Corn plant after the application of recommended rates of NPK (225:50:50 kg ha^{-1}) with 5 t FYM ha^{-1} and Azotobacter with PSB in India. However the result was disagreed to Ali *et al.* (2012) that reported insignificant differenc in the number of ears per plant of Maize crop after application of compost with nitrogen fertilizer

3.3.2. Number of grains per cobs (NGPC)

The number grains per cob (NGPC) were significantly affected ($p \leq 0.01$) by the main effect of Manure and lime (Table 4.8).The interaction of Manure fertilizer and lime rate had a significant effect on the number of grains per cobs ($p \leq 0.05$) (Table 4.9 and (Appendix Table 7).

The maximum (517) NGPC was recorded from plots treated with 16 tone ha^{-1} Manure as compared with the control NGPC (469) (Table 4.8). This is in line with Yihenew G. Selassie (2015) reported that, Manure fertilizer rates significantly ($p<0.05$) affected grain number per cob and number of cobs per plant. Similarly, Yihenew G.Selassie (2015) reported a significantly higher number of kernels per ear and ears per stand in plots treated with higher fertilizer rates carried as compared to the treatments with lower fertilizer rates Li.The reports of Abera Kechi (2013) indicated also increased kernel weight in maize after the application of higher rates of manure fertilizers. The number of harvestable kernels per ear to be an important contributor to the grain yield potential of maize plant (NSeilson, 2003).

In the sole application of lime, the maximum (501.706) NGPC was recorded from plots treated with 0.5 t ha^{-1} lime compared with control NGPC (498.7) (Table 4.8). This might be due to involvement of calcium in cell growth and division. This result agreed with Woubshet Demssie *et al.* (2017) where he reported increased number of kernels of malt barley after the application of 611 kg ha^{-1} lime on Barley on acidic soils of Wolmera District West Showa Ethiopia.

The ANOVA table indicates that the maximum NGPC (518.1) was recorded from plots treated with 0.5tha^{-1}lime and 16tone ha^{-1} Manure while the minimum NGPC (496.5) was recorded from plots treated with 0.5 ha^{-1} lime and 4tone ha^{-1} Manure (Table 4.9). This indicates that treatments with higher fertilizer rates applied with 0.5 t ha^{-1} lime supported a significantly higher number of grains per cob as compared to the treatments treated with lower fertilizer and lime rates.This high increase in grain number per cob with the increase of manure and lime rate might be due to the synergistic effects of fertilizers that improved nutrient use efficiencies and normal development of maize.

4.3.3.3. Thousands-grain weight (TGW)

The ANOVA showed that, TGW was significantly affected by Manure, lime, and combination of the two factors ($p \leq 0.01$) (Appendix Table 8).

The maximum TGW (405.36g) was recorded in plots treated with 16 tone ha^{-1} Manure and the minimum TGW (377.53g from the control. In the recommended rate of Manure fertilizer TGW was 392.06g. This might be due to the better availability of nutrients (Table 4.8) and the accelerated mobility of photosynthesis from the source to the sink as influenced by the growth hormones synthesized after application of Organic fertilizer (Table 4.8).

This is agreed with Anuradha (2003) that reported higher increase in TGW due to the synergistic effects of integrated application of manure and lime that increased growth and grain filling of maize crop in the Angrau, Hyderbad, India.. Similarly, higher values of 1000 grain weight was found in the Maize crop after the application higher doses of nitrogen in Nigeria reported by Onasanya *et al* (2009). The same result was reported by Begizew Golla (2018) where TGW of Maize crop increased from 340.89g to 353.56 g as N fertilizer rates were increased from 92 kg ha^{-1} to 115 kg ha^{-1} at Bako, Western Ethiopia. There was also significant ($p \leq 0.01$) and strong positive correlations between TWG and grain yield, and total above ground dry biomass (Table 4.8 and Table 4.10).

On the other hand lime had also a significant effect on TGW. The maximum mean TGW (402.37 kg ha-1) was recorded from plots treated with 0.5 t ha^{-1} lime than the control TGW (380.95 kg ha-1). This might be due to the positive correlation of Ca^{2+} with TGW (r=0.952) (Table 4.9). This is in line with the study of Woubshet Demssie *et al.* (2017) whofound the highest TGW of malt barley (36.52g) after the application of 611 kg ha^{-1} lime as compared with control (9.27g).

Combined application of lime with Manure had a significant effect on TGW (Table 4.9). The maximum TGW of maize (417.197g) was obtained from plots treated with 0.5 t ha^{-1} lime and 16 tone ha^{-1} Manure while the lowest TGW (369.57g) was recorded from the control plots compared to the sole application of lime TGW (385.49g) (Table 4.9).Such higher increase in TGW might be due to the synergistic effects of the combined fertilizers for better growth and grain filling of maize. The lowest TGW could be due to shrunken seeds that have small size which contributed to the less grain weight because of nutrient deficiency.

This was in line with Woubshet Demissie *et al.* (2017) that, reported the highest TSW of barley (44 g) after the application of lime, compost, NPSB, KCl, .Similarly, Mitiku Weldesenbet et al. (2014) reported that after the application of 5 t ha^{-1} FYM in combination with 75% recommended rate of inorganic NP, the highest TGW of barely was obtained compared with application of 100% recommended rate of inorganic NP. Likewise, Saidu et al. (2012) obtained the highest TGW of wheat grain from the application of 5 t ha^{-1} FYM and 50% inorganic NP, while the lowest TGW was recorded from control.

Table4. 6. Mean yield components of maize as influenced by main effect of Manure and lime

Main effect	NCPP	NGPC	TGW(g)	GY (kg ha^{-1})	AGDB (kg ha^{-1})	HI (%)	STY (kg ha^{-1})
Manure levels (tone ha-1)							
0	1.36^{e}	468.7333^{e}	377.533^{e}	3600.44^{e}	13098.60^{e}	27.50^{e}	9498.5^{d}
4	1.82^{d}	495.8333^{d}	382.1833^{d}	5678.54^{d}	17637.67^{d}	32.33^{d}	11900.3^{c}
8	2.08^{c}	507.8333^{c}	392.0680^{c}	6141.28^{c}	18319.6^{c}	33.5^{c}	12176.8^{b}
12	2.68^{b}	511.4667^{b}	401.1488^{b}	6619.29^{b}	19430.8^{b}	35^{b}	12714.7^{a}
16	2.87^{a}	517.1667^{a}	405.3633^{a}	7281.34^{a}	20498.1^{a}	35.67^{a}	12892.2^{a}
LSD (0.05)	0.173	0.9573	3.61	35.26	349.14	0.0065	221.44
CV	8.308	0.2036	1.008	2.277	2.352	2.6536	2.163
SE±	0.073	0.416	1.613	54.534	170.883	0.004	104.537
P	**	**	**	**	**	**	**
R value	0.934	0.997	0.952	0.9923	0.9818	0.938	0.971
Lime (kg ha^{-1})							
0	2 ^{b}	498.7067^{b}	380.947^{b}	5502.53^{b}	17109^{b}	32.4^{b}	11508.27^{b}
500	2.327^{a}	501.7067^{a}	402.37^{a}	6225.82^{a}	18484.9^{a}	33.2^{a}	12164.73^{a}
Mean							
LSD (0.05)	0.109	0.605	2.28	22.3	220.8	0.0041	140.05
CV	8.308	0.2036	1.008	2.277	2.352	2.6536	2.163
SE±	0.046	0.2036	1.02	34.490	108.076	0.002	66.115

P	**	**	**	**	**	**	**
R vale	0.934	0.997	0.952	0.9923	0.9818	0.938	0.971

Table4. 7. Mean yield components of maize as influenced by the interaction effect of lime and Manure fertilizer

Interaction effect			Yield parameters						
Lime	Manure fertilizer rate	Treatments	NCPP	NGPC	TGW(g)	GY (kg ha^{-1})	AGDB (kg ha^{-1})	HI (%)	STY (kg ha^{-1})
	M0	T1	1.00^{f}	466.33^{i}	369.577^{f}	3442.47^{j}	12959.2^{h}	28.33^{f}	9333^{g}
L0	M1	T2	1.66^{e}	495.13^{g}	374.27^{f}	5294.73^{h}	16904.6^{g}	31.67^{e}	11494.7^{e}
	M2	T3	1.93^{d}	506.06^{e}	380.56^{e}	5766.53^{g}	17474.1^{f}	32.67^{d}	11708.67^{e}
	M3	T4	2.60^{b}	509.73^{d}	386.79^{d}	6116.14^{e}	18513.5^{e}	34.33^{c}	12205.33^{d}
	M4	T5	2.8b^{a}	516.26^{b}	393.53^{c}	6892.8^{c}	19693.8^{c}	35^{bc}	12799.7^{bc}
L1	M0	T6	1.73^{ed}	471.13^{h}	385.49d^{e}	3758.42^{i}	13238^{h}	26.67^{g}	9664^{e}
	M1	T7	1.96^{d}	496.53^{f}	390.097^{dc}	6062.35^{f}	18370.8^{e}	33.0^{d}	12306^{d}
	M2	T8	2.23^{c}	509.6^{d}	403.57^{b}	6516.03^{d}	19165.1^{d}	34.33^{c}	12645^{c}
	M3	T9	2.76^{ba}	513.2^{c}	415.504^{a}	7122.44^{b}	20348.1^{b}	35.67^{ba}	13224^{a}
	M4	T10	2.93^{a}	518.067^{a}	417.197^{a}	7669.88^{a}	21302.4^{a}	36.33^{a}	12984.7^{ba}
LSD (0.05)			0.2446	1.3538	5.114	49.87	493.75	0.0092	313.17
SE±			0.080	0.645	1.767	59.739	187.193	0.004	114.515
CV			6.59	0.157	0.761	0.495	1.617	1.628	1.542
P			**	*	**	**	**	**	*

R- value	0.966	0.9987	0.9778	0.9997	0.9926	0.981	0.9878

NCPP=number of cobs per plant, NGPC=number of grains per cob, AGDB=above ground dry biomass, GY=grain yield, STY=Straw yield, TGW=thousand grain weight, HI= harvest index, LSD= Least significance difference, SE± =Standard error; CV= Coefficient of Variation, p=probability level; ** significantly different at $p<0.05$. Means followed by the same letters in a column are not significantly different at $p<0.05$.

4.3.3.4. Grain yield of maize

Manure, lime, and their interaction had a significant ($P \leq 0.01$) effect on grain yield of maize (Appendix Table 9).

The increased rate of Manure from 0 kg to 16 tone ha^{-1} had a significant effect on grain yield i.e it was increased from 3600.44 kg ha^{-1} to 7281.34 kg ha^{-1}.This might be due to favorable conditions, where increasing applications of nitrogen fertilizer increases dry matter production. On the otherhand, the correlation analysis calculated among yield components and grain yield indicated that all the yield components were correlated highly significantly with grain yield.

These results were in line with the finding of Yihenew G.Selassie (2015) where N fertilizer rate had a significant effect on grain, dry stubble and dry aboveground biomass yields of maize. Similarly, Begizew Golla (2018) reported that the application of highest N rate (115 kg N ha^{-1}) at closer plant spacing (20 cm) gave the maximum yield (10207.8kg ha^{-1}).

On the other hand lime had also a significant effect on maize grain yield. The maximum mean grain yield (6,225.82 kg ha^{-1}) was recorded from plots treated with 0.5 t ha^{-1} lime than the control (5,502.53 kg ha^{-1}) (Table 4.8). From the results presented, lime treatments produced more grain yield compared to thecontrol. This shows that lime alone has the capacity to increase yield by facilitation of nutrient availability to the crop by changing the soil pH.

Lime raised soil pH that increased availability of soil P by unlocking the soil fixed P into available P for crop use. Lime increases availability of other nutrient elements mostly basic cations essential to crop use especially calcium which forms plant structure.

This result was in agreement with Opala *et al*.(2018) who found maximum maize yield (2.35 t ha^{-1}) after the application of 2 t ha^{-1} lime as compared with the control Similarly, Woubshet Demsie *et al.* (2017) reported 1682.7 kg ha^{-1} grain yield of malt barley in plots reated with 611 kg ha^{-1} lime.

The ANOVA result indicated that, the maximum grain yield (7,669.88 kg ha^{-1}) was recorded from plots treated with 0.5 t ha^{-1} lime with *16 tone ha^{-1} Manure* while the minimum grain yield (6062.35 kg ha^{-1}) was recorded from plots treated with 0.5 t ha^{-1} lime and *4 tone ha^{-1} Manure* (Table 4.9).This might be due to improved soil condition as both Ca and N nutrient was efficiently taken by the plantSince grain yield has strong and positive correlation with lime and Manure (r=0.999).

Similarly, Woubshet Demissie *et al.* (2017) reported barley grain yield of 2744 kg ha^{-1} that made a significant differencedue to the synergistic effect of lime and plant nutrition. Besides, Shiferaw Bokore and Anteneh Fikadu (2014) reported significant increase of barley yield over the control after the application of lime and all combinations of fertilizers, either alone or combined.

4.3.3.5. Aboveground dry biomass (AGDB)

The analysis of variance showed that Manure lime, and their interaction had a significant effect on AGDB ($p \leq 0.01$) (Appendix Table 10).

In the sole application of Manure the maximum (20,498.1 kg ha^{-1}) and the minimum (17,637.6 kg ha^{-1}) AGDB was recorded from plots treated with *16 tone ha^{-1} Manure* and *4 tone ha^{-1} Manure* compared with control (13,098.6 kg ha^{-1}) (Table 4.8).This enable the maize to respond well to Manure fertilizer and lime application as a result of its well-developed root system which facilitates absorbtion of the required nutrients for effective dry matter production by the crop and reduction of exchangeable acidity in the soil

This result was agreed to Yihenew G.Selassie (2015) that indicated increased AGDB of maize as the rate of urea increased from 0 to 200 kg ha^{-1}. The result of the study also agreed with Barker and Pilbeam (2007) that showed strong interactions and nutritional effects of N fertilizers in on crop vegetative growth. Similarly, Tesfaye Bayu (2017) recorded at the highest (14.9 t ha^{-1}) AGDB of maize in plots treated with 10 t ha^{-1} compost and full recommendation of mineral fertilizer.

Regarding with lime effect the maximum (18,484.9 kg ha^{-1}) AGDB was recorded from plots treated with 0.5 t ha^{-1} while the minimum (17,109 kg ha^{-1}) was recorded from the control (Table 4.8).This might be improved condition of soil by calcium derived from the applied lime.

This was in line with Achalu Chimdi *et al.(*2012) who reported increased dry biomass of Barely in the plots treated with lime (2811.4 kg ha^{-1}) s than the the control (2452.7 kg ha^{-1}) .

The ANOVA indicated that, the maximum (21,302. kg ha^{-1}) AGDB was recorded from 0.5 t ha^{-1} lime and *16 tone ha^{-1} Manure* While the minimum (18,370.8 kg ha-1) AGDB was recorded from 0.5 t ha^{-1} lime with *4 tone ha^{-1} Manure* (Table 4.9). The increased AGDB of maize might be an indicator of grain yield improvement as well as straw yield for animal fodder.The increased AGDB yield might be due to the release of unavailable nutrients from highly acidic soil by liming and Organic fertilizers. Soil nutrient might be available to plants.Thus, contribute to increase AGDB of maize.This high difference in total AGDB might be due to the synergistic effects of Manure fertilizer and lime as well as high doses of Manure and lime which were well known to increase the vegetative growth of plants, OM and SOC and soil CEC.

These results were in agreement with Woldeyesus Sinebo *et al.* (2004); Getachew *et al*. (2012) and Woubshet Demissie *et al.* (2017) stated that there was significance effect of integrated use of lime and Organic fertilizer on AGDB of cereals. Likewise, Woubshet Demissie *et al.* (2017) reported that the maximum (11,500 kg ha^{-1}) biomass data was recorded from plots treated with lime, compost, and NPSB and N fertilizer than the control (3,433 kg ha^{-1}). Similarly, Kibunja *et al*. (2010) reported that total dry matter of maize was higher in treatment combinations of inorganic and organic fertilizers than chemical fertilizers alone. Furthermore, Fageria *et al.* (2011) stated that N availability delayed the vegetative and reproductive stages of phenological development and increase biomass production of maize.

4.3.3.6. Harvest index of maize

Harvest index is the ratio of economic yield to AGDB yield reported in percent. All treatments as the main effect of lime, Manure, and their interaction had a significant ($p \leq 0.01$) effect on harvest index (Appendix Table. 12).

In sole application of Manure the maximum (35.67%) HI was recorded from plots treated with *16 tone ha^{-1} Manure* While the minimum (32.33%) HI was recorded from plots treated with *4 tone ha^{-1} Manure* compared with control HI (27.5%) (Table4.8).This indicates that how the AGDB of maize is converted into yield. It might be due to the timely availability of N and improvement in soil condition.

The result was in line with Syed *et al.* (2009) who reported that HI was significantly affected by the organic and inorganic source of N. The results were agreed with Shah and Arif (2001), who observed the positive effects of different fertilizers rates on maize HI in maize based cropping system.

Regarding with lime effect, the maximum (33.2%) HI of maize was recorded from plots treated with 0.5 t ha^{-1} lime than control (32.4%)(Table 4.8). This might be due to the increment of grain yield and AGDB because of soil physicochemical improvement.

This result was in line with Tadese Moges *et al.* (2017) lime had a significantly ($p \leq 0.01$) effect on malt barley HI. Similarly, Tadese Moges *et al.* (2017) reported that the maximum HI (27.19%) of malt barley was obtained from plots treated with 4 t ha^{-1} lime than the control HI (24.77%).

In contradict with this Woubshet Demissie *et al*. (2017) reported that maximum (38%) HI of barely was obtained from the control plot and the minimum (37%) HI was recorded from plots treated with 611 kg ha^{-1} lime alone.

The ANOVA indicated that, the maximum (36.33%) HI was recorded from plots treated with 0.5 t ha^{-1} lime with *16 tone ha^{-1} Manure* While the minimum (33%) HI was recorded from plots treated with 0.5 t ha^{-1} lime and *4 tone ha^{-1} Manure* (Table 4.9).This might be due to overall improvement of soil by integrated use of lime and Manure.This indicated that combined use of lime and Manure improve both grain yield and AGDB. From the total AGDB yield 63.67% was straw yield. But HI of 33% revealed that remaining 67% of total AGDB was straw yield.

This was in agreement with Woubshet Demissie *et al.* (2017) reported that the HI of barley was significantly ($P \leq 0.01$) influenced with integrated application of lime and recommended rate of organic and inorganic fertilizers. Likewise, Woubshet Demissie *et al*. (2017) found the highest HI of barley (47%) was obtained with 0.611 t lime ha^{-1}, 5 t compost, 150 kg NPSB, 100 kg KCl and 72 kg Urea ha^{-1} as compared to other treatments that received less combination of applied lime and fertilizers.

4.3.3.7. Straw yield of maize

The ANOVA table (Appendix Table 13) showed that, STY was highly significantly ($p \leq 0.01$) affected by main effect of lime and Manure fertilizer but it was significantly ($p \leq 0.05$) affected by the interaction effect (Table 4.9).

In sole application of Manure the maximum (12,892.2kg ha^{-1}) STY was recorded from plots treated with *16 tone ha^{-1} Manure* but statically same with plots treated with *12 tone ha^{-1} Manure* straw yield (12,714 kg ha^{-1}) (Table 4.8). While the minimum (11,900.3 kg ha^{-1}) STY was recorded from plots treated with *4 tone ha^{-1} Manure* This result might be due to release of unavailable nutrients from acidic soil with liming of the soil. The rise of soil pH and improved soil conditions might be enables synergetic interaction of soil nutrients.This was agreed with Tesfaye Bayu (2017) found that STY was increased from 1.64 t ha^{-1} to 7.51 t ha^{-1} as 0kg N and 0kg NPSZnB fertilizer to 75 kg N and 100kg NPSZnB fertilizer.

Regarding with sole application of lime, STY was increased from 11,508.27 kg ha^{-1} to 12,164.7 kg ha^{-1} as lime was increased from 0 to 0.5 t ha^{-1} (Table 4.8). The application of lime is a prerequisite to achieve good straw yields on acid soils. This result was agreed with Woubshet

Demissie *et al.* (2017) reported that STY of barely was increased from 2116 kg ha^{-1} to 2801 kg ha^{-1} as lime was applied 0 to 611 kg lime ha^{-1}.

The interaction effect indicated that, the minimum (9,333 kg ha^{-1}) straw yield was recorded from control plot while the maximum STY was recorded from plots treated with 0.5 t ha^{-1} lime combined with *12 tone ha^{-1} Manure* (13,224 kg ha^{-1}) followed by STY (12,984.67 kg ha^{-1}) obtained from plots treated with the combined use of 0.5 kg ha^{-1} lime and *16 tone ha^{-1} Manure* (Table 4.9).

This might be due to adequate supply of nutrients to the crop helps in the synthesis of carbohydrates, which are required for the formation of protoplasm, thus resulting in higher cell division and cell elongation. Thus an increase in straw yield might have been on account of overall improvement in the vegetative growth of the plant due to the application of lime in combination with Manure.

This result was in line with Woubshet Demissie *et al.* (2017) the mean straw yield of Barley (6114 kg ha^{-1}) were obtained with 611 kg lime ha^{-1}, 5 t compost,150 kg NPSB, 100 kg KCl,72 kg N ha^{-1} as compared to control for straw yield (2115 kg ha^{-1}).Similar results were obtained by Makinde and Ayoola (2010) who reported that integrated application of organic,lime and inorganic fertilizers is effective for the growth of maize and improving straw yields.

4.4. Correlation of Maize Yield and Yield Components

A simple correlation analysis was done to evaluate the association of various agronomic parameters of maize (Table 4.10). The correlation study indicate that, STY was highly and positively correlated with DM (r=0.915), PH (r=0.857), NLPP (r=0.886), NCPP (r=0.841), NGPC (r=0.954), TGW(r=0.977), AGDB(r=0.987) and HI (r=0.959). This indicates that the effect of lime and Manure fertilizer showed positive increment. When the rate increased the STY increased as well as all the above parameters also increased. But DS (r=-0.887) and DT (r=-0.927) were highly and negatively correlated with STY (Table 4.9). This indicate that the effect of lime and Manure (i.e when the rate increased the STY increased while DS and DT decreased.

Similarly, grain yield was highly and positively correlated with DM (r=0.931), PH (r=0.909), NLPP (r=0.0.923), NCPP (r=0.885), NGPC (r=0.966), TGW (r=0.797), AGDB (r=0.996), HI(r=0.987) and STY (r=0.977). This indicate that the effect of lime and Manure fertilizer (i.e when the rate increased the GY increased as well as all the above parameters also increased. It was also highly and negatively correlated with DT (r=-0.957) and DS (r=-0.925). This indicate that the effect of lime and Manure (i.e when lime and Manure fertilizer rate increased the grain yield increased while DT and DS decreased (Table.4.10). This revealed that grain yield was highly significantly increases with an increase of grain yield per cobs, number of cobs per plant and plant height. In general all of the parameters (growth parameters and yield components) were positively and significantly correlated with GY except that of DT and DS.

This result is in line with Yihenew G. Selassie (2015); Habtamu Admas *et al*. (2015) and Tesfaye Bayu (2017) that grain yield of maize were positively and significantly correlated with yield components.

Table4. 8. Pearson's simple correlation coefficient among yield and yield components of maize

Correlations	DT	DS	DM	PH	NLPP	NCPP	NGPC	TGW	GY	AGDB	HI	STY
DTAS	1											
DSILK	.950**	1										
DM	-.853**	-.803**	1									
PH	-.888**	-.889**	.873**	1								
NLPP	-.904**	-.929**	.833**	.925**	1							
NCPP	-.936**	-.901**	.789**	.908**	.890**	1						
NGPC	-.936**	-.863**	.915**	.871**	.868**	.870**	1					
TGW	-.803**	-.887**	.658**	.792**	.905**	.794**	.676**	1				
GY	-.957**	-.925**	.931**	.909**	.923**	.885**	.966**	.797**	1			
AGDB	-.944**	-.906**	.942**	.897**	.912**	.865**	.962**	.779**	.996**	1		
HI	-.890**	-.856**	.961**	.899**	.888**	.821**	.955**	.710**	.987**	.974**	1	
STY	-.927**	-.887**	.915**	.857**	.886**	.841**	.954**	.743**	.977**	.987**	.959**	1

**=Correlation is significant at the 0.01 level (1-tailed).

HI= harvest index, STY=straw yield, GYPC=Grain yield per cob, GY=Grain yield, AGDB=Above ground dry biomass, PH=plant height, NCPP=number of cobs per plant, DM= Date of 90% maturity, DS= Date of 50% silking and DTAS=Date of 50% tasseling

4.5. Economic Feasibility Analysis

During the 2022/2023 rainy season the market price of Maize taken at Meket District was 10 Ethiopian Birr per kilogram (ETB kg-1). Field prices for NPS, Manure, and lime were taken as 10.50, 12.00 and 1.35 ETB kg-1. The cost of labour for harvesting and bagging were taken at 28 ETB 100 kg -1, the cost of labour for incorporation and transportation of lime 25 were taken at ETB 100 kg -1, the cost of application and transport for fertilizer during planting was 1000 ETB kg -1 considering that 10 laborers can apply fertilizer on a hectare of land in 1 day (daily wage of one laborer is 100 Birr). The same amount of money would be required for side dressing. So it should be 2000 ETB for Manure treated plot and daily wage of one labor was 100ETB.

As showed in Appendix Table 14, total variable costs which are responsible for yield increase in each treatment were listed. The marginal and dominances analysis of maize in T2, T7, T9 and T8 had greater than 100% in MRR (Table 4.11 and Table 4.12). The maximum net benefit (58,891.47 Ethiopian Birr) with MRR value of (805.24%) was obtained from T9- lime (0.5 t ha^{-1}) + *12 tone ha^{-1} Manure*) as compared to T8-lime (0.5 t ha^{-1}) + Manure (8 tone ha^{-1}) NB (47,701.04 ETB) with MRR (203.59%) (Table4.11). This means for T9 on average for each 1 Birr ha^{-1} invested, the return was 1 birr, plus 8.05 Birr ha^{-1} in the net benefit which is economically feasible as compared to T8 that showed 1Birr recovery plus 2.04 Birr ha^{-1} net benefit. The MRR analysis of treatment 2, 7, 8 and 9 was more than 100% but T9 is economically feasible to recommend for the farmers.

This study suggests that it could be advisable for farmers in the study area to apply integrated lime at 0.5 t ha^{-1} plus *12 tone ha^{-1} Manure* to enhance maize grain yield and ensuring maximum economic return.This recommendation is also supported by CIMMYT (1988) which stated that farmers should be willing to change from one treatment to another if the marginal rate of return of that change is greater than the minimum acceptable rate of return.

This result was in line with Woubshet Demelash *et al.* (2017) reported that integrated use of lime, compost,recommended NPS, KCl and urea fertilizer gave the highest grain yield net benefit and MRR on Barley production. Similarly, Trinh *et al.* (2008) reported that higher grain yield and higher net benefit was recorded from higher planting density with higher NPK rate of site specific nutrient management (SSNM).

Table4. 9. Dominances analysis of Maize

Treatments	TVC(ETB ha^{-1})	Net benefit (ETB ha^{-1})	Dominance
T1	5928.92	25842.43	Non-dominated
T6	6689.272	26356.478	Non-dominated
T2	8599.701	39052.869	Non-dominated
T7	9598.291	44962.859	Non-dominated
T3	9899.129	41999.641	Dominated
T8	10943.23	47701.04	Non-dominated
T4	11281.57	43763.69	Dominated
T9	12332.93	58891.47	Non-dominated
T5	12630.82	51769.03	Dominated
T10	13667.99	55360.93	Dominated

Treatment 3=with 8 tone ha^{-1} Manure alone, T4=with 12 tone ha^{-1} Manure alone and T5= with 16 tone ha^{-1} Manure, treatment 10=with 0.5 t ha^{-1} lime and 16 tone ha^{-1} Manure were dominated treatments. Hence, these are rejected from further consideration in marginal analysis. Based on this treatment 3, 4, 5 and 10 are rejected because they are dominated by other treatments.

Table4. 10. Marginal analysis of Maize

Treatments	Grain Yield (kg ha^{-1})	Adjusted yield (-10%) (kg ha^{-1})	Gross return (ETB ha^{-1})	TVC(ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR (%)
T1	3530.15	3177.135	31771. 35	5928.92	25842.43	---
T6	3671.75	3304.575	33045.75	6689.272	26356.478	67.6
T2	5294.73	4765.257	47652.57	8599.701	39052.869	664.5
T7	6062.35	5456.115	54561.15	9598.291	44962.859	591.8
T3	5766.53	5189.877	51898.77	9899.129	41999.641 D	---
T8	6516.03	5864.427	58644.27	10943.23	47701.04	203.59
T4	6116.14	5504.526	55045.26	11281.57	43763.69 D	---
T9	7122.44	6410.196	64101.96	12332.93	58891.47	805.24
T5	6892.8	6203.52	62035.2	12630.82	51769.03 D	---
T10	7669.88	6902.892	69028.92	13667.99	55360.93D	-----

D=dominated treatment

4.6. Agronomic Use efficiency

Agronomic use efficiency reflects the direct production impact of an applied fertilizer and relates directly to economic return. As showed in Table 4.13 the nutrient use efficiency (NUE) was good for those plots treated with 4 tone ha^{-1} Manure and has the highest NUE which is 5.88%. This was due to the fact inorganic and organic fertilizers were known in releasing nutrients to the soil and crop which account in yield increase. The maximum (5.88%) AUE was recorded from plots treated with 4 tone ha^{-1} Manure while the lowest AUE (0.202%) was recorded from plots treated with 0.5 t ha^{-1} lime alone. This confirms that, inorganic fertilizer release nutrients immediately while lime does not release nutrients immediately for maize. The remaining might be lost through erosion, leaching, dinitrification and changed to organic stock.

The results were similar with Tesfaye Bayu (2017) who reported that, the highest agronomic use efficiency (16.14%) of maize was obtained from plots treated with mineral fertilizer only (75 kg ha^{-1} N fertilizer plus 100 kg ha^{-1} NPSZnB fertilizer and lowest NUE (0.04%) was obtained from plots treated with compost only (5000 kg ha^{-1}). Similarly, William and Gordon (1999) who reported low nitrogen use efficiency in cereal production due to dinitrifecation. Plots treated with lime alone or in combination with urea fertilizer were low in their NUE. This is due to the fact that lime is not providing nutrients to the soil and crops immediately. William *et al.* (2012) found the effect of N fertilizer rate on agronomic use efficiency.

Table4.11. Agronomic use efficiency for maize

Treatments	lime(kg/ha)	Manure fertilizer (tone/ha)	NPS fertilizer (kg/ha)	Total nutrient added	Grain yield of (kg/ha)	AUE
L0M0	--	--	200	200	3530.15	--
L0M1	--	100	200	300	5294.73	5.88
L0M2	--	200	200	400	5766.53	5.59
L0M3	--	300	200	500	6116.14	5.17
L0M4	--	400	200	600	6892.8	5.604
L1M0	500	--	200	700	3671.75	0.202
L1M1	500	100	200	800	6062.35	3.16
L1M2	500	200	200	900	6516.03	3.32
L1M3	500	300	200	1000	7122.44	3.59
L1M4	500	400	200	1100	7669.88	3.76

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

From the result of the study the following can be concluded; Inherent physicochemical properties of the study area soil including; Bd was higher than the critical value, pH value was low, and the experimental site soils were under the critical value in SOC, OM, TN, available P and CEC as compared with the critical value but good in EC. Soil physicochemical properties were improved after harvest. Yield and yield components of maize were improved by combined use of lime and Manure fertilizer. Integrated use of lime and Organic fertilizer was found economically feasible for maize production. The optimum rate of lime and Organic fertilizer for yield increment, soil fertility improvement and to get maximum economic benefit was 0.5 t ha^{-1} lime and 12 tone ha^{-1} Manure with full recommendation of NPS and half recommendation of Manure fertilizer during maize planting. Application of Mnure fertilizer had good agronomic use efficiency than lime.

5.2. Recommendations

To increase crop production and improve soil fertility at Meket district on a sustainable way the following recommendations are suggested based on the result of the study.

- Farmers should use 0.5 t ha^{-1} lime and 12 tone ha^{-1} Manure with full recommendation NPS.
- The government should supply lime ($CaCO_3$) and Manure for the farmers. The government should also give training for development agents and farmers.
- Further study should be done in the residual effect of lime with organic and inorganic fertilizers short and long rainy season as well as economic feasibility for further growing seasons.
- Further study should be done in the effect of lime and Organic fertilizer in short and long rainy season.

6. REFERENCES

Abdissa Bekele, Kibebew Kibret, Bobe Bedadi,Tesfaye Balemi and Markku Yli-Halla. 2018. Effects of lime, vermicompost and chemical P fertilizer on yield of maize in Ebantu District, Western highlands of Ethiopia, Vol. 13(10), pp. 477-489, DOI: 10.5897/AJAR2017.12949.

Abera Girma and Endalkachew Woldemeskel, 2013.Soil properties, and soil organiccarbon stocks oftropical Andosol under different land use, Hawassa University, Hawassa, Ethiopia., *Journal of Soil Science,* 2013, 3, 153-162 doi:10.4236/ojss.2013.33018.

Abera Kechi. 2013. Growth, productivity and nitrogen use efficiency of maize (*Zea mays* L.) as influenced by rate and time of nitrogen fertilizer application in Haramaya District, Eastern Ethiopia

Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret, Abi Tadesse.2012.Response of barley to liming of acid soils collected from different land use systems of Western Oromia, Ethiopia. Journal of Biodiversity and Environmental Sciences (JBES), ISSN: 2220-6663 (Print) 2222-3045 (Online), Vol. 2, No. 5, p. 37-49, 2012

Achieng, J. O; Ouma, G; Odhiambo, G, Muyekho, F. 2010.*Effectof FMY and inorganic fertilizers on maize production on Alfisols and Ultisols in Kakamega, western Kenya.*

Adekayode F. and Ogunkoya M. 2010.*Effect of quantity and placement distances of inorganic 15-15-15 fertilizer in improving soil fertility status and the performance and yield of maize in a tropical rain forest zone of Nigeria.Federal University of Technology,* Akure, Nigeria. Vol.1 (7), 155-163.

Agegnehu Getachew., Van Beek C. and Bird M. 2014.*Influence of integrated soil fertility management in wheat and tef productivity and soil chemical properties in the highland tropical environment,* Journal of Soil Science and Plant Nutrition, 14:532-545.

Alam, S.M., Azam, S., Ali, S. and Iqbal, M. 2003. Wheat yield and P fertilizer efficiency as influenced by rate and integrated use of chemical and organic fertilizers. Pakistan Journal of Soil Science, 22(2):72-76.

Alemayehu Seyum. 2008. *Decomposition of growth in cereal production in Ethiopia*. Paper presented for DFID funded study "Understanding the constraints to continued rapid growth in Ethiopia: the role of agriculture". Ethiopia.

Ali, R. and Raouf, S. Sh. 2012.Effects of rates and nitrogen application timing on yield, agronomic characteristics and nitrogen use efficiency in corn.International Journal of Agriculture and Crop Sciences. (2):123-124).

Ali, S., Uddin, S., Ullah, O., Shah, S., Ali, S. U. D. T., & Ud Din, I. 2012. Yield and yield components of maize response tocompost and fertilizernitrogen.Retrived from https://www.iiste.org/Journals/index.php/FSQM/article/view/21360.

Amanullah Khalid, S. 2015. Phenology, growth and biomass yield response of maize (Zea mays L.) to integrated use of animal manures and phosphorus application with and without phosphate solubilizing bacteria. Journal of Microbial and Biochemical Technology, 7, 439-444.

Amanullah, K.B. Marwat, P. Shah, N. Maula and S. Arifullah.2009.Nitrogen levels and its time of application influence leaf area, height and biomass of maize planted at low and high density. Pak. J. Bot., 41(2): 761–768.

Antill R., Lovel D., Hateh J. and Jarvis C. 2001.Mineralization of nitrogen in permanent pastures amended with fertilizer or dung, Biol.Fertil.Soil. 33: 132-138.

Anuradha L. 2003.*Integrated nutrient management ingroundnut* (*Arachis hypogaea L.)*M.Sc. thesis.Angrau, Hyderabad.

Anwar, S.,Ullah, W., Islam, M., Shafi, M., Iqbal, A. and Alamzeb, M.2017.Effect of nitrogen rates and application times on growth and yield of maize (Zea mays L.).*Pure and Applied Biology*, *6*(3), pp.908-916.

Arif, M, Ali, S, Khan, A, Jan, T and Akbar, M. 2006. Influence of farm yard manure application on various wheat cultivars. Sarhad J. of Agric.22 (1):27-29.

Bache BW. 1988. Measurements and mechanisms in acid soils. *Communications in Soil Science and Plant Analysis* 19: 775-792.

Balesh Tulema, Bernt A., and Breland T. 2007. *Availability of organic nutrient sources and their effects on yield and nutrient recovery of tef [Eragrostis tef (Zucc.) Trotter] and on soil Properties*. Journal of Plant Nutrition and Soil Science. 170: 543–550.

Barker A. and Pilbeam J. 2007. *Handbook of Plant Nutrition*. 1st Ed, CRC/Taylor and Francis, London, pp: 613.

Begizew Golla Mekonen. 2018. Effect of Nitrogen Rate and Intra-Row Spacing on Yield and Yield Components of Maize (*Zea mays* L.*)* at Bako,Western Ethiopia, MSc thesis, Jimma

University.

Bello W. 2012. *Influence of Gypsum application on Wheat (Triticum aestivum) yield and Components on Saline and Alkaline Soils of Tigray region, Ethiopia*, Greener Journal of Agricultural Sciences, 2: 316-322.

Berhanu Gebremedhin, Fernandez-Rivera S., Mohammed Hassena, Mwangi W.and Seid Ahmed. 2007a. Maize and livestock: Their inter-linked roles in meeting human needs in Ethiopia. Research Report 6.ILRI (International Livestock Research Institute), Nairobi, Kenya. 103 p

Bertsch, P.M., and M.M. Alley. 1981.Conventional and suspension limestone influence on soil chemical properties and corn and soybean yields. Agronomy Journal 73:1075-1078

Brink, M. and. Belay G. (Editors).2006. Plant Resources of Tropical Africa 1. Cereal and pulses. PROTA Foundation, Wageningen,Netherlan d/ Backhuys Publishers, Foundation, Netherlands/ CTA, Wageningen, Netherlands. 298 p.

Buni A.2014. Effects of Liming Acidic Soils on Improving Soil Properties and Yield of Haricot SBean. J. Environ. Anal. Toxicol. 5:248.

Meket Woreda Aricultural Office. 2019. Unpublished annual report.

Meket Woreda Aricultural Office. 2020. Mean maize yield report in 2018/2019 crop production office of the District.

Catherine N. Kibunja, F. B. Mwaura2 and D. N. Mugendi .2010. Long-term land management effects on soil properties and microbial populations in a maize-bean rotation at Kabete, Kenya, African Journal of Agricultural Research Vol. 5 (2), pp. 108-113

Channon. P, and Farina, M.P.W. 1991. A field comparison of lime requirement indices for maize. Plant soil 134:127-135.

Charman, P and Rope, M. 2007. Soil Organic Matter. pp. 276-285. *In* Charman P. and Murphy B. (Eds.) Soils, Their Properties and Management. 3rd Edition.

Chendu, N. 2006. Design of biogas plant Booklet and Research materials of biogas training Centre, China.

CIMMYT.1988.From agronomic data to farmer recommendation. An economic training manual. Completely revised edition. D.F. Mexico. Pp. 9-12.

Clancy JA, Tillma BA, Pan WL, Ulrich SE.1991.Nitrogen effects on yield and malting quality of barley genotypes under no-till.Agronomy Journal;83(2):341-346.

Coleman NT, Thomas GW. 1967. The basic chemistry of soil acidity. In: Pearson RW, Adams F (eds), *Soil acidity and liming.* Agronomy Series no. 12. Madison: American Society of Agronomy. pp 1-41.

Coventry, DR, Slattery, WJ, Burnett, VF and Ganning, GW.1997. Longevity of wheat yield response to lime in southeastern Australia. Aust. J. Exp, Agric. 37: 571-575.

Craswell, E.T. and Godwin, D.C 1984. In: Mangel, K.andKirkby, E.A. 1996. *Principles of Plant Nutrition.* Panima publishing panima publishing Coperation. New Delhi, India.

CSA.2011.Report on large and medium scale manufacturing and electricity Industry Survey,Centeral Statistical Agency, Ethiopia.

CSA.2017. Agricultural Sample Survey 2016/17., *volume I ,Report on Area and Prodaction of major crop.Adis Abeba, Ethiopia.*

Dawadi, D.R. and Sah, S.K., 2012. Growth and yield of hybrid maize (Zea mays L.) in relation to planting density and nitrogen levels during winter season in Nepal. *Tropical Agricultural Research, 23*(3).

Day, P.R.1965. Hadrometer method of particle size analysis. Pp. 562-563. In: C.A. Black (ed.). Methods of soil analysis, II. American Soc. Agronomy, Madison, USA.

Devi, I.S. and Muhammad S. 2001. Character association and path co-efficient analysis of grain yield and yield components in double crosses of maize. Crop Research. 21: 355 359.

Esayas Eyasu, Dereje Shanka, Dawit Dalga and Eyasu Elias.2018. Yield Response of Maize (Zea mays L.) Varieties to Row Spacing Under Irrigation at Geleko, Ofa Woreda, Wolaita Zone, Southern Ethiopia, *20(1): 1-10, 2018; Article no.JEAI.37096 ISSN: 2457-0591*

Ethiopian Soil Information System (EthioSIS).2014.Towards improved fertilizer recommendations in Ethiopia Nutrient indices for categorization of fertilizer blends from EthioSIS *Woreda* soil inventory data. Addis Ababa, Ethiopia.

Fageria, N.K. and Baligar V. C. 2005. Enhancing nitrogen use efficiency in crop plants. Advanced Agronomy. 88: 97-185.

Fageria NK, Baligar VC, Jones CA.1997. Growth and mineral nutrition of field crops. Mercel Dekker Inc., New York

Fageria NK, Baligar VC, Zobel RW.2007. Yield, Nutrient uptake and Soil chemical properties as influenced by liming and Boron application in a No-tillage system. Communication in Soil Sci. Plant Anal. 38:1637-1652.

Fageria V , Moreira A. & Coelho A. M. 2011. Yield and yield components of upland rice as influenced by nitrogen sources, 361-370.

FAO (Food and Agriculture Organization of the United Nations). 2000. Fertilizers and their uses, 4th ed. International Fertilizer Industry Association Food and Agriculture Organization of United Nations. Rome, Italy

Farhad W.,Saleem MF., Cheema MA., and Hmmad HM.2009.Effect of polutrt manure levels on the productivity of spring maize (Zea mays L.).J Anim.plant sci,19(3),123-125.

Fassil Kebede and Charles Y.2009. Soil Fertility Status and Numass Fertilizer Recommendation of Typic Hapluusterts in the Northern Highlands of Ethiopia. World Applied Sciences Journal 6: 1473-1480.

Gardner, F.P., R.B. Pearce and R.L. Mitchell.1988. Physiology of crop plants. Ames: Iowa State University, 327p.

Garg S. and Bahla, G. 2008. Phosphorus availability to maize as influenced by organic manures and fertilizer P associated phosphatase activity in soils. Bio-resource Technology. 99: 5773-5777.

Gaurkar, S.G. and Bharad G.M.1998. Effect of plant population, de topping and nitrogen levels on growth and yield of maize. PKV Research Journal. 22: 136-137.

Gawai, P. P.2003. *Effect of integrated nutrient management system in sorghum-chickpea cropping sequence*, Ph.D. thesis submitted to M.P.K.V., Rahuri pp. 80-67.

Geremewu Taye. 2009. Effect of Nitrogen and Phosphorus Fertilizers on the Growth, Yield and Yield Components of Maize (Zea mays L) at Nejo Western Wollega, Ethiopia.

Getachew Agegnehu and Rezene Fessehaie.2006. Response of faba bean to phosphorus fertilizer and weed control on Nitisols of Ethiopian Highlands, Italian. Journal of Agronomy/Riv. Agron. 2: 281-290.

Getachew Agegnehu and Taye Bekele, 2005. *On-farm integrated soil fertility management in wheat on nitisols of central Ethiopian highlands*, Ethiopian journal of natural resource

Getachew Agegnehu, Chilot Yirga, and Teklu Erkossa.2019.Soil Acidity Management. Ethiopian Institute of Agricultural Research (EIAR). Addis Ababa, Ethiopia

Getachew, A and Sommer, K. 2000. Optimization of the efficiency of phosphate fertilizers in acidic- ferralitic soils of the humid tropics. Ethiopian J. of Natu. Reso. 2: 63-77.

Getachew Agegnehu and Chilot Yirga. 2009. Integrated Nutrient Management in Faba Bean and

Wheat on Nitisols of central Ethiopian Highlands. Research Report No. 72. Ethiopian Inst. of Agric. Res. Addis Ababa, Ethiopia, pp. 24.

Getachew Agegnehu, Angaw Tsigie and Agajie Tesfaye. 2012. Evaluation of Crop Residue Retention, Compost and Inorganic Fertilizer Application on barley productivity and Soil Chemical properties in the Central Ethiopia.

Ghafoor and Akhtar 1991. Growth and Yield Response of Maize (Zea mays L.) To Variable Rates of Compost and Inorganic Fertilizer Integration in Wolaita, Southern Ethiopia. DOI: 10.3923/ajpnft.2013.43.52

Ghafoor, A. M. R. 2016. Effect of Phosphorus Fertilizer Application on Some Yield Components of Wheat and Phosphorus Use Efficiency in Calcareous Soil. Journal of Dynamics in Agricultural Research, 3(4):46-52. (Accessed December 10/2017)

Giday, O., H. Gibrekidan, and T. Berhe. 2015. Soil fertility characterization in Vertisols of Southern Tigray, Ethiopia. Advances in Plants and Agriculture Research 2 (1):1–7. doi:10.15406/apar.2015.02.00034.

Gokmen, S., Sencar, O. and Sakin, M.A., 2001. Response of popcorn (Zea mays everta) to nitrogen rates and plant densities. Turkish Journal of Agriculture and Forestry, 25(1), pp.15-

Gozubenli, H. 2010. Nitrogen dose and plant density effects on popcorn grain yield. *African Journal of Biotechnology*, *9*(25), pp.3828-3832 Shrestha, 2013; and

Greef, J.M., Ott, H., Wulfes, R. and Taube, F. 1999. Growth analysis of dry matter accumulation and N uptake of forage maize cultivars affected by N supply. Journal of Agriculture Science, 132: 31-43.

Gudadhe N., Neeraj K., Pisal R., Mote B. and Dhonde M. 2013. Evaluation of Agrometeorological Indices in Relation to Crop Phenology of Cotton (Gossipium spp.) and Chickpea (Cicer aritinum L.) at Rahuri Region of Maharashtra. Trends in Biosciences 6: 246-250.

Gungula, D.T. Kling, J.G and Togun A.O.2003. CERES Maize predictions of maize phenology under nitrogen stressed conditions in Nigeria. Agronomy Journal, 95: 892 899.

Guo, J. H., Liu, X. J., Zhang, Y., Shen, J. L., Han, W. X., Zhang, W. F., Christie, P., Goulding, K. W. T.,Vitousek, P. M., and Zhang, F. S. 2010.Significant Acidification in Major Chinese Croplands. Science 327, 1008-1010.

Habtamu Admas, Heluf Gebrekidan, Bobe Bedadi and Enyew Adgo. 2015. *Effects of Organic and Inorganic Fertilizers on Yield and Yield Components of Maize at Wujiraba Watershed, North-western Highlands of Ethiopia,* American Journal of Plant Nutrition and Fertilization Technology, 5: 1-15.

Habtamu Yigermal, Kelemu Nakachew and Fenta Assefa.2019. Effects of integrated nutrient application on phenological, vegetative growth and yield-related parameters of maize in Ethiopia: A review, Cogent Food & Agriculture, 5:1, 1567998.

Hageman RH and FE Below.1984. The role of nitrogen productivity of corn, Pp. 145-156. In: Proc. 39th. Annual Corn and Sorghum Research Conference, Chicago, IL, American Seed Trade Association, Washington, DC.

Hailare,L. 2000. Corn: An American Native. Spanning the Gap The newsletter of Delaware Water Gap National Recreation Area Vol. 22 No. 1 Spring 2000. U.S. Dept. of the Interior National Park Service

Halvorson A.D. and Jantalia C.P. 2006. Nitrogen fertilizer effects on irrigated No-till corn Production and soil carbon and nitrogen. Agron J. 103:1423-1431.

Hassan A.M, V.O. Chude , S.A. Ibrahim and Peter C. Nnwanko , 2007. Effect of Hydrated Lime on the Growth of Maize at Federal Capital Territory, Abuja. *International Journal of Agricultural Research, 2: 495-499.* DOI: 10.3923/ijar.2007.495.499

Hefny M, Aly A.2008. Yielding Ability and Nitrogen Use Efficiency in Maize Inbred-lines and Their Crosses. International Journal of Agriculture. Research, 3. (1). 27-39.

Horneck,D.A, D. M. Sullivan, J. S. Owen, and J. M. Hart. 2011. Soil test interpretation guide. Oregon State University Extension Service.

Hue, N. 1992. Correcting soil acidity of a highly weathered Ultisol with chicken manure and sewage sludge. Comm. Soil Sci. Plant Anal. 23, 241-264.

Ige, D. V., J.A. Adepetu and O.A. Obi. 2005. *Effect of organic amendement on P release in soils of south western Nigeria,* Iife Journal of Agriculture, 21: 216-228.

Imran, S., Arif, M., Khan, A., Khan, M.A., Shah, W. and Latif, A.2015. Effect of nitrogen levels and plant population on yield and yield components of maize. *Advances in Crop Science and Technology,* pp.1-7.

Jassal, R.K., Kang, J.S., Singh, H. and Singh, T. 2017. Growth, Phenology and Seed Yield of Fodder Maize in Relation to Different Planting Methods and Nitrogen Levels. *Int.*

J. Curr. Microbiol. App. Sci, *6*(4), pp.1723-1735.

Jiban S. 2013. Effect of nitrogen and plant population on flowering and grain yield of winter maize. Sky Journal of Agricultural Research, 2(5):64 – 68.

Jones, J.B. 2002. Agronomic Handbook CRC Press, New York. 450p.

Jones, J. B. 2003. Agronomic Handbook: Management of Crops, Soils, and their Fertility. CRC Press LLC, Boca Raton, FL, USA. 482pp.

Kandil, E.E. 2013. Response of Some Maize Hybrids (Zea mays L.) to Different Levels of Nitrogenous Fertilization. Journal of Applied Sciences Research, 9(3): 1902-1908.

Karlen, D.L., Kramer, L.A. and Logsdon, S.D. 1998. Field-scale nitrogen balances associated with long-term continuous corn production. Agronomy Journal., 90: 644-650.

Kebede Dinkecha and Dereje Tsegaye.2017. Effects of Liming on Physicochemical Properties and Nutrient Availability of Acidic Soils in Welmera Woreda, Central Highlands of Ethiopia. *Biochemistry* and Molecular *Biology*. Vol. 2,No.6,,pp.102 109.doi: 10.11648/j. mb.20170206.16

Kebede Mulatu, Gizahagh Bogale, Mossisa Worku, Yigzaw Desalegn and Asefa Afeta.1992.Maize production trends and research in Ethiopia. Paper presented to the first National Maize Work shop. May, 1992 Addis Ababa, Ethiopia.

Kena Kelbesa.2015. Effect of nitrogen rates and inter row spacing on growth, yield and yield components of maize (zea mays l.) at nejo, western Ethiopia.

Kimiti Winnie Wanjiru.2018. Lime, Manure And Inorganic Fertilizer Effects On Soil Chemical Properties, Maize Yield And Profitability In Tharaka-Nithi County, Kenya.MSc thesis Environmental Science in the School of Environmental Studies of Kenyatta University

Kisinyo, P.O., C.O. Othieno, J.R. Okalebo, M.J. Kipsat, A.K. Serem and D.O. Obiero. 2005. Effects of lime and phosphorus application on early growth of Leucaenain on acid soils. *Afr. Crop Sci. Conf. Proc*., 7: 1233-1236.

Kumar, D., Kumar, M., & Kumar, R.2018. Evaluate the integrated nutrient use on growth and yield of hybrid maize under central plain zone of Uttar Pradesh, India. International Journal of Current Microbiology Applied Science, 7(3), 518–530. doi:10.20546/ ijcmas.2018.703.062.

Landon, J. R. 2014. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics, 532. Abingdon, UK: Routledge.

Landon, J.R. 1991. *Booker Tropical Soil Manual*: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. (Ed.). John Wiley & Sons Inc., New York.

Lee A. and Tollenaar M. 2007. Physiological basis of successful breeding strategies for maize grain yield. Crop Sci., 47: 202-215.

Lemcoff, J. H. and. Loomis, R. S. 1986. Nitrogen influence on yield determination in maize.

Liu, Weidon, Matthijs Tollenaar, Greg Stewart, and William Deen. "Response of Corn Grain Yield to Spatial and Temporal Variability in Emergence." Crop Science. 44 (2004) 847-854.

Lopez-Bellido RJ, and Lopez-Bellido, L.2001. Efficiency of nitrogen in wheat under Mediterranean condition: effect of tillage, crop rotation and N fertilization. Field Crop Research. 71(1): 31-64.

Makinde EA and Ayoola OT. 2010. *Growth, yield and NPK uptake by maize with* complementary organic and inorganic fertilizers. 10:2203-2217.

Makinde EA and Ayoola OT. 2010. *Growth, yield and NPK uptake by maize with* complementary organic and inorganic fertilizers. 10:2203-2217.

Malaiya S., Tripathi S.and Shrivastava K. 2004. Effect of variety, sowing time and integrated nutrient management on growth, yield attributes and yield of summer maize. Agri. Res.25:155-158.

Manna MC, Swarup A, Wanjari RH, Mishra B, Shahi DK. 2007.Long-term fertilization, manure and liming effects on soil organic matter and yields. *Soil and Tillage Research* 94: 397-409.

Mariga, I.K., Jonga, M. and Chivinge.2000. The effect of timing of application of basal and top dressing fertilizers on maize yield at two rates of basal fertilizer. Crop Research, 20: 372-380.

Marschner, H. 2002.Mineral nutrition of higher plants .2nd Edition. Academic Press: London. 674p.

Martin, A. P. 1993. Tropical soils and fertilizer use. Intermediate tropical agriculture series. University of Nairibi, Kenya.

Masresha Mitiku. 2014. *Response of Maize (Zea mays L.) to Application of Mineral Nitrogen Fertilizer and Compost in Godere District, GambellaRegion, Southwestern Ethiopia.* Haramaya University, Ethiopia.

Mengel, K., and E. A. Kirkby.1996. Principles of plant Nutrition. 5th Ed. Klewer Academic Publishers. Dordrecht. 849p

Mercik S. And Stêpieñ W.2012. Effect of nitrogen on crop yield as influenced by soil ph and fertilization with farmyard manure. Ecol Chem Eng A. l19 : 105-111.

Mesfin Abebe. 1998. Nature and Management of Ethiopian Soils. Alemaya University of Agriculture, Ethiopia

Mesfin Abebe. 2009. Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods.

Mesfine Abebe Bertukan Mekonen and Waga Mazingia. 2001. A review of fertilizer management Research on maize in Ethiopia. In: Enhancing the Contribution of Maize to Food Security in Ethiopia: Proceedings of the second national maize workshop of Ethiopia.12-16 November 2001, Addis Ababa, Ethiopia. Pp: 46-54.

Milkha S.and Aulakh A. 2010. Integrated nutrient management for sustainable crop production, improving crop quality and soil health, and minimizing environmental pollution, presented at the 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World 1– 6 August 2010, Brisbane, Australia.

Mitiku Haile, Herweg K. and Stillhardt B. 2006. *Sustainable land management*: *a new approach to soil and water conservation in Ethiopia.* Mekelle, Ethiopia

Mitiku Weldesenbet, Temedo, T, Singh, TN and Teferi, M. 2014. Effect of integrated nutrient management on Yield and Yield components of Barley (Hordium vulgare L.) in Keffa Zone, South western Ethiopia. Sci.Technol. Arts Res. J. 3(2): 34-42

Mitiku Woldesenbet, and Asnakech Haileyesus. 2016."Effect of nitrogen fertilizer on growth, yield and yield components of maize (zea mays l.) in decha district, southwestern Ethiopia" International Journal of Research - Granthaalayah, Vol. 4, No. 2: 95-100.

MoARD.2010. Ethiopia's Agricultural Sector Policy and Investment Framework (PIF) draft final report, 2010-2020.

Mohammadi GH, Kahrizi D, MF Sadeghi.2008. Maize, Academic Press of Islamic Azad University of Kermanshah, p 619.

Mohammadian Roshan, N., S.M. Sadeghi, E. Azarpour, H.R. Bozorgi and M. Moradi.2010. Study effect of different levels of nitrogen fertilizer and planting density on yield and yield components of corn cultivar SC704. Proceeding of 11th Iranian Crop Science Congress; 2758-2761.

Moll, R.H.; Kamprath, E.J. and Jackson, W.A. 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agronomy Journal, 74:562 564.

Moreira A, Fageria NK.2010. Liming Influence on Soil Chemical Properties, Nutritional Status and Yield of Alfalfa Grown In Acid Soil. R. Bras. Ci. Solo 34:1231-1239.

Mosisa Worku, Jemale Abdurehman, Leta Tulu, Haji Tuna, Legesse Wolde, Kassa Yihun, Wonde Abera, Aschalew Guta, Sewagegne Tarikue, Teshale Asefa, Tamirat Birhanu, Yosef Beyene and Habtamu Zeleke, 2001. Development of improved maize germ plasmplasma for the mid and low altitude sub humid agro ecologies of Ethiopia. pp:27: 27-30.

Mosisa Worku, Hadji Tuna,Mandefro Nigussie,Abera Deressa,Tanner D.,and Twumasi-Afriyie S.2002.Maize roduction trends and research in Ethiopia. Mandefro,N Tanner, DG, Twumasi-Afriyie S.(eds),10-14.

Mosisa Worku, Twumasi-Afriyie S.,Wolde Legesse,Tadesse Berhanu,Demisie Girma, Bogale Gezahegn,Prasanna BM.2012.Meeting the challenges of global climate change and food security through innovative maize research .Proceedings of the National Maize Workshop of Ethiopia,3;Addis Abeba, Ethiopia;18-20April,2011:CIMMYT.

Muhammad W., Vaughan M., Dalal C.and Menzies W. 2013. Crop residues and fertilizer nitrogen influence residue decomposition and nitrous oxide emission from a Vertisols. Biol Fertil Soils 47: 15-23.

Mungai, N.W., Macharia C.N. and Kamau A.W.1999. The effect of organic and inorganic phosphorus, and time of split application of nitrogen on maize in Kenya: In Proceedings of the sixth Eastern and Southern Africa Regional Maize Conference, Addis Ababa,Ethiopia.

Nagle, S.M. 1983. Evaluation of selected lime requirement tests for Virginia soils developed through field response of soil pH and crop yields.

Negash Teshome.2018. Influence of potassium fertilization and liming on growth, grain yield, and quality of soybean *(Glycine max* l. (merrill) on acidic soil in Gobu sayo district, western Ethiopia, Msc thesis, Jimma University.

Negassa Wakene and Heluf Gebrekidan, 2001. *Assessment of Important Physicochemical Properties of Dystric Udalf (Dystric Nitosols) under different Management Systems in Boko Area, Western Ethiopia.* MSc Thesis, Alemaya University, Ethiopa.

Neilson RE.2003. Ear initiation and size determination in corn. Corny news network.

Department of Agronomy, Perdue University, Perdue

Olsen, S. R., C.V. Cole, F. S. Watanabe and L. A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USA Circular 939: 1- 19.

Onasanya RO, Aiyelari OP, Onasanya A, Nwilene FE, Oyelakin O. 2009. Effect of Different Levels of Nitrogen and Phosphorous Fertilizers on the Growth and Yield of Maize (Zea mays L.) in Southwest Nigeria. International Journal Agriculture Research, 4. (6). 193-203.

Onasanya, R., Aiyelari P., Onasanya A., Oikeh S., Nwilene E., and Oyelakin O. 2009. *Growth and yield response of maize (Zea mays L.) to different rates of nitrogen and phosphorus fertilizers in southern Nigeria*, World Journal of Agricultural Scie. 4 :400-407.

Onwonga, R. N., Lelei, J. J. and B. Mochoge, B.2010. Mineral Nitrogen and Microbial Biomass Dynamics under Different Acid Soil Management Practices for Maize Production. *Journal Agricultural Science, 2*(1).

Opala P. A ,Martins O.D and Francis N. M.2018. Effects of lime and fertilizer on soil properties and maize yields in acid soils of Western Kenya, African Journal of Agricultural Research, Vol. 13(13), pp. 657-663, 29 ,DOI: 10.5897/AJAR2018.13066, ISSN 1991-637X.

Orkaido Olte. 2004. Effects of nitrogen and phosphorus fertilizers on yield and yield components of maize (zea mays l.) on black soil of regede konso.

Paul F., Frank B., Tom B., Fernando G., Rob N., and Shamie Z. 2014. Nutrient/fertilizer use efficiency: measurement, current situation and trends. International Plant Nutrition Institute, 2301 Research Park Way, Suite 126, Brookings, SD 57006 (U.S.)

Peter A. Opala, Martins Odendo and Francis N. Muyekho. 2018. Effects of lime and fertilizer on soil properties and maize yields in acid soils of Western Kenya, African Journal of Agricultural Research, Vol. 13(13), pp. 657 663, 29 ,DOI: 10.5897/AJAR2018.13066,ISS N 1991-637X

Ponette, Q., S. Belkacem and C.Nys, 1996. Ion dynamics in acid forest soils as affected by addition of Ca fertilizers. *Geoderma*, 71:53-76.

Rahman M., Begum M. F., Alam M. 2012. *Effect of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of chilli,* International Journal of Biosciences (IJB) Bangladesh.

Raisi, M. J., and Tohidi-Nejad, E. 2012. *Effect of organic manure and foliar potassium application on yield performance of wheat cultivars (Triticum aestivum L.),* International Research Journal of Applied and Basic Sciences, *3*: 286-291.

Rajcan, I. and Tollenaar, M.1999. Source, sink ratio and leaf senescence in maize. I. Drymatter accumulation and partitioning during kernel filling. Field Crops Research, 60: 245253.

Raouf Seyed Sharifi1,Ali Namvar.206. Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.), Biologija. 2016. Vol. 62. No. 1. P. 35-45

Reeuwijk V, LP. 1993.*Procedures for soil analysis*. 4th ed. Wageningen, The Netherlands: International Soil Reference and Information Center.

Rietra. R.P.J.J, M. Heinen, C. Dimkpa and P.S. Bindraban, 2015. Effects of nutrient antagonism and synergism onfertilizer use efficiency. VFRC Report 2015/5. Virtual Fertilizer Research Center, Washington, D.C. 42 pp.; 17 tables;1 fig.; 229 ref.

Rosan, G., O.Yerokun and J. D. T. Kumwenda.1997. Nitrogen and phosphorus uptake from Tithoniadiversifolia and inorganic fertilizers and their effect on maize yield in Malawi, pp.264-266. In Proceeding of Symposium on Maize Production Technology for the Future: Challenge and Opportunist in Africa. A. A., Ethiopia.

Rowell, D. L. 2014. *Soil science: Methods & applications*. Routledge.

Sabir, M.R. Ahmad, I and Shahzad.2007. Effect of nitrogen and phosphorus on yield and quality of two hybrids of maize (Zea mays L.). Journal of Agricultural Research, 4: 339346.

Sahlemedhin Sertsu and Taye Bekele, 2000. Procrdures for soil and plant anlysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Sahrawat K., Wani S., Pathak P., and Rego T. 2010. Managing natural resources of watersheds in the semi-arid tropics for improved soil and water quality: A review. *Agricultural Water Management*, *97*(3), 375-381.

Saidu, A, Ole, K and Leye, BO. 2012. Performance of Wheat (*Triticum aestivum* L.) as influenced by complementary use of organic and inorganic fertilizers. Intern. J. of Sci. and Nature 5(4): 532-537.

Salisbury, F. B. and. C. W., Ross. 1992. Plant physiology. 4th ed. Wadsworth Publishing Company, Belmont, California. 243pp.

Samuel Taye, Werner.N, James .B, John .H.2000. *Soil fertility and fertilizers, 5thed,* Prenticehall

of India private limited, New Delhi.

Sanjeev K,. and AS. Bangarwa. 1997. Yield and yield components of winter maize (Zea mays L.) as influenced by plant density and nitrogen levels. Agricultural Science. Digest (Karnal),.17:181-184.

Shah, K.P and Arif, M. 2001. Management of organic farming: Effectiveness of farmyard manure and nitrogen for maize productivity. Sarhad Journal of Agriculture, 16: 461-466.

Shahid Rasool, Raihana H. Kanth, Shabana Hamid, Bashir A. Alie, Waseem Raja and Zahoor A. Dar. 2016. Effect of Integrated Nutrient Management on Yield and Yield Attributes of Sweet Corn (Zea mays L. saccharata) Under Wet Temperate Conditions of Western Himalayas (India). American Journal of Experimental Agriculture 13: 1-9.

Sharifi, R.S. and Namvar, A. 2016. Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (Zea mays L.). *Biologija, 62*(1)

Sharma, S. and Subehia S. 2003. Effects of twenty five years of fertilizer use on maize and wheat yields and quality on acidic soil in the western Himalayas. Exp. Agric., 39:55-63.

Shiferaw Bokore and Anteneh Fikadu. 2014. Lime and NPK Effect on Soil Acidity and Yield of Barely in different Acid Soils of Southern Region, Ethiopia. Intern. J. of Natu. Sci. Res. 2(7): 113-122.

Shimeles D, Mohammed A, Abayneh E. 2006. *Characterization and Classification of the Soils of Tenocha-Wenchancher Micro Catchment, Southwest Shewa.* M.Sc thesis, Alemaya University, Ethiopia. pp 111.

Shirani H., Hajabbas M. A., Afyuni M.and Hemmat A. 2002. Effects of Farmyard Manure and Tillage Systems on Soil Physical Properties and Corn Yield in Central Iran. Soil and Tillage Research, 68: 101-108.

Shrestha, J. 2013. Effect of nitrogen and plant population on flowering and grain yield of winter maize. *Sky J Agric Res*, *2*(5), pp.64-68.

Singh, A.K. and S.S. Singh. 2002. Effect of planting dates nitrogen and phosphorus levels on yield contributing characters in French bean. Legume Res., 23: 33-36.

Singh, S., Verma S. C. and Singh R. P. 2001. *Effect of integrated nutrient management on yield, nutrient uptake andchanges in soil fertility under rice (Oryza sativa)- lentil (Lens culinaris) cropping system*, Indian J.of Agron.,36: 191-197.

Slattery, WJ and Coventry, DR.1993. Response of wheat, triticale, barley, and canola to lime on

four soil types in north-eastern Victoria. Aust. J. of Experi. Agric. 33: 609-618.

Sosulski, F. W., Hutcheon, W. L. and Paul, E. A. 2011.The influence of soil moisture, nitrogen fertilization, and temperature on quality and amino acid composition of Thatcher wheat.

Sugiharto, B., K. Miyata, H. Nakamoto, H. Sasakawa and P. Sugiyama.1990. Regulation of expression of carbon-assimilating enzymes by nitrogen in maize leaf. Plant Physiology, 92: 936-969.

Syed T., M. Shahid I., Waseem M., Asghar A., Tahir M.and Waleed B. 2009. Growth and Yield Response of Maize (Zea mays L.) to Organic and Inorganic Sources of Nitrogen. Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

Tadese Moges. Asmare Melese and Girma Tadesse. 2018 Effect of lime and phosphorus fertilizer levels on growth and yield components of malt barley (Hordeum distichum L.) in Angolela Tera District, North Shewa Zone, Ethiopia.Advances in Plants and Agriculture Research,Volume 8 Issue 6 p 582-589.

Taye Belachew and Yifru Abera. 2010. Assessment of Soil Fertility Status with Depth in Wheat Growing Highlands of Southeast Ethiopia, World Journal of Agricultural Sciences 6: 525-531.

Taylor and Francis. 2006. Soil Sampling and Methods of Analysis 2nded, vol. 1, Canadian Society of Soil Science, Canada.

Tekalign Mamo, Hague, I. and Kamara, C.S. 1988. Phosphorus status of some Ethiopian highland Vertisol. In: Jutz, S.C., F. Hague Mcintric (eds.). Soil in sub-Sahara Africa, ILCA, Addis Ababa, Ethiopia. Pp. 232-242

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis: Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Teklu Erkossa. 2005. *Land preparation methods and soil quality of a vertisol area in the central highlands of Ethiopia*. PhD thesis, University of Hohenheim, Stuttgart.

Tesfaye Bayu.2017. Effect of Integrated Fertility Management on Soil Physico-Chemical Properties and Yield and Yield Components of Maize (Zea Mays L.) and Tef (Eragrostis Tef) at Yilmana Desnsa District, Northwestern Ethiopia, MSc thesis Bahir Dar University.

Thanki JD, Patel PG, Thanki SD. 1988. Response of hybrid maize (Zea maysL.) to graded levels of nitrogen, phosphorus and potash in the summer season. Journal of Agriculture

Research. 14:55-57.

Tilahun Getahun. 2007. Soil fertility status as influenced by different land uses in Maybar areas of South Wello Zone, North Ethiopia. Haramaya University Ethiopia.

Tisdale Semahegn, W.L. Nelson, J.D. Beaton and J.L. Havlin. 1995. Soil Fertility and Fertilizers. 5th ed., Macmillan, New York.

Tolcha Tufa. 2018. Soil Fertility Status and Response of Maize (*Zea mays* L.) to NPS and DAP Fertilizers Rates in Bako Tibe District, Western Ethiopia, MSc Thesis ,Haramaya University.

Tolessa Debelle, Gemechu Gedeno, and MelakeselamLeul. 1994. Response of maize to split application of nitrogen fertilizer at Bako. *Sebil* 6: 56-60. Tolessa Debelle, TesfaBogale, WakeneNegassa, TenawWorayenu, MinaleLiben.

Tollenaar, M., A. Aguilera and S.P. Nissnka. 1997. Grain yield is reduced more by weed interference in an old than in a new maize hybrid. Agronomy Journal. 89(2): 239-246.

Trinh, Q.K., Pham, S. T., and Christian, W. 2008. Improving of maize yield and profitability through site specific nutrient management (SSNM) and planting density, International Plant Nutrition Institute, Southeast Asia Program, Singapore 16: 88-92.

Troeh, F. and Thompson, M. 1993, *Soils and soil fertility 5thed.* New York, Oxford University.

Tsedeke Abate, Bekele Shiferaw, Abebe Menkere, Dadne Wagary, Yilma Kebede, Kendie Tesfay, Tolera Keno.2015.Factors that transformed maize productivity in Ethiopia. Food security ,7(5),965-981.

Uhart, S.A., and F.H. Andrade.1995. Nitrogen deficiency in maize: II. Carbon–nitrogen interaction effects on kernel number and grain yield of corn. Crop Science, 35: 1384-1389.

Wagh, D. S. 2002. Effect of spacing and integrated nutrient management on growth and yield of sweet corn (Zea mays L. saccharata). M.Sc. Thesis Mahatma Phule Krishi Vidyapeeth, Rahuri, Pune. doi:10.1044/ 1059-0889(2002/er01).

Wajid, A., Ghaffar, A., Maqsood, M., Hussain, K. and Nasim, W. 2007. Yield response of maize hybrids to varying nitrogen rates. Pakistan Journal of Agricultural Sciences, 44(2), pp.217-220.

Walkley, A. and. Black, C.A.1934. An examination of Degtjareff method for determining soil organic matter.

Waluchio Nadir S, Caleb O. Othieno, Wilson K. Ngetich and Julius O. Ochuodho.2015. Evaluation of Nitrogen Fertilizer and Lime on Grainn Yield, Protein Content and Kernel Weight of Barley (Hordeum vulgare L.) in Kenya; International Journal of Plant & Soil Science; 8(4): 1-7, 2015; Article no.IJPSS.6239,ISSN: 2320-7035

Wang, X., Hoogmoed, W.B., Cai, D. Perdok, U.D. and Oenema O. 2007. Crop residue, manure and fertilizer in dry land maize under reduced tillage in northern China: II nutrient balances and soil fertility. Nutrient Cycling in Agro ecosystems, 79: 17-34.

Wende Abera, 2013. Genetic Diversity, Stability, and Combining Ability of maize Genotypes for Grain Yield and Resistance to NCLB in the Mid-Altitude Sub-Humid Agro-Ecologies of Ethiopia, PhD dissertation, African Center for Crop Improvement School of Agricultural, Earth and Environmental Sciences College of Agriculture, Engineering and Science University of KwaZulu-Natal Republic of South Africa.

Whalen JK, Chang C, Clayton GW .2002. Cattle manure and lime amendments to improve crop production of acidic soils in northern Alberta. Can. J. Soil Sci. 82:227-238.

White, R.E. 1997. *Principles and practices of soils science*: The soil is the natural resource.

William F, Jean bonhtel, and Tom Fiesinger. 2012. Compost sampling for nutrient quality parameters: variability of sampler, timing and pile depth. New York State Energy Research and Development Authority, Albany, New York.

William R. Raun and Gordon V. Johnson. 1999. Improving Nitrogen Use Efficiency for Cereal Production. Oklahoma State University, Stillwater, OK 74078.

Wiqar Ahmad, Zahir Shah, Farmanullah Khan, Shamsher Aliand Wasiullah MalikMaize. 2013. Yield and soil properties as influenced by integrated use of organic, inorganic and bio-fertilizers in a low fertility soil. Soil Environ. 32: 121-129.

Mitiku Woldesenbet and Asnakech Haileyesus. 2016. Effect of Nitrogen Fertilizer on Growth, Yield and Yield Components of Maize (Zea mays L.) in Decha District, Southwestern Ethiopia. Intl. J. Res. Granthaalayah, 4(2), pp.95-100.

Woldeyesus Sinebo, Gretzmacher, R and Edelbauer, A. 2004. Genotypic variation for nitrogen use efficiency in Ethiopian barley, Field Crop Res. 85: 43-60.

Wondimu Bayu, Rethman G., Hammes S. and Getachew Alemu, 2006. Application of Farmyard Manure Improved the Chemical and Physical Properties of the Soil in a Semi-Arid Area in Ethiopia. Biological Agriculture and Horticulture, 24 : 293-300.

Woubshet Demissie, Selamyihun Kidanu, Tolera Abera and Cherukuri V Raghavaiah.*2017*.Effec ts of Lime, Blended Fertilizer (NPSB) and Compost on Yield and Yield Attributes of Barley (*Hordium Vulgare* L.) on Acid Soils of Wolmera District, West Showa, Ethiopia. *Ethiop.J.Appl.Sci. Technol. Vol.8 (2): 84-100(2017)*

Yihenew G.Selassie.2015. The effect of N fertilizer rates on agronomic parameters, yield components and yields of maize grown on Alfisols of North-western Ethiopia. *Environ Syst Res (2015) 4:21,* DOI 10.1186/s40068-015-0048-8

Yuli Lestari, Azwar Maas, Benito Heru Purwanto & Sri Nuryani Hidayah Utami.2016. The Influence of Lime and Nitrogen Fertilizer on Soil Acidity, Growth and Nitrogen Uptake of Corn in Total Reclaimed Potential Acid Sulphate Soil, Journal of Agricultural Science; Vol. 8, No. 12; 2016 ISSN 1916-9752 E-ISSN 1916-9760.

Zamir M.S.I., Yasin G., Javeed H.M.R., Ahmad A.U.H., Tanveer A., Yaseen M. 2013. Effect of different sowing techniques and mulches on the growth and yield behavior of spring planted maize (Zea mays L.). Cercetări Agronomice în Moldova, 1(153): 77-82.

Zelleke Gete, Getachew Agwgnehu, Dejene Abera and Shahid R. 2010. Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and opportunities for enhancing the system. IFPRI, Ethiopia.

Zsolnay, A and Gorlitz G. 1994. Water extractable organic matter in arable soils: Effects of drought and long term fertilization. Soil Biology and Biochemistry. 26: 1257-1261.

Bremner, J.M. and Mulvaney, C.S. (1982) Nitrogen-Total. In: Page, A.L., Ed., Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America, 595-624.

Assefa Derebe 2009 Assessment of upland erosion processes and farmer's perception of land Conservation inDebre-mewiwatershed, near lakeTana, Ethiopia.

Blake G.R. 1965. Bulk density In: Methods of Soil Analysis. Agronomy Part I, No. 9, pp.374-399 (Black, C.A. ed.), American Society of Agronomy, Madison, Wisconsin, USA.

Brady N.C.and Weil R.R. 2002. The nature and properties of soils. 13thEd,Prentice-HallInc.,NewJersey,USA.960p, 360p.Carrow R.N, Stowell L, Gelernter W, Davis S,

Gupta P.K. 2004.Soil, plant, water and fertilizer analysis. Shyam Printing Press, Agro bios, India.438p.

7. APPENDICES

Appendix Table1.Critical level used for classifying soil fertility parameters analysis result (Ethiosis team analysis, 2014)

Soil parameters	Status	Critical level	Soil parameters	Status	Critical levels
Soil pH(water)	Strongly acidic	<5.5	Available P mg/kg	Very low	0-15
	Moderately acidic	5.6-6.5		Low	15-30
	Neutral	6.6-7.3		Optimum	30-80
	Moderately alkaline	7.3-8.4		High	80-150
	Strongly alkaline	>8.4		Very high	>150
EC(dS/m)	Salt free	< 2	Organic matter (%)	Very low	<0.2
	Very slightly	2–4		Low	2.0-3.0
	Saline	4-8		Optimum	3.0-7.0
	Slightly saline	8–16		High	7.0-8.0
	Moderately saline	> 16		Very high	> 8.0
Total N (%)	Very low	< 0.1	CEC(cmol/ kg)	Very low	<0.2
	Low	0.1–0.5		Low	5-15
	Optimum	0.15–0.3		Medium	15.25
	High	0.3–0.5		High	25-40
	Very high	> 0.5		Very high	>40

AppendixTable2. ANOVA table for days to 50% tasseling

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	111.66	27.91	279.17	<.0001
Lime	1	14.70	14.70	147.00	<.0001
Rep	2	0.86	0.43	4.33	0.0531
Manure*lime	4	1.80	0.45	4.50	0.0338
Rep*Manure	8	2.133	0.26	2.67	0935
Rep*lime	2	0.200	0.10	1.00	0.4096

Appendix Table 3 ANOVA table for days to 50% silking

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	153.20	38.30	287.25	<.0001
Lime	1	50.70	50.70	380.25	<.0001
Rep	2	0.466	0.233	1.75	0.2342
Manure*lime	4	4.133	1.033	7.75	0.0074
Rep*Manure	8	1.200	0.150	1.13	0.4359
Rep*lime	2	0.60	0.33	2.25	0.1678

Appendix Table 4.ANOVA table for Days to 90% physiological maturity

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	101.466	25.366	179.06	<.0001
Lime	1	0.833	0.833	5.88	0.0415
Rep	2	0.466	0.233	1.65	0.2517
Manure*lime	4	6.667	1.667	11.76	0.0020
Rep*Manure	8	0.533	0.441	3.12	0.0642
Rep*lime	2	0.866	0.433	3.06	0.1031

Appendix Table 5.ANOVA table for plant height

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	3.84385333	0.96096333	243.85	<.0001
Lime	1	0.15987000	0.15987000	40.57	0.0002
Rep	2	0.00748667	0.00374333	0.95	0.4264
Manure*lime	4	0.09081333	0.02270333	5.76	0.0175
Rep*Manure	8	0.03364667	0.00420583	1.07	0.4645
Rep*lime	2	0.00854000	0.00427000	1.08	0.3833

Appendix Table 6.ANOVA table for the Number of leaves per plant

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	83.33	20.83	312.50	<.0001
Lime	1	16.13	16.13	242.00	<.0001
Rep	2	2.60	1.30	19.50	0.2301
Manure*lime	4	2.60	0.47	7.00	0.0100
Rep*Manure	8	1.87	0.13	2.00	0.1733
Rep*lime	2	0.47	0.23	3.500	0.0809

Appendix Table 7.ANOVA table for the number of cobs per plant

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	9.1580	2.28	249.76	<.0001
Lime	1	0.800	0.80	87.31	<.0001
Rep	2	0.200	0.100	10.95	0.114
Manure*lime	4	0.344	0086	9.40	0.0041
Rep*Manure	8	0.276	0.0345	3.76	0.0394
Rep*lime	2	0.0167	0.0083	0.91	0.4408

AppendixTable 8.ANOVA table for the number of grains per cobs

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	8893.752000	2223.438000	4092.22	<.0001
Lime	1	67.500000	67.500000	124.23	<.0001
Rep	2	3.082667	1.541333	2.84	0.1172
Manure*lime	4	11.613333	2.903333	5.34	0.0215
Rep*Manure	8	4.464000	0.558000	1.03	0.4854
Rep*lime	2	2.400000	1.200000	2.21	0.1723

Appendix Table 9 ANOVA table for1000 seed weight of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	3404.134120	851.033530	161.83	<.0001
lime	1	3442.858239	3442.858239	654.68	<.0001
Rep	2	40.663398	20.331699	3.87	0.0669
Manure*lime	4	183.511173	45.877793	8.72	0.0051
Rep*Manure	8	98.668231	12.333529	2.35	0.1246
Rep*lime	2	19.214743	9.607372	1.83	0.2221

AppendixTable 10.ANOVA table for Grain yield of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Manure	4	46885701.17	11721425.29	13769.9	<.0001
Lime	1	3923591.48	3923591.48	4609.30	<.0001
Rep	2	1977.34	988.67	1.16	0.3607
Manure*lime	4	377347.59	94336.90	110.82	<.0001
Rep*Manure	8	6808.13	851.02	1.00	0.5001
Rep*lime	2	1595.84	797.92	0.94	0.4308

AppendixTable 11.ANOVA table for above ground dry biomass of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
manure	4	194031964.4	48507991.1	580.09	<.0001
lime	1	14197334.2	14197334.2	169.78	<.0001
Rep	2	170256.6	85128.3	1.02	0.4037
manure*lime	4	2363235.1	590808.8	7.07	0.0098
Rep*manure	8	659186.5	82398.3	0.99	0.5081
Rep*lime	2	163140.9	81570.5	0.98	0.4177

Appendix Table 12.ANOVA table for harvest index of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
manure	4	0.02511333	0.00627833	163.78	<.0001
Lime	1	0.00048000	0.00627833	12.52	0.0076
Rep	2	0.00002000	0.00001000	0.26	0.7767
manure*Lime	4	0.00115333	0.00028833	7.52	0.0081
Rep*manure	8	0.00014667	0.00048000	0.48	0.8414
Rep*Lime	2	0.00006000		0.78	0.4893

AppendixTable 13.ANOVA table for the Straw yield of maize

Source	DF	Type I SS	Mean Square	F Value	Pr > F
manure	4	44830525.67	11207631.42	336.65	<.0001
Lime	1	3232113.63	3232113.63	97.08	<.0001
Rep	2	66734.60	33367.30	1.00	0.4089
manure*Lime	4	842560.87	210640.22	6.33	0.0134
Rep*manure	8	266601.73	33325.22	1.00	0.4995
Rep*Lime	2	67000.47	33500.23	1.01	0.4076

Appendix Table 14.Partial budget analysis of lime andmanure fertilizer rates applied for maize in Meket District

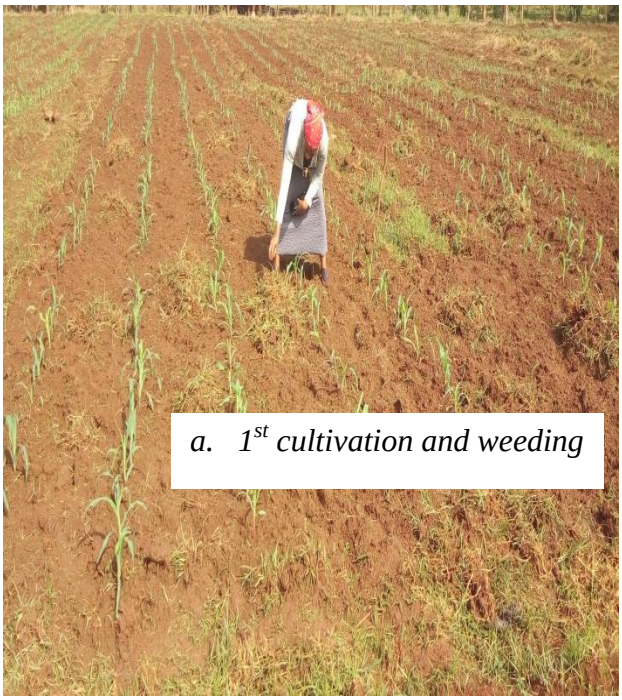
Items	Treatments									
	1	2	3	4	5	6	7	8	9	10
GY (kg/ha)	3530.15	5294.73	5766.53	6116.14	6892.8	3671.75	6062.35	6516.03	7122.44	7669.88
GB (ETB/ha)	35301.5	52947.3	57665.3	64461.4	68928	36717.5	60623.5	65160.3	71224.4	76698.8
Cost of BH661/ha	520.83	520.83	520.83	520.83	520.83	520.83	520.83	520.83	520.83	520.83
Cost of NPS fertilizer/ha	2080	2080	2080	2080	2080	2080	2080	2080	2080	2080
Cost of lime	0	0	0	0	0	675	675	675	675	675
Cost of manure	0	1200		3600	4800	0		2400	3600	4800
Cost of munure fertilizer application	0	1000	1000	1000	1000	0	1000	1000	1000	1000
Cost of NPS application	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Cost of lime application	0	0	0	0	0	125	125	125	125	125
Cost of weeding and cultivation	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
Cost of harvesting and bagging	1028.09	1498.87	1598.298	1780.744	1929.98	988.442	1697.46	1842.40	2032.097	2167.1636
TVC	5928.9	8599.701	9899.129	11281.57	12630.82	6689.272	9598.291	10943.23	12332.93	13667.99
NB (ETB/ha)	29,372.5	44,347.59	47,766.2	53,179.83	56,297.18	30,028.2.	51,025.21	54,217.07	58,891.5	63,030.81

GY=grain yield, GB=gross benefit, TVC=total variable cost, NB=net benefit

Appendix Table 15.Summary of 10 years (2012-2021) mean rain fall and temperature data of study area

Climate data	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total RF
	Average Rain fall (mm)												
RF(mm)	7.2	7.8	46.2	52.6	194.0	242.8	313.1	201.3	144.0	84.8	71.9	10.0	1375.8
	Mean Monthly Temperature(ºC)												
Mean Temperature													
MinT.(ºC)	10.37	11.19	12.65	12.59	14.01	14.4	12.53	13.80	12.40	12.19	11.81	9.67	12.31
Max.T.(ºC)	27.81	28.71	29.25	28.74	24.69	24.92	23.10	22.33	24.28	25.70	24.85	26.81	25.93
MeanT.(ºC)	19.09	19.95	20.95	20.66	19.35	19.70	17.82	18.06	18.34	18.94	18.33	18.24,	19.12

APPENDEX FIGURES



a. 1st cultivation and weeding



b. Urea dressing and weeding



c. Tasseling & Silking stage

Appendix Figure 1. Partial view of ten treatments with three replication and yield