2025-03

Impact of Bitter White Lupine Green Manure, Vermicompost and Chemical Fertilizer Rates on Wheat (Triticum Aestivum) Yield and Soil Physicochemical Properties in Mecha District, Northwestern Ethiopia

Aschalew, Tiruneh

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF PLANT SCIENCES

POSTGRADUATE PROGRAM IN AGRONOMY

IMPACT OF BITTER WHITE LUPINE GREEN MANURE, VERMICOMPOST AND CHEMICAL FERTILIZER RATES ON WHEAT (*Triticum aestivum*) YIELD AND SOIL PHYSICOCHEMICAL PROPERTIES IN MECHA DISTRICT, NORTHWESTERN ETHIOPIA

MSc. Thesis

By

Tiruneh Aschalew

March, 2025

Bahir Dar, Ethiopia

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF PLANT SCIENCES

IMPACT OF BITTER WHITE LUPINE GREEN MANURE, VERMICOMPOST AND CHEMICAL FERTILIZER RATES ON WHEAT (*Triticum aestivum*) YIELD AND SOIL PHYSICOCHEMICAL PROPERTIES IN MECHA DISTRICT, NORTHWESTERN ETHIOPIA

MSc. Thesis

By

Tiruneh Aschalew

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSc.) IN AGRONOMY

Major Advisor: Professor Enyew Adgo

Co-advisor: Dr. Yayeh Bitew

March, 2025

Bahir Dar, Ethiopia

APPROVAL SHEET

As members, of the board of examiners of the Master of Sciences (MSc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Tiruneh Aschalew** entitled **Impact of Bitter White Lupine Green Manure, Vermicompost and Chemical Fertilizer rates on Wheat (Triticum aestivum) Yield and Soil Physicochemical Properties in Mecha District, Northwestern Ethiopia**. We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of Master of Sciences (MSc.) in **Agronomy**.

Board of examiners

Mulatu Kassaye (PhD)	______	30/03/2025
Name of External Examiner	Signature	Date
Dereje Ayalew (PhD)	______	30/03/2025
Name of internal Examiner	Signature	Date
Merkuz Abera	______	2/04/2025
Name of Chairperson	Signature	Date

College of Agricultural & Environmental Sciences
Department of Plant Sciences

DECLARATION

This is to certify that this thesis entitled "**Impact of Bitter White Lupine Green Manure, Vermicompost and Chemical Fertilizer rates on Wheat (*Triticum aestivum*) Yield and Soil Physicochemical Properties in Mecha District**, **Northwestern Ethiopia."** submitted in partial fulfillment of the requirement for the award of the degree master of sciences (MSc.) in **Agronomy** to the graduate program of the college of agriculture and environmental sciences, Bahir Dar University, by Mr. **Tiruneh Aschalew** (ID No. BDU 1500876) is an authentic work carried out by him under our guidance. The matter embodied in this project has not been submitted earlier for award of my degree or diploma, to the best of our knowledge and belief.

Tiruneh Aschalew	______________	30/03/2025
Name of the student	Signature	Date
Enyew Adgo (Prof)	Enyew Adgo Tsegaye (Prof.) e President for Research & Community Engagement	30/03/2025
Name Major Advisor	Signature	Date
Yayeh Bitew (PhD)	______________	30/03/2025
Name of Co-advisor	Signature	Date

ACKNOWLEDGEMENTS

The success of this study cannot solely be attributed to efforts of one individual. Generally, there must be joining of efforts to make such an exercise a success. On that note, the following deserve my thanks and feelings of gratitude. Primary, I would like to thank the Almighty God who gave us life and protection. I also express my gratitude to the administrative and teaching staff of the faculty of Agriculture and Environmental Sciences, Department of plant science Bahir Dar University (BDU) for the favorable learning environment and cooperation during my stay at university. I am indebted to my supervisor Professor Enyew Adgo, for undertaking the task of supervising this work, his willingness, his expertise, invaluable criticism during the entire course of my investigations, guidance and assistance to identify gaps in this research. I gained a tremendous amount of knowledge under his supervision. It is his constant encouragement, constructive criticisms and suggestions that made this work possible and I would like to thank Healthy Food Africa Project for supporting my research work financially.

I thankful to esteemed Dr. Yayeh Bitew for his proper guidance during the entire course of present studies I expressed my heartfelt thanks to my friends, field workers, classmates and roommates for their cooperation, encouragement, moral and timely help when required. I avail the blessings, affection and moral encouragement of my gracious parents, brothers and sisters, constant moral encouragement inspired me to search ahead.

LIST OF ACRONYMS/ABBREVIATIONS

AARC	Adet Agricultural Research Center
ANOVA	Analysis of Variance
Av.P	Available phosphorus
BD	Bulk density
BNB	Blue Nile Basin
CEC	Cation exchange capacity
CIMMYT	International Maize and Wheat Improvement Center
EC	Electrical conductivity
FYM	Farm yard manure
IFPRI	International Food Policy Research Institute
ISFM	Integrated soil fertility management
LGM	Lupine green manure
LSD	Least significant difference
MCM	Million cubic meters
MoA	Ministry of Agriculture
MRR	Marginal Rate of Return
NPSB	Nitrogen, phosphorus, sulfur and boron fertilizer
OC	Organic carbon
OF	Organic fertilizer
PH	Power of hydrogen
RCBD	Randomized complete block design
RCF	Recommended chemical fertilizer
RF	Rain fall
SNNP	Southern Nation’s Nationalities and Peoples of Ethiopia
SOM	Soil organic matter
TN	Total nitrogen
VC	Vermicompost

Impact of Bitter White Lupine Green Manure, Vermicompost and Chemical Fertilizer rates on Wheat (*Triticum aestivum*) Yield and Soil Physicochemical Properties in Mecha District, Northwestern Ethiopia.

ABSTRACT

Wheat is a significant cereal crop in terms of production and cultivated area. In the majority of Ethiopia's highlands, crop production is severely hampered by acidity and deterioration of the soil properties. As a result the actual yield of crops in general and wheat in particular much lower than the potential yields. Thus, this research was initiated to: assess the productivity of wheat crops in response to applications of chemical fertilizers, vermicompost, and bitter lupines green manure. The study was carried out at Koga Irrigation Scheme during 2023 main cropping season. Three levels of chemical fertilizers (0, 50%, and 100% of the recommended rate which is 0/0, 125/100, 250/200 kg/ha urea & NPSB respectively), three levels of bitter lupine green manure fresh biomass (0, 2.5, and 5 t/ha dry matter based) and three levels of vermicompost (0, 2.5 and 5 t/ha) were the treatments included in the experiment. The experiment was laid out in a randomized complete block design replicated three times per treatment. Data were collected on, selected soil properties before and after experimentation and on phenological, vegetative growth, and yield related parameters of wheat. All the collected soil and wheat parameters were analyzed using SAS software and for significant test the mean separation was performed using Tukey (HSD). The results indicated that the higher total N (0.29%), was recorded from the combined application of 5 t/ha Lupine green manure with 2.5 t/ha vermicompost. The highest available phosphorus (Av.P) (19.18) was recorded from the combined application of 50% RCF with 5 t/ha Lupine green manure and 5 t/ha vermicompost. The highest organic carbon (1.86%) and CEC (28.7 cmol (+)/kg) of the soil was recorded on integrated application of 100% RCF with 5 t/ha Lupine green manure and 5 t/ha vermicompost application. The maximum grain yields (3922.5 kg ha^{-1}) and biomass yields (9599.2 kg ha^{-1}) were recorded from 100% RCF with 5 t/ha vermicompost and 5 t/ha Lupine green manure, whereas the lowest was recorded from the control. According to the partial budget analysis, the highest net profit (199353.5 ETB) was achieved when 50% RCF, 5 t/ha vermicompost and 5 t/ha Lupine green manure, resulting in a respective marginal rate of return (MRR) of 29465.6%. The combined application of RCF, Lupine green manure, and vermicompost improved the overall soil properties and yield and yield- related traits of wheat. Based on the wheat yield, soil improvement, and economic return, farmers should apply an integrated 50% RCF with 5 t/ha Lupine green manure and 5 t/ha vermicompost. Further research should be conducted over seasons and locations to draw sound recommendation.

Key words: Chemical fertilizers, Lupine green manure, Soil health, Vermicompost, Wheat productivity

TABLE OF CONTENTS

APPROVAL SHEET........ii
DECLARATION........iii
ACKNOWLEDGEMENTS........iv
LIST OF ACRONYMS/ABBREVIATIONS........v
ABSTRACT........vi
LIST OF TABLES........x
LIST OF FIGURES........xi
LIST OF APPENDIX TABLES........xii
Chapter 1. INTRODUCTION........1
1.1. Background and Justification........1
1.2. Statement of Problem........2
1.3. Objectives........4
1.3.1. General objective........4
1.3.2. Specific objectives........4
Chapter 2. LITERATURE REVIEW........5
2.1. Overview of Ethiopian Soils and Wheat Production........5
2.2. Production and Productivity of Wheat in Ethiopia........6
2.3. Effect of Lupine Green Manure on Crop Productivity and Soil Properties........7
2.4. Effect of Vermicompost on Soil Physicochemical Properties and Crop Productivity........10
2.5. Effect of Chemical Fertilizers on Crop Productivity and Soil Properties........13
2.6. The Effect of Integrated Use of Organic and Inorganic Fertilizers on Wheat Productivity and Soil Health........15
2.6.1. Effect of integrated organic fertilizer and inorganic fertilizer on soil fertility........15
2.6.2. Effect of integrated organic and inorganic fertilizer on growth and yield of wheat........16
Chapter 3. MATERIALS AND METHODS........18
3.1. Description of the Study Area........18
3.2 Experimental Test Materials........20
3.3. Experimental Treatments and Design Procedures........21
3.4. Data Collection........22
3.4.1 Soil sample collection and analysis of experimental field........22

TABLE OF CONTENTS (Continued)

3.4.2. Chemical Composition of vermicompost and lupine green manure 23
3.4.3 Agronomic data collection.. 23
3.5. Data Analysis.. 26
3.5.1 Statistical data analysis 26
3.5.2 Partial budget analysis 26
Chapter 4. RESULTS AND DISCUSSION 27
4.1. Selected Physicochemical Properties of Soil before Treatment Application 27
4.1. Effect of Treatments on Soil Physical Properties 28
4.1.1. Soil bulk density 28
4.1.2. Total porosity 29
4.2. Effect of Soil Amendments on Selected Soil Chemical Properties 30
4.2.1. Soil pH 30
4.2.2. Organic Carbon 31
4.2.3. Total Nitrogen 32
4.2.4. Available Phosphorous 33
4.2.5. Available Potassium 33
4.2.6. Cation Exchange Capacity 34
4.3. Effect of Soil Amendments on Phenological and Vegetative Parameters of Wheat 37
4.3.1. Days to 50% heading 37
4.3.2. Days to 90% maturity 38
4. 3.3. Plant height 38
4.3.4. Number of productive tillers 39
4.3.5. Spike length 40
4.5. Effect of Soil Amendments on Yield Components of Wheat 42
4.5.1. Number of grains per spike 42
4.5.2. Grain yield 43
4.5.3. Thousand grain weight 43
4.5.4. Straw yield 44
4.5.5. Biomass yield 45
4.5.6. Harvest index 45

TABLE OF CONTENTS (Continued)

4.6. Correlations 47
4.7. Partial Budget Analysis 48
Chapter 5. CONCLUSIONS AND RECOMMENDATIONS 51
5.1. Conclusions 51
5.2. Recommendations 51
6. REFERENCES 53
7. APPENDICES........ 61
AUTHOR'S BIOGRAPHY 64

LIST OF TABLES

Tables **Page**

3.1. Kakaba wheat variety information used for planting……………………………………..21

Selected physicochemical properties of soil before treatment application…………..…………27

4.1. Chemical Composition of vermicompost and lupine green manure before application……………………………………………………………………………….……28

4.2. Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on soil bulk density and total porosity.. 29

4.3. Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on soil pH and organic carbon 35

4.4. Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on total nitrogen and available phosporus……………………………………..….35

4.5. Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on cation exchange capacity and available potassium……………………………..36

4.6. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on days to 50% heading, days to 90% maturity and plant height of wheat ...39

4.7. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on spike length and productive tiller of Wheat 40

4.8. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on number grains per spike, thousand seed weight and grain yield of wheat…………………………………………………………………………….……………44

4.9. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on straw yield, biomass yield and harvest index of wheat………………….45

4.10. Correlations of Major agronomic Parameters... 46

4.11 Economic analysis of LGM, VC and chemical fertilizers in terms of partial budget and marginal rate of return (MRR) for wheat production 47

LIST OF FIGURES

Figure 3.1. Map of the study area 19

Figure 3.2. Rainfall and temperature distributions at the study area 20

LIST OF APPENDIX TABLES

Appendix Tables **Page**

1. Mean squares of ANOVA for 50% heading date (HD), 90% maturity date (MD), plant height (PH), spike length (SL) and tiller number (TN) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer 61

2. Mean squares of ANOVA for thousand seed weight (TSW), number of grains (NG), grain yield (GY), straw yield (SY), biomass yield (BY) and harvest index (HI) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer. 61

3. Mean squares of ANOVA (main and interaction) effects for days to 50% heading (HD), days to 90% maturity (MD), plant height (PH), tiller number (TN), spike length (SL) and thousand grain weight (TSW) of wheat as affected by lupine green m 62

4. Mean squares of ANOVA (main and interaction) effects for number of grains (NG), grain yield (GY), straw yield (SY), biomass yield (BY) and harvest index (HI) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer. 62

5. Mean squares of ANOVA for physicochemical properties of soil as affected by lupine green manure, vermicompost and recommended chemical fertilizer 62

6. Treatment combination and arrangement………………………………………………..……63

Chapter 1. INTRODUCTION

1.1. Background and Justification

Wheat (*Triticum aestivum L.*) is one of the most important staple food grain crops cultivated next to rice, both in area and production but it stands first in productivity amongst the cereals. Soil degradation is the most significant biophysical factor that causes a decrease in soil fertility and quality and limits crop production in Ethiopia (Gete Zelleke *et al*., 2010). As a result, the soils of the country are losing organic carbon, phosphorus, and nitrogen due to extensive cultivation, erosion, and residue removal (Yihenew G. Selassie, 2015). Lower wheat productivity and inferior quality of the produce is due to various constraints including inadequate and imbalanced nutrient application (Wasson *et al*., 2012). Therefore, adequate and balanced fertilization is necessary to increase the wheat productivity. Utilizing organic manures enhances the physical, chemical, and biological characteristics of soil, increases the effectiveness of fertilizer use, alleviates micronutrient shortages, maintains soil fertility, and enhances the rhizosphere's ecological balance.

Organic fertilizers have been used to ameliorate the soil nutrient level owing to their slowly release of nutrients to be taken up by plants (Adediran *et al*., 2015). In sustainable agricultural system, integrated soil fertility management is an important approach that available and environmentally sound soil amendments and mineral fertilizers to increase land productivity while maintaining or enhancing soil fertility. As a result, the use of combined inorganic and organic fertilizer should be practiced to increase the yield of crops and maintain environmental sustainability (Efthimiadou *et al*., 2010).

Using organic manures is a great way to add nutrients back to the soil. Apart from offering nutrients to the plants, they also improve the physical properties of the soil, such as bulk density, water retention capacity, infiltration, aeration permeability, and soil aggregation, reduced soil crusting, and rooting depth (Kumar & Niwas, 2022). Since ancient times, organic matter has been utilized to enhance soil health and provide nutrients to plants. Although organic wastes come from a variety of sources and forms, most of them go unused in agriculture, particularly in nations with limited resources. These actions endanger the ecosystem and deplete the valuable supply of plant nutrients. Large quantities of organic materials can be found in farm manure, urban garbage, chicken manure, and industrial wastes from the production of food, sugar, cotton, and rice. These substances have the potential to pollute the air, land, and water if they build up (Valeem *et al*., 2008).

Chemical fertilizers not only supply a variety of nutrients for crop growth, but they can also increase crop yields considerably. Nevertheless, over fertilization can lead to detrimental environmental problems that endanger the water and soil quality. Moreover, prolonged use of excessive chemical fertilizers can reduce crop growth, erode soil fertility, and ultimately reduce farmers' income (Kasem Adem *et al*., 2023). Under intense cropping, the intended level of crop yield cannot be reached and maintained by using chemical fertilizers or organic manure alone. It is crucial to employ chemical fertilizers and organic manures together because doing so not only maintains greater levels of productivity but also improves soil health and increases nutrient use efficiency (Kumar *et al*., 2015).

One method to enhance soil health conditions is integrated soil fertility management, which combines green manure, compost and/or vermicompost, chemical fertilizers, and enhanced crop types. These methods can enhance the physicochemical and biological features of the soil (Belay Yebo, 2015). But for Ethiopian smallholder farmers, inorganic fertilizers, which are necessary to sustain crop yields; are usually expensive and hard to come by. Researchers and the Ethiopian Federal Government have determined that the country's declining soil fertility and food insecurity are largely caused by the lack of mineral fertilizers, their high cost, and their low rate of use. Additionally, the probable extensive use of chemical fertilizers may have detrimental externalities on human health, pollution, global warming, soil biodiversity loss, and the possibility of nutrient imbalance in the soil (Abraha Reda & Hagos Hailu, 2017).

1.2. Statement of Problem

Soil fertility decline is a major problem impacting crop yield significantly. Use of mineral fertilizer alone has significant negative impacts on soil health and so land productivity. Use of organic fertilizer alone improves soil health and yet the nutrient supply doesn’t satisfy crop demands. So integrating organic and inorganic fertilizers seems the solution and has many advantages. However, not much evidence is available in the research area so that farmers can use this available organic fertilizers integrated with mineral fertilizer.

In the majority of Ethiopia's highlands, crop production is severely hampered by acidity and deterioration of the soil. Ethiopia's farming system is severely hampered by its most important issue, which is soil deterioration. Continuous and sole use of inorganic fertilizers may lead to deterioration in soil chemical and physical properties. As a result the actual yield of crops in generally and wheat in particular much lower than the potential yields. Ethiopia's soil deterioration problem is the most serious and a bottleneck in the country's farming system (Tsegaye Bekele, 2019).

For decades, small-scale farmers, in particular, have extracted enormous amounts of nutrients from their soils without using enough manure or fertilizers to restore the soil (Abraha Reda & Hagos Hailu, 2017). Farmers are confronted with a variety of issues as a result, including soil degradation, reduced crop yield, climatic change issues, weed infestation, pests, diseases, and local seed depletion. This also refers to a variety of socioeconomic problems, political instability, marginalization, poverty, and recurring natural disasters (Simachew Bantigegn, 2020). Hence, there is a pressing need to improve soil health in the region to achieve high agricultural yields and eliminate other obstacles caused by soil health problems.

Poor soil health management and insufficient nutrient supply have been identified as major obstacles to bridging the gap between best practices and present production systems within the farming sector. To ensure short-term production and long-term sustainability in such a scenario, achieving a balance between soil fertility management inputs and outputs in terms of soil health within the farm system is crucial. Evaluating the comparative effects of bitter lupine green manure, vermicompost, and chemical fertilizer is one feasible technique to optimize soil health and crop productivity.

In the research area, applying organic fertilizer is impractical and does not improve soil health in a sustainable manner. In contrast, inorganic fertilizer applications are useful. In addition, the study area's farmers lack the knowledge and proficiency required to handle problems pertaining to soil fertility crop productivity, including lupine green manure and vermicompost and the combined use of organic and inorganic fertilizers. Furthermore, no research has looked into how applying vermicompost, lupine green manure, and chemical fertilizers together increases crop productivity and soil fertility. Therefore, it is crucial to evaluate integrated nutrient management not only to efficiently manage nutrients but also to lower crop production costs, increase wheat yields, and reduce environmental damage caused by excessive chemical fertilizer application. This study was therefore designed with the aim of evaluating the effect of integrated soil fertilizer management on wheat yields and soil properties of Koga irrigation farm land area, Ethiopia.

1.3. Objectives

1.3.1. General objective

To evaluate the effects of integrating bitter white lupine green manure, vermicompost, and chemical fertilizer on bread wheat productivity and soil physicochemical properties in Mecha District, North-western Ethiopia.

1.3.2. Specific objectives

- To assess the effects of bitter white lupine green manure, vermicompost, and chemical fertilizer on bread wheat growth, yield, and yield components (e.g., plant height, grain yield, harvest index) and soil physicochemical properties (e.g., pH, organic carbon, nitrogen, phosphorus, bulk density).
- To determine the optimal combination of bitter lupine green manure, vermicompost, and chemical fertilizer for maximizing wheat productivity and soil health.

Chapter 2. LITERATURE REVIEW

2.1. Overview of Ethiopian Soils and Wheat Production

The definition of soil fertility and productivity is "the physical, biological, and chemical characteristics of soil, for example, its organic matter content, acidity, texture, depth, and water retention capacity all influence fertility. As the most difficult issue pertaining to rural lives, soil fertility and agricultural productivity are subjects of great importance to the developing world as well as the rest of the globe. Improving crop nutrition through sensible soil fertility management is crucial to achieving sustained crop output. Africa's soil productivity is decreasing due to depletion of organic matter (OM), nutrients, and soil erosion. Croplands in Sub-Saharan Africa have a negative nitrogen balance, with yearly losses ranging from 1.5 to 7.1 tons, and this is primarily due to soil fertility depletion (Mintesinot Desalegn, 2022).

According to Gete Zelleke *et al*. (2010) Ethiopia has a wide variety of soil types, some of which have inherent characteristics that could make them difficult to cultivate and necessitate special handling. These issues included acidity, topsoil erosion, salinity, organic matter depletion, and the loss of macro and micronutrients. Because of soil-forming elements and management techniques, the fertility condition of soil varies greatly between different agro-ecologies. Low levels of organic carbon, very low levels of total nitrogen, and low levels of accessible P are characteristics of Ethiopian soil's arid agro ecology. The country's soil fertility is considered to be very low due to substantial soil erosion, widespread nutrient mining, and little usage of outside inputs (Haile Hasana *et al.*, 2023). Getachew Agegnehu *et al*. (2016) also stated that soil fertility is decreasing due to intensive land use without adequate fertilizer replenishment for nutrients extracted from harvested materials or loss through erosion and leaching.

One of the biggest obstacles to Ethiopia producing more food is declining soil fertility. Due lost year from Ethiopia's farmed areas. The availability of nutrients in soil varies with time. Ethiopian soils, mostly due to inadequate soil management, contain approximately 42 t ha^{-1} of rich soils and vital plant nutrients. It has been revealed that micronutrients, especially Cu, Mn, B, Mo, and Zn, and elements like K, S, Ca, and Mg, are getting depleted, with deficiencies showing up on important crops across the nation. To supply the remaining amounts of required plant nutrients, it is vital to evaluate a soil's nutrient-supplying capacity (Mintesinot Desalegn, 2022).

2.2. Production and Productivity of Wheat in Ethiopia

According to CSA, (2021), wheat is grown on a total of 1.89 million hectares (5.8 million t of grain) with an average productivity of 3.05 t/ha in Ethiopia. After teff [*Eragrostis tef* (*Zucc.) Trotter*] and maize (*Zea mays* L.), wheat accounts for about 17% of Ethiopia's total grain production, making it the third most important grain crop in the country. The area of wheat production in Ethiopia has increased over the years due to its rising prices, and the government has paid significant attention to wheat production.

Ethiopia's economy is growing primarily due to its agricultural sector. The agriculture sector, which has occasionally shown signs of progress, has contributed the most to the growth of the national economy. The country's agricultural industry contributes significantly to the economy mainly because of its steady modernization and productivity increases, which are reinforced by ongoing investment in a large public extension system that reaches from the federal to the regional levels (Fantu Bachewe *et al*., 2017). Under agricultural production system, commodities like crops, pulses, oilseeds, vegetables and fruits are produced every year. From those commodities, crops take the highest share in total production and area coverage and hence crop agriculture constituted on average 68% of the Ethiopian agricultural growth domestic product (Adugnaw Anteneh & Dagninet Asrat, 2020). The production of wheat, especially in the highland areas, has a major influence on the food security of farm households. It ranks third in terms of productivity and output, and it trails teff, maize, and sorghum in terms of area covered (Sawyer, 2013).

In Ethiopia, one of the main factors limiting wheat productivity and quality content is low source and soil accessible nitrogen (Negessa Gadisa & Abdisa Mekonnen, 2021). Birhanu Bayeh (2010) stated that many obstacles prevent or restrict Ethiopia's ability to produce wheat. The following are the main limitations derived from these: Increased fertilizer costs and delayed delivery: Farmers can boost output and productivity by applying fertilizer, but this has led to a decrease in the amount of fertilizer they use due to rising fertilizer prices and credit availability issues. Soil erosion: Preserving soil fertility helps boost output and productivity, which in turn fosters the growth of marketable surplus. In addition to technological advancements such as fertilizer application, which boosts output, preventing soil erosion and preserving the soil's inherent fertility are essential for increased productivity.

According to Adediran *et al*. (2015) artificial fertilizers must be used responsibly because overusing them can negatively affect soil fertility, future crop yield, and farmer income. Moreover, there is debate among farmers regarding the rising cost of inorganic fertilizers and their burning impact on crops due to increased dosage. Although wheat is one of the cereal crops that are grown extensively in Ethiopia, the crop's productivity is low as seen by the yields that have continually lagged considerably below average for both Africa and the world. This only amounted to 77% of the average African wheat yields and 56% of the average global wheat yields, even in the year with the highest yields (2008).

2.3. Effect of Lupine Green Manure on Crop Productivity and Soil Properties

In Ethiopia bitter white lupine is commonly used as a green manure crop, valued for its ability to improve soil fertility due to its deep root system, nitrogen fixation, and potential to enhance soil structure, even though its bitter taste limits its direct consumption as food by humans. Small holder farmers often cultivate it especially for its soil enhancing properties. Like other legumes lupine can fix atmospheric nitrogen, adding valuable nitrogen to the soil for subsequent crops (unpublished).

Crops planted for the benefit of the soil are generally referred to as green manures, or fertility building crops. They have been a part of traditional agriculture for thousands of years, but as the use of pesticides and fertilizers increased, conventional agricultural systems essentially ignored them. Even though they play a variety of roles, organic farmers today frequently underuse them. Nonetheless, the conventional sector is becoming more interested as a result of the current emphasis (prompted by new legislation) on lowering the environmental effect of all agricultural systems (Knight, 1914). Farmers cultivate some species of plants, typically legumes, such as trees, bushes, vines, crawling plants, or algae, as green manure in order to suppress weeds and preserve soil fertility, even if they have many other motivations for doing so. The practice of adding green plants to the soil, either by growing them in the same field or by growing them elsewhere when they were still green, is known as "green manuring" (Fageria, 2007). In sustainable agricultural systems, green manuring technology is commercially feasible, environmentally sound, and socially acceptable (Chimouriya *et al*., 2018).

Like the majority of their family, white lupines are able to repair atmospheric nitrogen into ammonia. This enables lupines to be tolerant of infertile, acidic, and sandy soils as well as to enhance the quality of poor soils, so fertilizing the soil for other plants (Yilkal Tadele, 2015). As part of the GIZ's ISFM project, bitter lupine has recently been implemented as a green manure technique in a few chosen districts of the Amhara region. It has demonstrated some encouraging results in terms of crop productivity (unpublished). David *et al.* (2014) found that cultivating wheat after white lupine resulted in a 26% increase in yield, or 748 kg/ha, and a difference like the variants fertilized with 20 t/ha animal manure (an increase of 29 %) and chemical fertilizers $N_{60}P_{60}K_{60}$ (32%). These findings are consistent with these unpublished reports and observations. The white lupine (*Lupinus albus* L.), according to these researchers, is a plant that may generate grain yields of more than 3000 kg/ha, or more than 1000 kg/ha of protein, and it grows well on acidic soil.

Mclenaghen *et al*. (2004) stated that because lupine solubilizes the sparingly soluble (reactive) phosphate rock, lupine green manure can be used to enhance P cycling and nutrition of the subsequent crop. Additionally, it has been reported that using lupine green manure has great potential for sustaining crop yields for resource-poor farmers (Tilahun Amede *et al*., 2021) as weed infestation in crop fields can be controlled (Kayeke *et al*., 2007) and about 40–60% of the total nitrogen contained in green manure crops is available to the following crop (Bista & Dahal, 2018). The most major source of soil microbial biodiversity is lupine green manure, which dramatically alters the microbial richness and community composition, particularly enhancing bacterial species involved in the nitrogen cycle (Longa *et al*., 2017).

According to Talgre *et al*. (2012), green manure crops can fix up to 153 kg K/ha and up to 20 kg P/ha. Similarly Dey *et al*., (2015) studied green gram increased the soil available potassium by 2.4 percent. Green manure crops contain appreciable amounts of NPK including other trace elements (Bhuiyan and Zaman, 1996). P and K utilization to an extent of 10 to 12 percent was observed in field conditions due to green manure incorporation. Cheng *et al*. (2011) stated that white lupine can be a phosphorus efficient plant and could help reduce the need for P fertilizer and enhance yields. It forms cluster roots in response to phosphorus starvation. The application of manure is the most effective way to increase soil carbon and nitrogen concentrations (Adams *et al*., 2020).

Applying manure can boost soil TN by enhancing soil physiochemical and biological characteristics, soil organic matter/fertility, and other aspects (Zhao *et al*., 2019). A comparatively slower release of nutrients with an increase in the rate of organic fertilization may account for the higher effective panicle numbers and grain production in ~ 25% manure replacement compared to ~ 50% (Lin *et al*., 2022). This may result in an inadequate supply of nutrients from the soil during the early stages of wheat elongation and tillering, which would cause the crop to ripen later and produce less grain. In contrast, plants can easily get nutrients from chemical fertilizers (Xiao *et al*., 2022), which explains why OF has the highest effective panicle number and grain yield. However, there were no appreciable variations in 1000-grain weight between the treatments, which may have been due to the brief nature of the study (Kasem Adem *et al*., 2023).

Bista & Dahal, (2018) found that green manures can provide nutrition for the reproduction of soil microorganisms creating diversity and making the environment feasible for the new microorganisms yet to establish in that particular location. Green manure applications not only increased the amount of soil microorganisms, but also increased soil enzymatic activities due to root exudations and the efficiency of the transformation of soil nutrients, which are all beneficial and improve soil fertility.

More so than applying any of them alone, the crop rotation system's incorporation of crop residues and/or green manure from previous crops enhanced the manure application's recovery effect on soil health and crop productivity. Because of the cumulative direct and residual impacts of the organic inputs over the course of crop years, productivity recovery of bread wheat equivalent grain by regular crop rotation and manure application was highly significantly boosted with the progress of rotation phases (Dar *et al*., 2022).

According to USDA, (2012), white lupine has a positive effect on succeeding crops due to its ability to fix nitrogen, enhance the availability of phosphorus, and improve soil health. White lupine can be a phosphorus efficient plant and could help reduce the need for P fertilizer and enhance yields of crops. Soil health is one of the major requirements for successful plant growth. However, the majority of agricultural soils lack nutrients and organic matter. It can be extremely dangerous in the future if soil health improvement and maintenance techniques are not incorporated into the agricultural system. Because of improved nutrient uptake, the combined application of fertilizers and green manure is thought to have improved the physical and chemical properties of the soil (Patra *et al*., 2000).

Thus, in our agricultural system, using green manuring practices also helps to maintain the health of the soil. The nutrient status of the soil was improved by adding green manure. The amount of soil organic carbon improved was roughly 12% more than suggested. Green manuring improved the NPK of the soil by 12 to 21% (Kumar *et al*., 2011). Green manure crops significantly improved soil health, crop growth, and organic matter content. Compared to fallow, three weeks of vetch green manuring produced a lower pH and higher soil organic carbon levels. Crops grown with green manure not only supply nitrogen to the soil, but their addition enriches it with organic matter (Taye Belachew & Yifru Abera, 2011).

Farmers cultivate some species of plants, typically legumes, such as trees, bushes, vines, crawling plants, or algae, as green manure in order to suppress weeds and preserve soil fertility, even if they have many other motivations for doing so. The practice of adding green plants to the soil, either by growing them in the same field or by growing them elsewhere when they were still green, is known as "green manuring" (Fageria, 2007). In sustainable agricultural systems, green manuring technology is commercially feasible, environmentally sound, and socially acceptable (Chimouriya *et al*., 2018).

2.4. Effect of Vermicompost on Soil Physicochemical Properties and Crop Productivity

Vermicompost is a good quality manure that contain several essential nutrients needed by the crops such as nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients viz. iron, zinc, copper, manganese in sufficient quantity that increase the productivity and quality of crops. Application of vermicompost in soil improves physical, chemical and biological properties of the soil. It improves soil structure due to which soil become porous and permeable to soil and water (Kumar *et al*., 2018).

Physically, soils enhanced with vermicompost have more porosity, a lower bulk density, and a greater capacity to hold water (Lim *et al*., 2014). The physical characteristics of soil are impacted by the vermicompost treatment. The use of VC can enhance the physical fertility of the soil, including bulk density, moisture content, soil porosity, and structure. The bulk density, field capacity, accessible water capacity, saturated hydraulic conductivity, and total porosity are all impacted by VC treatments, according to the majority of researchers. Thalkar & Patil, (2019) reported that VC application resulted in lower bulk density of soil (1.14 Mg m^{-3}) than with mineral fertilizer check (1.27 Mg m^{-3}).

Singh *et al*. (2008) observed improvement in soil physical properties such as bulk density and water infiltration rate due to addition of VC compared with mineral fertilizer and control checks. Zeynep Demir (2019) found that the application of a high amount of VC under a high irrigation regime reduces the bulk density of the soil and increases the field capacity of the soil. Similarly, Tesfu Mengistu *et al*. (2017) reported that the application of VC fertilizer increases the total porosity of the soil and decreases the soil bulk density. They reported that the application of 15 t ha^{-1} of VC can boost the porosity by 2.3% and decrease the bulk density by 2.3% compared with those of the control. Workineh Ejigu *et al*. (2022) stated that the application of compost separately or with synthetic fertilizer can increase the porosity and reduce the soil bulk density.

According to Lim *et al*. (2014), the use of vermicompost greatly enhanced the chemical attributes of the soil, including pH, electrical conductivity, organic matter, and nutrient status, which in turn improved plant growth and output. Vermicompost increases soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants. Soil Cation Exchange Capacity (CEC) and crop yield are increased by vermicompost (Marinari *et al*., 2000). Vermicompost is utilized for soil organic carbon enhancement and saline-sodic soil quality improvement through deep tillage practices (Ding *et al*., 2021). According to Tesfu Mengistu *et al*. (2017), regardless of the mineral fertilizer used, VC application can increase the soil's organic matter linearly. The plot with the highest organic matter content was the one that received the maximal VC rate, while the control treatments had the lowest organic matter content. Based on the study of Demir (2019), the organic matter content is affected by the amount of VC and the irrigation regime, with an increase in organic matter content resulting from increased VC fertilizer.

The soil pH increased significantly in VC-amended plots compared with mineral fertilizer treatment (Thalkar & Patil, 2019). As described by Girma Chala *et al.* (2020), the highest soil pH was recorded with the use of VC and compost, whereas the lowest was recorded from mineral fertilizer (N and P). On the contrary, some scholars have confirmed that the application of VC did not change the pH of the soil. Nigus Demelash & Wondimu Bayu, (2014) reported that there was no apparent pH variation between the rates at which compost was applied. Tesfu Mengistu *et al*. (2017) also reported that the application of VC and mineral fertilizer did not significantly differ among the treatments. Adams *et al*. (2020) stated that the application of manure resulted in a buffering fertilizer-induced decrease in pH. The application of the maximum rate of VC (15 t ha^{-1}) improved the CEC (23.425 Cmol (+) kg^{-1}) of the soil, whereas the lowest value was recorded from the control (20.614 Cmol (+) kg^{-1}) (Tesfu Mengistu *et al*., 2017).

Atiyeh *et al*. (2000) stated that the application of vermicompost to soil has been shown in numerous studies to have positive impacts. Research has shown that because vermicompost contains a high concentration of nutrients, humic acids, and humates, plants react to its application like they would to hormone-induced activity. Compacted soils are renewed and have better water penetration when earthworms are present. The eating, burrowing, and casting behaviors of earthworms alter the biological, chemical, and physical characteristics of soil and organic materials. As was previously said, vermicompost typically has a greater nutrient profile than regular compost. Vermicompost actually has the ability to physically, chemically, and biologically improve soil fertility (Lim *et al*., 2014).

When vermicompost is added, some researchers have observed increased plant growth even if the plants are already getting the best nourishment. Additionally, vermicompost promotes the growth of roots and shoots during vegetative phase. Other benefits of applying vermicompost include changes in crop plant morphology, such as increased leaf area and root branching and encouraged flowering; additionally, there is a rise in the quantity and biomass of flowers, as well as an overall improvement in fruit output (Singh *et al*., 2008). Molla Hadis *et al*. (2018) found that application of vermicompost significantly increased the yield components, yield and nutrient uptake of wheat grown in the greenhouse suggesting that there was net mineralization of nutrients contained in the vermicompost and availed to the growing wheat.

Joshi *et al.* (2013) stated that all the growth, yield and quality parameters in vermicompost treatments varied significant from control through differences with in various vermicompost treatments are not to be significant. Lenin & Ravimycin, (2013) investigated that 5 t/ha VC + AMF application increase all the nutrient content of groundnut plants. The vermicompost are termed rich in nitrogen, phosphorous, potassium and micronutrients. According to Gedefa Sori & Dagne Chimdessa, (2022) increasing the vermicompost rate from 1.5 to 3 t ha^{-1} increased grain yield by 20 to 35% compared to the control treatment

2.5. Effect of Chemical Fertilizers on Crop Productivity and Soil Properties

Chemical fertilizers have a significant impact on crop plant development. While these have a positive impact on plant growth and biological output, chemical fertilizers have drawbacks as well; they contaminate the environment and erode soil surface. Compared to using organic fertilizers alone, the combination of chemical and organic fertilizers improved soil health and crop development. The use of chemical fertilizers alone was also not found to be significant; therefore, the combination of chemical fertilizers and organic matter promotes the absorption of NPK in sugarcane and various crops (Deshmukh, 2022).

Kumar *et al*. (2018) stated that the long term fertilizer experimental studies indicated that continuous sole application of chemical fertilizer in imbalanced manner produce detrimental effects on soil physical, chemical and biological properties further, inducing secondary and micronutrient deficiencies in soil, nutrient imbalance in soil and plants, environmental hazards and decrease in total factor productivity. Chemical fertilizers have the ability to immediately restore soil fertility and provide plants with access to nutrients as soon as they breakdown in the soil, therefore their addition may be necessary. By increasing root residues, inorganic fertilizer indirectly increases organic matter. As a result, farmers have recently placed more emphasis on applying artificial fertilizers to boost output. Enhancing soil fertility and agricultural yields need the application of inorganic fertilizer (Mintesinot Desalegn, 2022).

Because the nutrients in inorganic fertilizers are already soluble in water, they are beneficial for plants that grow quickly. As a result, the impact is typically quick and complete, containing all required nutrients that are ready for usage. The nutrient content of inorganic fertilizers is rather high, and production only requires small amounts of these fertilizers. Applying inorganic fertilizer in the right amounts can raise the amount of organic matter in the soil by increasing the amount of crop leftovers and root mass (Tesfaye Burju, 2018).

According to Garcı *et al.* (2007), the application of chemical fertilizers to soil reduces pH and increases its electrical conductivity. Urea is the most commonly used nitrogen (N) fertilizer and has high N content per unit material (46%) lower cost, ease of storage, along with solid and liquid formulation options make it a popular choice for farmers (Witte, 2011). As the study indicated by Angus, (2001), band application of urea and ammonia fertilizers significantly reduces total microbial activity in proximity areas of treated for a period of five weeks and then returns to normal.

According to Girma Fana *et al.* (2012), Nitrogen is the most important plant nutrient for metabolic processes, vegetative growth, plant productivity, protein production, and grain quality. They also stated that any increase in nitrogen fertilizer also increases the grain yield of wheat. Okubay Giday, (2019) showed that an increasing trend with increasing N fertilizer rates, resulting in an increase in the grain yield of wheat, as he reported that the maximum grain yield was recorded at the highest rate of 69 kg N ha^{-1} application. Similarly, Fresew Belete *et al* .(2018) reported that as the rate of nitrogen fertilizer application to a wheat field increases, the grain yield of the wheat also increases. This shows that most of the soil nitrogen nutrient status is too low to increase the yield of wheat, and additional nitrogen fertilizer is essential. Nitrogen is the most yield-limiting nutrient.

According to the study conducted by Muslic & Gogic (2015), nitrogen fertilizer significantly affects both the grain yield and yield-related characteristics of wheat. The maximum grain yield was recorded from the treatment that received the highest amount of nitrogen. Similarly, Rotar *et al*. (2020) stated that the application of nitrogen fertilizer resulted in maximum grain yield, whereas the unfertilized plots had lower grain. Similarly, as described by Sidahmed *et al*. (2020), nitrogen fertilizer had a significant yield increment in every fertilizer increment; the maximum grain and biomass yield was recorded from the maximum fertilization. The application of N fertilizer has a significant effect on wheat yield, but the application of too much N fertilizer reduces the yield of wheat. Noureldin & Saudy (2013) reported that nitrogen fertilization increased the yield of wheat (biomass and grain yield) as N fertilizer increased from 0 to 75 kg ha^{-1}, whereas as N fertilizer increased from 75 kg to 100 kg, the grain yield and biomass decreased significantly.

Getachew Agegnehu *et al.* (2014) stated that in comparison to the control and the lowest farmers' NP rates, the application of the recommended NP at a rate of 60/20 kg NP ha^{-1} enhanced wheat grain production by roughly 151% and 85%, respectively. According to Yousefi *et al*. (2014), the application of vermicompost and urea together significantly affected grain weight The maximum yield of the treatments 100% of the recommended urea with 10 and 15 t/ha vermicompost and treatments recommended by 75% urea and 15 t/ha vermicompost, respectively, there was no significant difference between the three groups (4977.3, 4890.7 and 4953 kg/ha, respectively). Thus use the vermicompost then reduce the urea up to 25%.

2.6. The Effect of Integrated Use of Organic and Inorganic Fertilizers on Wheat Productivity and Soil Health

2.6.1. Effect of integrated organic fertilizer and inorganic fertilizer on soil fertility

Research demonstrated that applying LGM either by itself or in conjunction with inorganic fertilizers improves healthy nutrition and soil fertility maintenance. Higher yields of maize and wheat were observed in a study by Brar *et al*. (2015) that demonstrated the integrated use of inorganic fertilizer in addition to organic fertilizer (100% NPK + FYM) to improve soil physical parameters like CEC and pH. As described by Han *et al*. (2016), the application of NPK fertilizer causes soil acidification, while the combination of NPK and organic manure treatments markedly elevated the pH of the soil. The integration of a nutrient management system leads to an increase in the organic carbon content, accessible nitrogen, potassium, and phosphorus, which rise from 0.390% to 0.543%, 171.7 to 219.3 kg/ha, and 20.5 to 43.3 kg/ha, respectively. Similar findings were reported by (Walia *et al*., 2010).

According to multiple studies, using inorganic fertilizer in conjunction with organic fertilizer, such as manure, enhances soil organic C content, total N, and accessible nutrients significantly improved the overall characteristics of the soil (Alem Reda & Fassil Kebede, 2015). When it comes to a balanced supply of nutrients, the use of chemicals in combination with organic fertilizer has shown to be particularly advantageous for sustainable productivity. The yields obtained from applying organic fertilizer alone are also much lower. Additionally, microbial biomass and, consequently, soil health were more positively impacted by the application of organic fertilizers in conjunction with the proper chemical fertilizers (Abedi *et al*., 2010).

The current soil research indicates that when vermicompost was added in an acidic environment, the soil's micronutrient status decreased as the pH of the soil rose. Based on the results of this study, it is typically recommended to add a small amount of mineral fertilizer to vermicompost in order to improve soil. To improve plant nutrient availability and maintain soil sustainability, apply less nitrogen fertilizer to the soil. As a result, the environmental impact will be reduced (Negesa Gadisa & Tesfaye Wakgari, 2021). Based on the study conducted by Tesfaye Burju, (2018) when organic fertilizer is given to the soil and has a gradual release of nutrients, microorganisms from the soil breaks it down so that plants may use the nutrients.

Increased organic matter in the soil improves soil structure, increases air space and water retention, increases soil nitrogen content, improves nutrient availability, releases nutrients more gradually and consistently, enhances nutrient mobilization, and shields the soil from wind and rain erosion. These are just a few benefits of using organic fertilizers to increase soil fertility. Mycorrhizal colonization and soil biological activity are both improved by organic fertilizer. This strengthens the relationship of mutuality between fungus and higher plants. Because organic fertilizer promotes soil aggregates, improves cation exchange capacity, and improves soil structure, it encourages root growth. An effective buffer against unfavorable pH variations in the soil is provided by organic fertilizer (Mintesinot Desalegn, 2022)

2.6.2. Effect of integrated organic and inorganic fertilizer on growth and yield of wheat

Crop productivity increased significantly when fertilizers and organic manures were applied together. Using both organic and inorganic fertilizers together has greatly improved crop quality in terms of protein and plant uptake of N, P, and K (Kumar *et al*., 2019). The maximum wheat grain yield was reported in treatments that received 50% N from urea and 25% N from FYM plus 25% N from either chicken manure or municipal garbage. In comparison to other organic manure applications, wheat plots treated with poultry litters (20 t/ha) had the highest plant height and the greatest number of productive tillers. The greater nutritional composition of this manure was the cause of the higher growth characteristic with 20 t/ha of poultry litters (Fazily, 2020).

According to Hammad *et al*. (2011), applying green manure, poultry litter, sewage, and sludge increased grain yield when compared to applying RDF alone. Plots that received 60 kg N through FYM + rice residue 6 t/ha + biofertilizers were the most cost-effective treatment in terms of increasing net profit, while vermicompost + rice residue 6 t/ha + biofertilizers was the most productive treatment, according to the mean of two years' worth of pooled field experimental data. This resulted from vermicompost higher cost as opposed to FYM. The grain's ability to absorb nutrients and maintain its quality was enhanced by both of these combinations (Ram *et al*., 2009).

According to Kumar *et al*. (2015), the combined use of 100% NPK + 12.5 tonnes FYM/ha was found to be beneficial in increasing the productivity of wheat and improving soil fertility status as compared to sole application of 100% NPK. The uptake of nutrients was higher in FYM along with NPK fertilizers. With the cost of inorganic fertilizers rising and crop fertilizer use efficiency poor, using locally accessible, nutrient-rich organic sources is a good way to boost soil fertility and boost crop output (Wassie Haile, 2012). Several research have been carried out to investigate alternative sources of organic nutrients and partially replace inorganic fertilizers through biomass transfer, compost, farmyard manure (FYM), and green manure.

Chapter 3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at the Koga Irrigation Scheme, 35 km south of the city of Bahir Dar (capital of Amhara region) and Lake Tana, just outside the village of Merawi, in the West Gojam zone, and about 540 km from the capital city, Addis Ababa in northwest Ethiopia. The Koga Watershed lies within the Blue Nile Basin (BNB), in the headwaters of the Blue Nile covering an area of 266 km^2. The BNB consists of land drained by the Koga River above its confluence with the Gilgel Abay (Little Nile). The Koga River flows south to the northwest with a total length of 49 km to Gilgel (Little) Abay and Lake Tana; its tributaries effectively drain the total catchment area, which is 27,850 ha and lies to the North of the Wezem Mountains.

The geographic location of the Koga Watershed extends from 11.16°N to 11.410°N latitude and 37.03°E to 37.28°E longitude (Figure 3.1). The topography of the area exhibits distinct variation and contains flat low laying plains. The slope ranges from nearly flat to very steep. The altitude ranges from 1875 to 3089 m.a.s.l. the nature of the topographical features has made it very liable to gully formation and extensive soil erosion. Koga River is a tributary of the Gilgel Abay River in the headwater of the Blue Nile catchment. The major crops grown in the study area are maize, finger millet, wheat, teff, barley, etc. The soil type of the study area was nitisols based on FAO classification system.

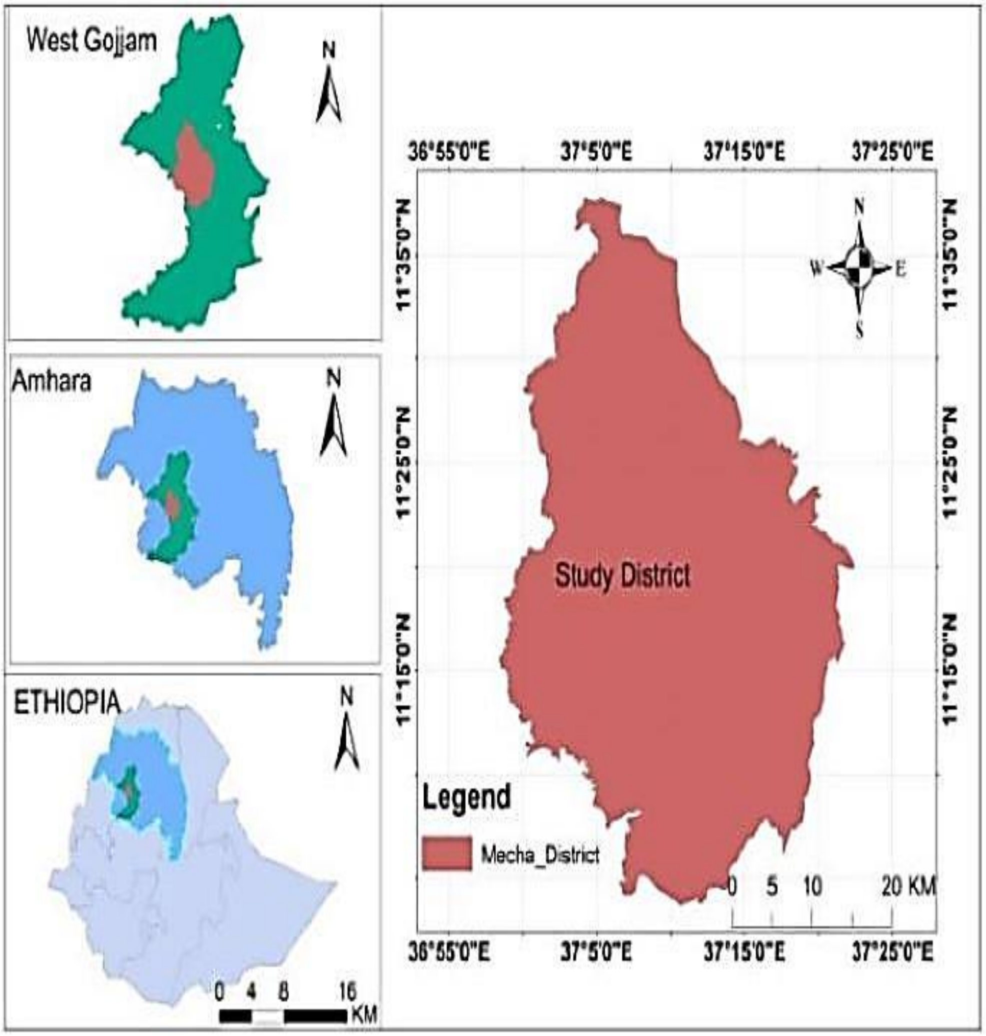

Figure 3.1; Map of the study area

The mean annual rainfall (RF) recorded at Merawi station is 1480 mm, of which 90% falls from May through October. The monthly mean temperature is 25.8°C (Figure 3.2). The dry season limits the water availability in the study area.

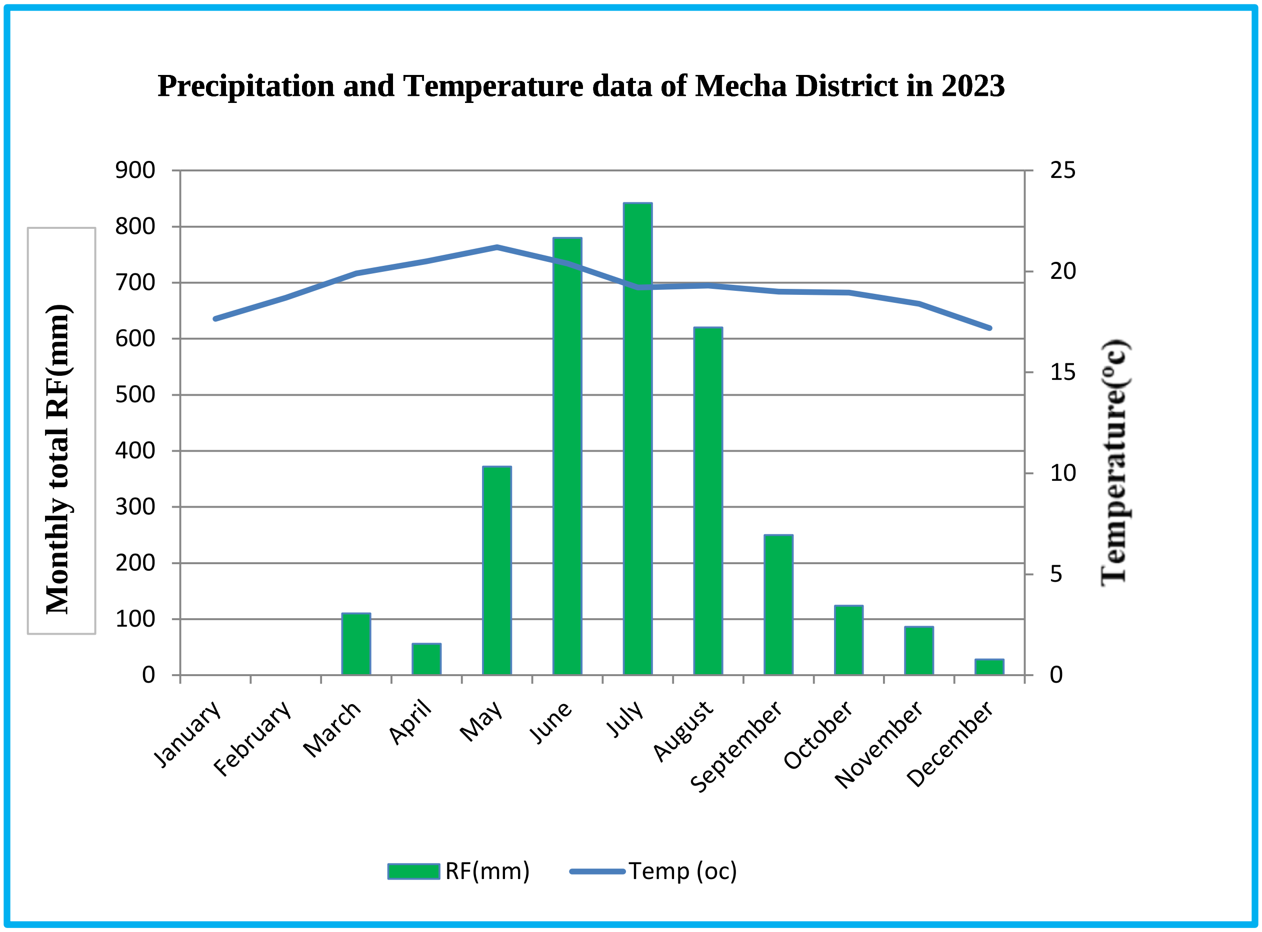

Figure 3.2. Rainfall and temperature distributions at the study area (Koga Irrigation Meteorological Station, 2023).

3.2 Experimental Test Materials

The Kakaba wheat variety was used as the test crop and sown at a rate of 150 kg ha^{-1}. This variety was released by Kulmsa Agricultural Research Center (Table 3.1). The vermicompost was provided by Adet Agricultural Research Center (AARC). This VC was prepared following standard procedures from locally available materials like wheat straw, animal dung, ash and was processed with the help of vermiworms (earthworms). The urea and NPSB fertilizers were obtained from Healthy Food Africa project and Kakaba wheat variety seeds were obtained from the Adet Agricultural Research Center (AARC). For the experiment bitter white lupine (*Lupinus albus*) was used as a green manure taken from the neighboring Koga sites. The bitter white lupine crop was collected at 50% flowering stage for green manuring purpose. The recommended chemical fertilizer rates of NPSB and urea was 200 kg/ha and 250 kg/ha respectively for the study area.

Table 3.1. Kakaba wheat variety information used for planting.

Varity name	Rainfall (mm)	Temperature (^{O}C)	Altitude(m)	Agro ecology	Productivity(t/ha)
Kakaba	500-800	15-25	1500-2200	Kola, Woyinadega	33-52

Source: Ministry of Agriculture and Animal package manual (2010)

3.3. Experimental Treatments and Design Procedures

The experiment was conducted during the 2023 cropping season in Koga irrigation area. The treatments consisted of three rates of recommended chemical fertilizers [0, 50% (100 kg NPSB/125 kg urea) and 100% (200 kg NPSB/250 kg urea)], three rates of bitter white lupine green manure fresh biomass (0, 2.5 and 5 t/ha dry mater based) and three rates of vermicompost (0, 2.5 and 5 t/ha) (Table 3.2). The experiment was laid out in randomized complete block design (RCBD) in factorial combination and replicated three times. Each plot had a gross area of 1.6 m × 2.4 m (3.84 m^2), with 0.2 m, 0.5 m, and 1 m spacing between rows, plots, and blocks, respectively, and 12 rows per plot. A full dose of blended NPSB and half dose of urea were applied at planting, and the remaining half of urea was applied at vegetative stages (35 days after planting). Vermicompost was incorporated into the soil at a depth of 0-10 cm, which was then covered with soil one week before the test crop was planted.

The experimental field was plowed two times by tractor and following breaking clods and leveling the land was done manually. Finally, the unit plots were prepared with spade for sowing. The bitter white lupine crop was also chopped and directly incorporated to the soil as new biomass, and the plots were allowed to decompose for three weeks before wheat seeds were sown. The seed of variety Kakaba was used at the rate of 150 (kg/ha) in 20 cm rows space in maize previously planted field. The field was kept free of weeds by hand weeding during the growing period of the experimental crop. All other recommended agronomic management practices for disease and insect pest control were done.

3.4. Data Collection

3.4.1 Soil sample collection and analysis of experimental field

One composite soil sample was collected to a soil depth of 0–20 cm. Before planting, soil samples were collected from 20 points at the experimental site and bulked together to have one composite sample. On the other hand after crop harvest five subsamples were collected by the zigzag method from each treatment plot to form one composite soil sample in three replications. As a result, a total of 81 composite soil samples (27 treatment plots × 3 replications) were collected after crop harvest. In addition, undisturbed core soil samples were collected using a core sampler (98.125 cm^3 volume) for bulk density determination.

The disturbed composite soil samples collected from the representative treatment plots were air-dried, mixed well and passed through a 2 mm sieve for all parameters that were determined except for total nitrogen and organic carbon which passed through a 0.5 mm sieve. These soil samples were analyzed in the Bahir Dar University Soil and Plant Testing Laboratory. The soil bulk density was determined after the soil dry weight was determined. The dry weight was obtained by drying the sample for 24 hours to a constant weight in an oven at 105°C. Following the determination of the bulk density, soil porosity was determined by using bulk density.

The bulk density of the soil was determined by the following formula (Hillel, 1998). The soil particle density was assumed as 2.65 g/cm^3. The soil particle size distribution was analyzed via the hydrometer method (Bouyoucos, 1962). The soil textural class names were determined following the textural triangle of the United States Department of Agriculture (USDA) system as described by Rowell, (1994). The soil pH was measured at a 1:2.5 (soil-to-water) ratio using a glass calomel combination electrode (Van Reeuwijk, 1992). Soil organic carbon was determined following the wet digestion method (Walkley and Black, 1934). Total nitrogen was analyzed using the Kjeldahl digestion, distillation and titration method as described by Van Reeuwijk, (1992). Available phosphorus was determined by Bray-II Method as described by Sahlemedhin Sertsu & Taye Bekele, (2000). The cation exchange capacity (CEC) was determined after the samples were extracted with 1 N ammonium acetate method (Van Reeuwijk, 1992). The determination of available K was performed by a flame photometer (Morgan, 1941).

3.4.2. Chemical Composition of vermicompost and lupine green manure

To determine the chemical composition of the vermicompost, 1 kg sample was taken for its physicochemical analysis. Vermicompost sample was analyzed for the chemical parameters such as pH, organic carbon, total Nitrogen, potassium and Phosphorus. The pH of vermicompost was determined using a pH meter glass electrode (Van Reeuwijk, 1992). Total organic carbon was determined by wet digestion method (Walkley and Black, 1934). The total Nitrogen content of vermicompost was determined using Kjeldahl procedure. The total phosphorus content was determined by method described by Bray-II Method and total potassium content was described by Hesse.

Lupine green manure was prepared by taking an equal amount of samples randomly from the experimental plots. Composited samples of the Lupine green manure were further oven-dried at 65^0C until a constant weight was attained. Samples were taken during the addition of fresh biomass bitter white lupine green manure, and they were dried in an oven at 65°C to determine the dry biomass and analyze the dry matter properties. Their dry matter contents were estimated as the ratio of sample weights after and before oven drying and expressed in percentile. Oven-dried samples were then crushed and sieved for further analysis for organic carbon, total nitrogen, and available phosphorous and potassium contents in the soil laboratory. Organic carbon and total nitrogen contents of manure samples were determined by wet digestion method (Walkley and Black, 1934) and the Kjeldahl digestion method as described by Van Reeuwijk, (1992), respectively. Available phosphorous and exchangeable potassium contents of organic input samples were determined by Bray-II Method as described by Sahlemedhin Sertsu & Taye Bekele, (2000) and flame photometer (Morgan, 1941) respectively.

3.4.3 Agronomic data collection

All data on phenological, vegetative growth and yield-related parameters of wheat crops were collected from 10 randomly selected plants from the net plot area.

A. Phenological parameters

Days to 50% heading

It was recorded by counting the number of days from sowing up to the date when the 50% tips of the spike first emergence from the main shoot. Days to 50% heading was recorded when about 50% of the plants in a plot produced spikes. It was collected from 10 randomly selected plants from the net plot area

Days to 90% physiological maturity

It was recorded by counting the number of days from the date of sowing up to the date when 90% of the crop stands in a plot to light white color. Days to physiological maturity was recorded (10 plants) when about 90% of the plants reached physiological maturity based on visual observation. It was indicated by senescence (turning to light yellow) of the leaves and vegetative parts as well as free threshing of grain from the glumes when pressed between the forefinger and thumb.

B. Vegetative growth parameters

Plant height (cm)

It was measured as the height from the soil surface to the spike at physiological maturity and the average was taken for analysis. At maturity, 10 effective tiller plants were taken randomly from the net plot area of each plot and height was measured from the ground to the tip of tillers using tape meter and the mean value were determined in cm. The height of 10 randomly selected plants was measured at physiological maturity, specifically from the base of the stem to the tip of the spike, excluding the awns.

Spike length (cm)

It was recorded by measuring the length of a spike from randomly selected plants in each plot by using a ruler in cm. At maturity, 10 spikes from the effective tillers were taken randomly from the net plot area of each plot and measured from the bottom of the spike to the tip of the spike with excluding the awns and then, the mean value was determined in cm. The average length of the main tiller spikes was measured in 10 randomly selected plants at physiological maturity. The measurements were taken from the base of the spike to the tip.

Number of tillers

It was recorded by counting tillers from randomly taken plants in each plot. Productive tillers (effective tillers) were determined at maturity by counting all the productive (head bearing) tillers. It was collected from 10 randomly selected plants from the net plot area

C. Yield related parameters

Numbers of grains per spike

It was recorded by counting the number of grains per spike from randomly selected plants in each plot. The average number of kernels per spike was determined by counting the kernels on 10 randomly selected plants within a net plot area at harvest maturity.

Grain yield (t ha^{-1})

The grain yield was recorded from the harvestable area by left two rows and two plants from the border area of the plot. It was determined by using a sensitive balance after it is adjusted to 12.5% moisture content and was converted per hectare base (kg ha^{-1}). After harvesting, threshed grains were separated, cleaned, and weighed by electronic balance. It was recorded from 10 randomly selected plants from the net harvestable area.

Thousand seed weight (g)

It was recorded by taking 1000 seeds from the selected plant in each plot and measuring it by using sensitive balance. Thousand seed weights (g) were determined by counting 1000 kernels using an electronic seed counter randomly selected from the net plot harvest and adjusted yield of the harvest at 12.5% grain moisture content and weighing them with an electronic balance.

Straw yield (t ha^{-1})

SY per net plot was obtained out by subtracting total GY weight from the total biomass yield for respective treatments. Later, the SY ha^{-1} were computed and expressed in kg ha^{-1}.

Biomass yield (t ha^{-1})

The total above-ground biomass produced was recorded and measured by sensitive balance. At maturity, the whole aboveground plant parts, including leaves, stems, and seeds from the net plot area in each plot was harvested and sun dried until a constant weight and then the aboveground biomass was weighed and then expressed in kg ha^{-1}.

Harvest index (%)

It refers to the ratio of grain yield (GY) (GY at 12.5% grain moisture content to the biomass (grain + straw) and it is expressed in percentage. It was calculated according to the following formula.

3.5. Data Analysis

3.5.1 Statistical data analysis

All data were subjected to analysis of variance (ANOVA) using SAS software version 9.4 (SAS, 2013). A Tukey's test (HSD) was used for mean separation at a corresponding level of error of 0.05 when the analysis of variance revealed the existence of a significant difference among treatments for a parameter (Gomez & Wiley, 1984). In order to improve the soil health condition and provide agronomic interpretations for the post-harvest soil test findings of the research area, critical levels of soil parameters were taken into account. Correlations between major agronomic parameters were done by Pearson correlation method.

3.5.2 Partial budget analysis

To determine economically profitable treatment (s), partial budget analysis was performed following the procedure of the International Maize and Wheat Improvement Center (CIMMYT) (CIMMYT, 1988). Urea and NPSB fertilizers, labor requirements for fertilization, preparation costs of vermicompost, vermicompost and green manure application were considered input and variable costs. Other production costs, such as labor for land preparation, weeding, harvesting, trashing, and cleaning, were considered constant costs across treatments. Grain and straw yields were considered the output yields.

All costs were calculated as the average value of the months of July to December during 2023. The local costs of urea and NPSB fertilizer were 44 and 42 Birr kg^{-1}, respectively. The grain yield was adjusted downward to 12.5% so as to reduce the yield gap between experimental plots and farmers` field. Finally, total variable cost (TVC), gross benefit (GB), net benefit (NB), and marginal rate of return (MRR) were calculated.

Chapter 4. RESULTS AND DISCUSSION

4.1. Selected Physicochemical Properties of Soil before Treatment Application

Before sowing physical and chemical properties of the soil analyses were carried out for the surface composite soil (20cm) of the experimental field. The result of the soil analysis showed that the textural class of the surface soil was clay with particle size distribution of 36% sand, 22% silt and 42% clay. The bulk density of the soil before treatment application was 1.31 g/cm^3 which is high, that is why organic fertilizers are needed to reduce bulk density for crop production. The total porosity of the soil was found to be 48.6% (Table 4.1). The result on chemical properties of the soil showed pH of 4.51, available phosphorus of 13.45 (ppm), CEC of 23.2 cmol (+) kg^{-1}, organic carbon of 0.55 %, and total nitrogen of 0.24%. Available potassium was found to be 0.44 mg/kg (Table 4.1). These results explicitly justify that the need for the application of organic (green manure, vermicompost, etc...) in combination with inorganic sources based on the base recommendation for the different crops (particularly wheat crop) grown in the study area.

Table 4.1. Selected Physicochemical Properties of Soil before Treatment Application

Physical properties	Values
Sand (%)	36
Silt (%)	22
Clay (%)	42
Texture	clay
Bulk Density (g/cm3)	1.31
Total Porosity (%)	48.6
Chemical properties	
pH	4.51
OC (%)	0.55
TN (%)	0.24
Avai.P (mg/kg)	13.45
Avai.K (mg/kg)	0.44
CEC (cmol(+)kg-1	23.2

Selected Physicochemical Properties of vermicompost and lupine green manure

The vermicompost used for the field experiment had a pH of 7.22, OC content of 11.72%, TN of 1.5%, Phosphorus content of 17.95 mg kg^{-1} (Table 4.2). The CEC content of vermicompost was 38.9 cmol (+) kg^{-1}). Thus, the results indicate that vermicompost application has a beneficial effect in enhancing soil fertility status and wheat productivity. The Lupine green manure used for the experiment had a TN of 1.95%, OC content of 28.97%, AP content of 0.31 mg kg^{-1} and K content of 0.88 (Table 4.2).

Table 4.2. Chemical Composition of vermicompost and lupine green manure before application

Variables	Parameters					
	pH	OC (%)	TN (%)	P(mg Kg^{-1})	K(cmol (+) kg^{-1})	CEC (Cmol (+) kg^{-1})
VC	7.22	11.72	1.5	17.95	0.99	38.9
LGM	-	28.97	1.95	0.31	0.88	-

VC = Vermicompost; LGM = Lupine green manure pH = power of hydrogen; OC = Organic carbon; N = Nitrogen; P = Phosphorus; K = Potassium; CEC = Cation exchange capacity

4.1. Effect of Treatments on Soil Physical Properties

4.1.1. Soil bulk density

The combined application of lupine green manure, vermicompost and chemical fertilizers had significant ($P < 0.05$) effect on the bulk density of the soil (Appendix Table 5). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant influence on soil bulk density. The highest bulk density (1.12 g/cm^3) was obtained from the control plot and the lowest bulk density 1.09 g/cm^3 was from the combined application of 5 t/ha VC with 5 t/ha LGM (Table 4.3). The reduction of bulk density might be due to the availability of organic matter applied that improve soil aggregation and hence, improve soil total porosity and reducing soil compaction. In line with this result Mekonnen Workineh *et al*. (2020) reported that combined application of inorganic and organic fertilizers decreased bulk density. This finding is in agreement with the result of Tolera Emamu & Tesfaye Wakgari, 92021) who reported that combined application of organic and inorganic fertilizers reduced soil bulk density. Negessa Gadisa & Tesfaye Wakgari, (2021) also confirmed that the results of main effect of vermicompost indicated that application of different levels of vermicompost significantly reduced soil bulk density.

4.1.2. Total porosity

The main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant influence on soil total porosity (Appendix Table 5). The highest total porosity (60%) was recoded from the application of 5 t/ha VC and 5 t/ha LGM in combination with 100% recommended NPSB + urea fertilizers (Table 4.3). On the other hand, the lowest total porosity (44%) was recorded from the control. This increased porosity with the combined application of organic and inorganic fertilizer might be due to increased root growth leading to accumulation of more organic residues. In line with this Tolera Emamu & Tesfaye Wakgari, (2021) reported that the highest value of total porosity (65.6%) was obtained from application of 15 t/ha VC + 100 kg/ha NPS fertilizer and the lowest value (52.8%) was recorded from control treatment.

The result agreed with the report of Papini *et al*. (2011) who reported that VC application enhanced soil porosity, soil moisture contents and water holding capacity while reduced soil compaction and bulk density. This finding is in agreement with the result of Negessa Gadisa & Tesfaye Wakgari, (2021) who reported that maximum improvement in total porosity of the soil (55.16%) was observed in plot that treated with vermicompost (7.5 t/ha) followed by 5 t/ha vermicompost rate compared to control. Mintesinot Desalegn, (2022) stated that the total porosity in the soil was increased with the application of organic and inorganic fertilizers two years after harvesting maize.

Table 4.3; Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on soil bulk density and total porosity in Mecha District, Northwestern Ethiopia during of 2023 main cropping season.

GM (t/ha)	VC (t/ha)	Parameters					
		BD			TP		
		Chemical fertilizers (kg/ha)					
		0	50%	100%	0	50%	100%
0	0	1.12^{l}	1.16^{r}	1.24^{e}	57^{b-e}	58^{a-c}	53^{fg}
	2.5	1.20^{g}	1.21^{f}	1.12^{m}	55^{d-g}	55^{d-g}	57^{a-d}
	5	1.25^{d}	1.13^{k}	1.15^{i}	52^{g}	56^{c-f}	44^{h}
2.5	0	1.10^{o}	1.10^{o}	1.1^{o}	59^{a-c}	59^{a-b}	59^{a-c}
	2.5	1.1^{o}	1.13^{k}	1.14^{j}	58^{a-c}	58^{a-d}	55^{d-g}
	5	1.27^{c}	1.11^{n}	1.21^{f}	52^{g}	58^{a-d}	53^{f-g}
5	0	1.21^{f}	1.19^{p}	1.19^{p}	54^{e-g}	58^{a-d}	54^{e-g}
	2.5	1.24^{e}	1.26^{a}	1.13^{k}	52^{g}	43^{h}	56^{b-e}
	5	1.09^{e}	1.29^{b}	1.27^{q}	53^{f-g}	52^{g}	60^{a}
Mean		1.18	1.18	1.17	54.67	55.22	54.56
LSD		0.003			0.03		
CV (%)		0.10			1.80		

Means within column followed by the same letters are not significantly different at $P \leq 0.05$; LSD = Least significant difference; CV = Coefficient variation; BD = soil bulk density, TP = total porosity;

4.2. Effect of Soil Amendments on Selected Soil Chemical Properties

4.2.1. Soil pH

The integrated application of lupine green manure, vermicompost and chemical fertilizers showed a significant influence on soil pH after crop harvest ($P < 0.05$) among treatments (Appendix Table 5). The main effects of lupine green manure and vermicompost significantly affected the pH, but not chemical fertilizers alone. The highest and lowest pH values were 5.38

and 4.61 were recorded from the application of 5 t/ha VC and 5 t/ha LGM with 50% recommended NPSB + urea fertilizers and application of 5 t/ha VC alone respectively (Table 4.4). This might be due to the combined application of organic and inorganic fertilizer which lowered the soil pH to neutral range owing to the release of H^+ ions via microbial decomposition of organic fertilizers.

This finding is in agreement with the result of Singh, (2015) who reported that the maximum pH value was obtained from the combined application of inorganic and organic fertilizers (8.06). Similarly, this result was in line with Kumar & Niwas, (2022) who reported that the application of organic fertilizer in combination with inorganic fertilizer (100% NPK + 5 t ha^{-1} FYM + 5 t ha^{-1} vermicompost) (8.4) increases soil pH content over control (8.01). Similarly Tolera Emamu & Tesfaye Wakgari, (2021) reported that the pH value after application of the different rates of organic and inorganic fertilizers was relatively increased. In contrary to this result Alem Reda & Fassil Kebede, (2015) revealed that the soil pH was highly significantly affected by the main effects of the organic fertilizer FYM and the main effect of inorganic fertilizers but not by their combined effect. Negessa Gadisa & Tesfaye Wakgari, (2021) investigated that maximum improvement in soil pH (5.38) was observed in plot that received vermicompost along with nitrogen1 fertilizer. Meraj Ahmad *et al*. (2022) also observed that there was improvement in soil pH was noticed in all integrated plots as well as only organic manures applied over control.

4.2.2. Organic Carbon

The analysis of the result showed that the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant ($P < 0.05$) effect on soil OC (Appendix Table 5). The highest soil OC content 1.86% was obtained from the combined application of 5 t/ha VC and 5 t/ha LGM with 100% recommended inorganic NPSB + UREA fertilizers and the lowest organic carbon 0.13% was obtained from the application of 50% RCF (Table 4.4). The increased OC content might be due to higher soil OM added through vermicompost and LGM application. Similarly, this result was in harmony with Ding *et al*. (2012) who reported that the application of organic fertilizer in combination with inorganic fertilizer increases OC content.

Likewise, these results support the investigation of Biosci *et al*. (2012) who reported that the combined application of organic fertilizer with inorganic NP in rice has increased the soil OC content after harvest by 65% as compared to the application of 100% recommended inorganic NP alone. This result agrees with the findings of Alem Reda & Fassil Kebede, (2015) who indicated that combined application of FYM and inorganic significantly improved soil organic carbon. The same to this result Getachew Agegnehu *et al*. (2014) investigated that relatively higher soil organic carbon was recorded on experimental plots, which received either organic or inorganic and organic nutrient sources than plots received only inorganic fertilizers.

4.2.3. Total Nitrogen

Integrated application of organic and inorganic fertilizer showed significant effect ($P < 0.05$) on soil total nitrogen (Table 4.5). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant effect on soil total nitrogen (Appendix Table 5). The highest TN (0.29%) was observed from the combined application of 2.5 t/ha VC with 5 t/ha LGM. Whereas, the lowest TN (0.21%) was recorded from the application of 5 t/ha LGM (Table 4.2). This might be due to high nitrogen content of organic fertilizers, as there was no fertilizer applied to the control plots. This finding is in agreement with the result of Kumar *et al*. (2015) who reported that the maximum available N was obtained from the combined application of inorganic and organic fertilizers (100% NPK + 12.5 t/ha FYM) (178.8 kg/ha).

This result is in line with the findings of Tolera Emamu & Tesfaye Wakgari, (2021) who reported that combined application of VC and inorganic fertilizer significantly increased soil total nitrogen. Getachew Agegnehu *et al*. (2014) reported that relatively higher total N, NO_3-N and NH_4-N values were obtained from the plots treated with 50% recommended NP and 50% organic fertilizer as inorganic N equivalence followed by plots treated by 100% manure and compost as recommended inorganic N equivalence. Negessa Gadisa & Tesfaye Wakgari, (2021) observed that application of vermicompost at the rate of (7.5 t/ha) with nitrogen fertilizer at the rate of (69 kg/ha) followed by vermicompost (5 t/ha) with nitrogen fertilizer (46 kg/ha) respectively observed increased total-soil nitrogen content by about 52.10 and 49.34 percent over the control plot. Subehia *et al*. (2013) observed that application of varying levels of NPK and manures significantly influenced the available nitrogen status of soil.

4.2.4. Available Phosphorous

Phosphorous (P) is the most important limiting plant nutrient next to nitrogen for crop production. The combined applications of organic and inorganic fertilizers significantly affect Av. P in soil. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant effect on soil Avai.P (Appendix Table 5). The highest and lowest Avai.P (19.18. mg/kg and 6.88 mg/kg) were obtained from the application of 5 t/ha VC and 5 t/ha LGM in combination with 50% recommended chemical fertilizers and the application of 100% chemical fertilizers (Table 4.5) respectively. The increased in Avai.P might be attributed to organic fertilizer application could enhance releasing more Avai.P from the soil.

The results indicate that a combination of both organic and inorganic fertilizers was better in improving soil Avai.P compared to their sole applications. The highest available phosphorus might be due to release of phosphorus from vermicompost and LGM and supply of phosphorus to soil by NPSB fertilizer. This finding is in agreement with the result of Kumar & Niwas, (2022) who reported that the maximum Avai.P was obtained from the combined application of inorganic and organic fertilizers (100% NPK + 5 t ha^{-1} FYM + 5 t ha^{-1} vermicompost) (22.50 kg ha^{-1}). This result is in line with the findings of Alem Reda & Fassil Kebede, (2015) who indicated that the interaction effect of FYM with inorganic fertilizers (DAP and Urea) was significantly increased available P.

This investigation is similar to that of Tolera Emamu & Tesfaye Wakgari, (2021) who reported that the maximum available phosphorus (23.49ppm) was obtained from 15 t ha^{-1} VC + 100 kg ha^{-1} NPS fertilizer and the minimum (9.22 ppm) was observed from without vermicompost and NPS treatment. Similarly, Meraj Ahmad *et al*. (2022) observed that the maximum available phosphorous content was recorded in 50% RDF + 50% N through vermicompost which was significantly higher over the treatments control. Subehia *et al*. (2013) indicated that the available P content of the soil varied from 18.18 kg ha^{-1} in control to 93.68 kg ha^{-1} in plots which received 50% NPK through chemical fertilizers + 50% N through FYM.

4.2.5. Available Potassium

Potassium is needed in large quantities by many crops next to nitrogen and phosphorous. Available potassium was significantly affected by the combined application of organic and inorganic fertilizers. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant effect on soil Avai.K (Appendix Table 5). The highest Avai.K of 0.60 mg/kg was obtained from the combined application of 5 t/ha VC and 5 t/ha LGM in combination with 100% recommended chemical fertilizers and the lowest Avai.K 0.40 mg/kg were obtained from the control (Table 4.6). The increase in Avai.K with the application of VC and LGM might be due to the K from the organic sources.

This finding is in agreement with the result of Kumar & Niwas, (2022) who reported that the maximum Avai.K was obtained from the combined application of inorganic and organic fertilizers (100% NPK + 5 t ha^{-1} FYM + 5 t ha^{-1} vermicompost) (330 kg ha^{-1}). This finding is in agreement with the result of Negessa Gadisa & Tesfaye Wakgari, (2021) who indicated that the application of vermicompost at the rate of (7.5 t/ha) observed increased1 soil exchangeable K by about 14.59% over the control plot. In line with this Meraj Ahmad *et al*. (2022) revealed that the effect integrated of vermicompost, FYM and chemical fertilizers enhanced available K content in soil.

4.2.6. Cation Exchange Capacity

Soil CEC refers to the total amount of various cations that can be adsorbed by the soil colloids. It is an important basis for evaluating soil fertility capacity, and for soil environmental capacity and or pollutant migration and transformation (Kasem Adem *et al*., 2023). The combined applications of lupine green manure, vermicompost and chemical fertilizers significantly effect on the CEC ($P < 0.05$) of the soil. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant effect on soil CEC (Appendix Table 5). The highest CEC of 28.70 cmol (+) kg^{-1} was obtained from the combined application of 5 t/ha VC and 5 t/ha LGM with 100% recommended chemical fertilizers, while the lowest CEC 14.43 cmol (+) kg^{-1} was recorded from the application of 5 t/ha LGM with 100% RCF (Table 4.6). The increased CEC over the control might be directly related with increasing of soil organic matter as a result of application of increasing dose of vermicompost.

This finding is in agreement with the result of Mekonnen Workineh *et al*. (2020) who reported that the highest CEC of 34.36 cmol (+) kg^{-1} was recorded for plots treated with combined application of 2.84 t/ha VC with 50% recommended NPS + urea fertilizers, while the lowest

CEC 22.66 cmol (+) kg^{-1} was recorded from the control plot. This investigation is similar to that of Alem Reda & Fassil Kebede, (2015) who reported that the interaction effect of FYM with inorganic fertilizers (DAP and Urea) indicated significance effect on Cation Exchange Capacity (CEC). Similarly, Tolera Emamu & Tesfaye Wakgari, (2021) indicated that the highest value of CEC (25.23 cmol(+)Kg^{-1}) was recorded from the combined application of organic and inorganic fertilizer, whereas, the lowest value (22.20 cmol (+) Kg^{-1}) was recorded from control treatment. In contrary to this result Negessa Gadisa & Tesfaye Wakgari, (2021) found that the main effect of nitrogen as well as the interaction effect of vermicompost and nitrogen fertilizer had not significantly influenced cation exchange capacity.

Table 4.4; Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on selected soil chemical properties and before application soil sample.in Mecha District, Northwestern Ethiopia during of 2023main cropping season.

GM (t/ha)	VC (t/ha)	Parameters					
		pH			OC (%)		
		Chemical fertilizers (kg/ha)					
		0	50%	100%	0	50%	100%
0	0	4.93^{c-g}	4.92^{c-g}	5.03^{b-f}	0.62^{k}	0.43^{l}	0.23^{l}
	2.5	5.07^{b-f}	4.83^{d-h}	4.82^{d-h}	0.13^{l}	0.87^{j}	1.04^{g-i}
	5	4.61^{h}	5.07^{b-f}	5.02^{b-f}	0.59^{k}	1.12^{f-h}	1.09^{f-h}
2.5	0	5.15^{a-c}	5.15^{a-c}	5.1^{a-e}	0.56^{l}	0.92^{ij}	1.07^{f-i}
	2.5	5.16^{a-c}	4.93^{c-g}	5.03^{b-f}	0.66^{l}	1.12^{f-h}	1.15^{f-h}
	5	4.85^{d-h}	4.81^{e-h}	4.79^{f-h}	0.64^{k}	1.18^{e-g}	1.22^{ef}
5	0	5.25^{ab}	5.27^{ab}	5.12^{a-d}	1.02^{h-j}	1.42^{cd}	1.49^{c}
	2.5	4.9^{c-h}	5.3^{ab}	5.11^{a-d}	1.01^{h-j}	1.32^{de}	1.65^{b}
	5	5.04^{b-f}	5.38^{a}	5.06^{b-f}	1.04^{g-i}	1.45^{cd}	1.86^{a}
Mean		5.00	5.07	5.01	0.70	1.09	1.20
LSD				0.29			0.15
CV (%)				1.85			5.15

Means within column followed by the same letters are not significantly different at $P \leq 0.05$; LSD = Least significant difference; CV = Coefficient variation; pH = power of hydrogen, OC = Organic carbon;

Table 4.5; Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on soil TN and AP .in Mecha District, Northwestern Ethiopia during of 2023main cropping season.

GM (t/ha)	VC (t/ha)	Parameters					
		TN			AP		
		Chemical fertilizers (kg/ha)					
		0	50%	100%	0	50%	100%
0	0	0.246^{d-f}	0.24^{ef}	0.26^{b-d}	14.47^{h}	13.74^{j}	6.88^{y}
	2.5	0.25^{c-e}	0.24^{ef}	0.276^{ab}	11.48^{o}	11.69^{m}	8.78^{x}
	5	0.273^{ab}	0.25^{c-e}	0.26^{b-d}	18.28^{c}	13.93^{i}	11.34
2.5	0	0.22^{g-i}	0.263^{b-d}	0.27^{b}	18.38^{b}	8.92^{w}	10.45^{s}
	2.5	0.213^{hi}	0.266^{bc}	0.26^{b-d}	18.39^{b}	8.75^{x}	15.89^{g}
	5	0.25^{c-e}	0.27^{b}	0.26^{b-d}	17.25^{e}	10.18^{t}	10.56^{r}
5	0	0.21^{i}	0.23^{f-h}	0.266^{bc}	12.74^{l}	11.56^{n}	10.7^{q}
	2.5	0.29^{a}	0.231^{fg}	0.273^{ab}	17.82^{d}	13.37^{k}	10.14^{u}
	5	0.263^{b-d}	0.25^{c-e}	0.23^{f-h}	16.98^{f}	19.18^{a}	9.65^{v}
Mean		0.25	0.25	0.26	16.20	12.37	10.49
LSD				0.01			0.03
CV (%)				2.09			0.09

Means within column followed by the same letters are not significantly different at $P \leq 0.05$; LSD = Least significant difference; CV = Coefficient variation; TN = Total nitrogen, AP = Available phosphorus.

Table 4.6; Effects of combined application of lupine green manure, vermicompost and chemical fertilizers on soil total nitrogen and available potassium in Mecha District, Northwestern Ethiopia during of 2023main cropping season.

GM (t/ha)	VC (t/ha)	Parameters					
		CEC			AK		
		Chemical fertilizers (kg/ha)					
		0	50%	100%	0	50%	100%
0	0	21.43^{o}	26.73^{c-e}	23.8^{hi}	0.40^{ef}	0.53^{bc}	0.49^{cd}
	2.5	25.26^{fg}	23.43^{h-j}	23.26^{h-j}	0.55^{ab}	0.53^{bc}	0.53^{bc}
	5	20.90^{l}	28.4^{ab}	21.4^{kl}	0.58^{ab}	0.38^{f}	0.49^{cd}
2.5	0	26^{d-f}	22.43^{jk}	24.43^{g-i}	0.53^{bc}	0.56^{ab}	0.56^{ab}
	2.5	25.63^{e-g}	26.83^{c-e}	27.4^{bc}	0.53^{bc}	0.54^{a-c}	0.55^{ab}
	5	25.23^{p}	26.06^{d-f}	18.06^{m}	0.45^{de}	0.44^{d-f}	0.53^{bc}
5	0	25.06^{fg}	24.5^{gh}	14.43^{n}	0.45^{de}	0.55^{ab}	0.53^{bc}
	2.5	23.63^{h-j}	23.43^{h-j}	23.23^{ij}	0.56^{ab}	0.56^{ab}	0.58^{ab}
	5	27.2^{b-d}	26.1^{d-f}	28.7^{a}	0.55^{ab}	0.47^{d}	0.60^{a}
Mean		24.48	25.32	22.75	0.51	0.51	0.54
LSD				1.25			0.05
CV (%)				1.70			3.57

Means within column followed by the same letters are not significantly different at P ≤ 0.05; LSD = Least significant difference; CV = Coefficient variation; CEC = Cation exchange capacity, AK = Available potassium;

4.3. Effect of Soil Amendments on Phenological and Vegetative Parameters of Wheat

4.3.1. Days to 50% heading

The analysis of variance revealed that the combined application of lupine green manure, vermicompost and chemical fertilizer had significant ($P < 0.05$) influence on days to 50% heading of wheat (Table 4.7). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant influence on days to 50% heading

(Appendix Table 3). The longest duration to reach 50% heading (70) was observed in control treatments. However, the minimum duration of 50% heading (55) was recorded from the combined application of 5 t/ha lupine green manure + 5 t/ha vermicompost + 100% recommended chemical fertilizers (Table 4.4).

Application of lupine green manure, vermicompost and chemical fertilizers reduced the days to 50% heading by 15 days as compared to control. This finding indicated that the combination of lupine green manure, vermicompost and chemical fertilizers enhanced the early heading of wheat. This finding is in agreement with the result of Gedefa Sori & Dagne Chimdessa, (2022) who reported that days to heading were significantly ($P < 0.05$) affected due to the application of NPS, vermicompost and their interactions. According to the study of ÇİRKA, (2022), the effect of vermicompost doses on the number of heading days of bread wheat was found significant.

4.3.2. Days to 90% maturity

The analysis of variance showed that the effects of combined application of lupine green manure, vermicompost and inorganic fertilizer application significantly ($P < 0.05$) influenced days to 90% physiological maturity of wheat (Table 4.7). The interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant influence on days to 90% physiological maturity, but the main effects of lupine green manure and chemical fertilizer had not significant influence on days to 90% physiological maturity (Appendix Table 3). The results showed that wheat plants that received 5 t/ha VC + 5 t/ha LGM combined with 50% recommended inorganic NPSB + urea fertilizers required less duration to reach 90% physiological maturity than wheat plants grown from the control plots. This finding is in line with the result of Kumar & Niwas, (2022) who reported that combined application of inorganic and organic fertilizers promoted days to 90% physiological maturity.

4. 3.3. Plant height

Plant height is an important growth character directly linked with the productive potential of the plants in terms of fodder and grain yield. The analysis results of the present study showed that all the treatments increased plant height significantly ($P < 0.05$) over control (Table 4.7). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant influence on plant height (Appendix Table 3). The tallest plants (82.16cm) were observed in the plots treated with the combined application of 5 t/ha VC + 5 t/ha LGM (Table 4.7). On the other hand, the lowest plant height (40.38cm) was obtained from control plot.

Considering the maximum height in VC plus mineral fertilizers combination, the mineral fertilizers fulfill the N requirements at early growth stages while, VC enhanced crop growth by releasing adequate amount of nutrients in the later stages. This finding is in agreement with the result of Kumar & Niwas, (2022) who reported that combined application of inorganic and organic fertilizers promoted plant height. Similarly, Kumar *et al*. (2019) investigated that the application of organic and inorganic fertilizers gave maximum plant height at all the growth stages. Valeem *et al*. (2008) also observed that the organic manure and compost significantly increased the plant height. In line with this Aslam *et al*. (2019) revealed that the maximum plant height was recorded from the combined application of NPK fertilizers and vermicompost.

4.3.4. Number of productive tillers

An examination of tillering is one of the useful ways to determine the growth status of wheat plant. During the research year, the number of productive tillers per plant was considerably increased by combining VC and lupine green manure with varying amounts of chemical fertilizer (Table 4.8). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significantly influenced productive tillers (Appendix Table 3). According to the data, the application of LGM + VC + Full RCF treatment resulted in the highest increase in productive tillers ($P < 0.05$). This finding is in agreement with the result of Kumar *et al*. (2015) who reported that the maximum number of tillers was recorded from the combined application of inorganic and organic fertilizers (100% NPK + 5 t ha^{-1} FYM + 5 t ha^{-1} + vermicompost) and the minimum number of tillers was recorded in the (Control).

Ali & Dhaked, (2023) also stated that all the organic and inorganic fertilizer treatments had significant bearing on the number of tillers m^{-2}. Similar results were studied by Kumar *et al*. (2019) who revealed that the application of FYM and vermicompost along with inorganic fertilizers increased the number of tillers over the control. Khan *et al*. (2013) reported that the maximum increase in productive tillers were recorded by the application of FYM + Full NPK treatment and it was followed by with the application of farmyard manure + ½ NPK treatment respectively.

4.3.5. Spike length

Spike length is the most important yield attributing character. According to the data obtained in the experiment, the effect of LGM, VC and inorganic fertilizer doses on the spike length of wheat was found significant ($P < 0.05$). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significantly influenced spike length (Appendix Table 3). The longest spike length was measured in treatment T27 (9.44 cm). Whereas the shortest spike length was occurred in control treatment T1 (3.88cm) (Table 4.8). This finding is in agreement with the result of Kumar & Niwas, (2022) who reported that combined application of inorganic and organic fertilizers promoted vegetative growth and spike length.

Jackson *et al*. (2019) also found similar findings which suggested that the results might be due to the integration of organic and inorganic sources. Similarly Ali & Dhaked, (2023) found that the various organic and inorganic fertilizer treatments had a significant bearing on the number of spike. ÇİRKA, (2022) investigated that the effect of vermicompost doses on the spike length of bread wheat was found significant. Bizuwork Desta & Yibekal Almayehu, (2020) found that the combined application of blended NPSB with nitrogen fertilizers (150/92 kg ha^{-1}) exceeded the SL by about 39.23% than that of the control plot.

Table 4.7. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on days to 50% heading, days to 90% maturity and plant height of Wheat in Mecha District, Northwestern Ethiopia during of 2023 main cropping season.

GM(t/ha)	VC(t/ha)	Parameters								
		HD			MD			PH		
		Chemical fertilizers (kg)								
		0	50%	100%	0	50%	100%	0	50%	100%
0	0	70^{a}	67^{ab}	67^{ab}	106.33^{ab}	100.33^{b}	105.33^{ab}	40.38^{i}	48.11^{hi}	54.58^{f-h}
	2.5	67^{ab}	67^{ab}	60^{c-e}	100.67^{b}	105.33^{ab}	101.67^{ab}	59.22^{e-h}	61.66^{c-g}	64.19^{b-f}
	5	67^{ab}	60^{c-e}	67^{ab}	108^{a}	102^{ab}	103.33^{ab}	64.64^{b-f}	70.35^{a-e}	74^{a-c}
2.5	0	70^{a}	67^{ab}	67^{ab}	104.67^{ab}	108^{a}	103.33^{ab}	51.40^{g-i}	53^{f-h}	62.29^{c-g}
	2.5	60^{c-e}	64^{b-d}	64.3^{b-d}	103^{ab}	101^{ab}	100^{b}	60.72^{d-g}	72.05^{a-d}	70.19^{a-e}
	5	67^{ab}	59de	57^{e}	100.67^{b}	100^{b}	105^{ab}	65.36^{b-f}	72.27^{a-d}	75.637^{ab}
5	0	66^{ab}	64.3^{b-d}	63.7^{b-d}	105^{ab}	105^{ab}	103^{ab}	54^{f-h}	62.78^{c-g}	61.74^{c-g}
	2.5	60^{c-e}	64.7^{a-c}	59.3^{c-e}	102^{ab}	101.33^{ab}	102.67^{ab}	69.75^{a-e}	72.58^{a-d}	73.39^{a-c}
	5	59de	59.6^{c-e}	55^{e}	100^{b}	101.67^{ab}	101.33^{ab}	82.164^{a}	75.944^{ab}	81.917^{a}
Mean		65.11	63.62	62.26	103.37	102.74	102.85	60.85	65.42	68.66
LSD				5.39			7.03			21.96
CV (%)				2.65			2.14			10.80

Means within column followed by the same letters are not significantly different at $P \leq 0.05$; LSD= Least significant difference; CV= Coefficient variation; HD = Days to 50% heading; MD = Days to 90% maturity; PH = Plant height.

Table 4.8. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on spike length and productive tiller of Wheat in Mecha District, Northwestern Ethiopia during of 2023 main cropping season.

GM (t/ha)	VC (t/ha)	Parameters					
		SL			PT		
		Chemical fertilizers (kg/ha)					
		0	50%	100%	0	50%	100%
0	0	3.88^{j}	4.687^{ij}	5.67^{f-i}	1^{h}	1^{h}	1.61^{h}
	2.5	6.44^{e-h}	7^{c-f}	8^{a-e}	2.55^{d-h}	2.30^{e-h}	2.88^{c-h}
	5	8.33^{a-c}	8.73^{ab}	8.93^{ab}	4^{b-e}	5.05^{ab}	4.55^{a-c}
2.5	0	5.16^{g-j}	5^{h-j}	6.97^{c-f}	1.32^{h}	1^{h}	2.61^{d-h}
	2.5	6.67^{d-g}	7.72^{b-e}	8.25^{a-c}	2.06^{f-h}	3.94^{b-f}	5^{ab}
	5	7.47^{b-e}	8.35^{a-c}	8.85^{ab}	4^{b-e}	3.67^{b-g}	5.33^{ab}
5	0	4.33^{IJ}	6.52^{e-h}	6.87^{c-f}	1^{h}	2.27^{e-h}	1.72^{gh}
	2.5	8.19^{a-d}	8.33^{a-c}	8.17^{a-d}	5.17^{ab}	4.33^{a-d}	4.16^{a-e}
	5	9.33^{a}	8.10^{a-d}	9.44^{a}	5.33^{ab}	4.92^{ab}	6^{a}
Mean		6.64	7.16	7.91	2.94	3.16	3.76
LSD				1.57			1.91
CV (%)				6.81			18.31

Means within column followed by the same letters are not significantly different at P ≤ 0.05; LSD = Least significant difference; CV = Coefficient variation; SL = Spike length; PT = productive tiller.

4.5. Effect of Soil Amendments on Yield Components of Wheat

4.5.1. Number of grains per spike

Results revealed that numbers of grains spike^{-1} were affected significantly by the use of LGM and VC in combination with different doses of chemical fertilizer (Table 4.9). Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer had significant influenced numbers of grains spike^{-1} (Appendix table 4). The data depicted that maximum number of grains per spike 46.33 was observed with LGM + VC + recommended NPSB and

Urea and the minimum 15.55 grains spike^{-1} were obtained from the control plots. Similar result were conducted by Thalkar & Patil, (2019) who found that the combined application of organic and inorganic soil amendment (25% RDF + 25 % Vermicompost + 25% FYM + 25% Sludge) showed better result in number of grains/spike (66.33). Khan *et al*. (2013) shown that numbers of grains spike^{-1} were affected significantly by the use of FYM in combination with different doses of chemical fertilizer. Bizuwork Desta & Yibekal Almayehu, (2020) revealed that the main effect of blended NPSB was significant and the main effect of N as well as their interaction effects was highly significant in influencing the number of grains per spike.

4.5.2. Grain yield

The effect of organic and inorganic fertilizer application was significant ($P < 0.05$) on grain yield among treatments. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer significantly affected grain yield of wheat (Appendix table 4). Thus, the highest grain yields (3.92 t/ha) were obtained from the combined application of 5 t/ha LGM + 100% recommended NPSB + urea fertilizers with 5 t/ha VC. On the other hand, the lowest grain yield (0.91 t/ha) was obtained from control plots (Table 4.9). This finding was also supported by the results of Gedefa Sori & Dagne Chimdessa, (2022) who stated that the combined application of NPS and mineral vermicompost ensured higher returns in wheat crop yields. In line with this study conducted by Mekonnen Workineh *et al*. (2020) revealed that application of combined inorganic with organic fertilizers (50% recommended NPS + urea fertilizers with 2.84 t/ha VC) has the maximum grain of 5.93 t/ha. Similar results also reported by Kumar *et al.* (2015) combined application of organic and chemical fertilizers increased on grain yield. Similar results were studied by Kumar *et al*. (2019) who found that the combined use of inorganic fertilizers, FYM and vermicompost produced significantly higher grain yield of wheat. Abedi *et al*. (2010) also confirmed that the use of chemical fertilizer (N) in combination with compost significantly increased the grain yield of wheat crop.

4.5.3. Thousand grain weight

Significant differences ($P < 0.05$) were observed in 1000-grain weight with the application of VC and LGM in combination with different doses of chemical fertilizer. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer significantly affected 1000-grain weight (Appendix table 3). It was observed that maximum 1000-grain weight of 38.7 g was produced where LGM + VC + Full NPSB & urea were applied and it was followed by 38.2 g was observed with the application of LGM + ½ NPSB & urea were applied whereas the lowest 1000-grain weight of 30.3 g was observed from the control treatment (Table 4.9). This finding is in agreement with the result of Thalkar & Patil, (2019) who reported that the maximum 1000-grain weight was recorded from the combined application of inorganic and organic fertilizers (41.60) and the minimum 1000-grain weight was recorded in the (Control) (30.87).

Similar findings with this study conducted by Cheraghi *et al*. (2016) stated that combined application of 10 ton/ha vermicompost and 75% P fertilizer treatment had the highest 1000-grain weight (43.5 g) and control treatment had the lowest 1000 grain weight (36 g) and difference between them was significant. Khan *et al*. (2013) observed that significant differences were observed in 1000-grain weight with the application of FYM in combination with different doses of chemical fertilizer. Negessa Gadisa & Abdisa Mekonnen, (2021) indicated that the main effects of vermicompost, N fertilizer level as well as their interaction effect had significant affected thousand kernel weight of wheat. In contrary to this result Getachw Agegnehu *et al*. (2014) reported that the applications of inorganic and organic nutrient sources either alone or in combination had not a significant effect on 1000-grain weight of wheat. Valeem *et al*. (2008) stated that the production at various levels of organic manure and compost revealed that the maximum 1000-grain weight (45.26 g) was produced when organic manure was applied.

4.5.4. Straw yield

The analysis of variance illustrated that straw yield of wheat was significantly ($P < 0.05$) different among treatments. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer significantly affected straw yield (Appendix table 4). The maximum straw yields (5.67 t/ha) were obtained from the combined application of 5 t/ha lupine green manure and 100% recommended chemical fertilizers with 5 t/ha VC (Table 4.10). The minimum straw yields (2.74 t/ha) were recorded from the control plots. In line with this study conducted by Mekonnen Workineh *et al*. (2020) revealed that application of combined inorganic with organic fertilizers (50% recommended NPS + urea fertilizers with 2.84 t/ha VC) has the maximum straw yield of 8.07 t/ha.

This result is in line with that of Sarwar *et al*. (2009) who reported that straw yield was significantly increased by the application of organic fertilizers along with the application of inorganic fertilizers. Similar results were studied by Kumar *et al*. (2019) who revealed that the combined use of inorganic fertilizers, FYM and vermicompost produced significantly higher straw yield of wheat. In agreement with this result Getachew Agegnehu *et al*. (2014) found that the applications of inorganic and organic nutrient sources either alone or in combination had a significant effect on grain yield, total biomass and harvest index of wheat.

4.5.5. Biomass yield

The effect of combined application of lupine green manure, vermicompost, and inorganic fertilizer application was significant on biomass yield (Table 4.10). Both the main and interaction effects of lupine green manure, vermicompost and chemical fertilizer significantly affected biomass yield ($P < 0.05$) (Appendix table 4). The comparison of the mean values of biomass yield for interaction effect of organic and inorganic fertilizer showed that combined application of 5 ton/ha vermicompost and 100% RCF treatment had the highest (9.59 t/ha) and control treatment had the lowest biomass yield (3.66 t/ha) and difference between them were significant (Table 4.5). In agreement with this study conducted by Cheraghi *et al*. (2016) who reported that biomass yield was increased with application of organic and chemical fertilizers.

Thalkar & Patil, (2019) conducted an experiment on the effect of organic and inorganic fertilizers increase wheat yield components and biomass under rainfed condition and he found that the biological yield (10000 kg ha^{-1}). Getachew Agegnehu *et al*. (2014) also reported that the applications of inorganic and organic nutrient sources either alone or in combination had a significant effect on total biomass of wheat. Valeem *et al*. (2008) Total dry biomass of wheat increased significantly over control with the use of organic manure and compost.

4.5.6. Harvest index

Harvest index significantly ($P < 0.05$) varied in response to application of the LGM and VC with chemical fertilizers. Both the main and interaction effects of lupine green manure, vermicompost, and chemical fertilizer significantly affected harvest index (Appendix table 4). The highest harvest indices were recorded for all combined application rates of the three fertilizers whereas the lowest were recorded for the application of lone full dose of the blanket recommended mineral NPSB & UREA fertilizers, lone full dose of LGM, and the control treatments (Table 4.10). This result is in agreement with that of Getachew Agegnehu *et al*. (2014) who reported that harvest index was significantly increased by the application of organic fertilizers along with the application of inorganic fertilizers. Bizuwork Desta & Yibekal Almayehu, (2020) also observed that the main effect of N rates highly significantly influenced the harvest index. Similarly, Aslam *et al*. (2019) observed that the maximum harvest was recorded from the combined application of NPK fertilizers and vermicompost.

Table 4.9. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on Number of grains, thousand seed weight and grain yield of Wheat.in Mecha District, Northwestern Ethiopia during of 2023 main cropping season.

GM(t/ha)	VC(t/ha)	Parameters								
		NG			TSW(g)			GY(t/ha)		
		Chemical fertilizers (kg)								
		0	50%	100%	0	50%	100%	0	50%	100%
0	0	15.55^{f}	19.88^{ef}	26.1^{c-f}	29.00^{de}	30.26^{b-e}	32.56^{a-e}	0.91^{h}	1.11^{gh}	1.69^{c-h}
	2.5	36.44^{a-d}	28.22^{c-f}	37.44^{a-d}	33.90^{a-d}	34.50^{a-d}	34.60^{a-d}	2.56^{b-f}	2.04^{c-h}	2.66^{a-f}
	5	24.33^{d-f}	39.44^{a-c}	38.99^{a-c}	29.00^{de}	35.76^{a-d}	37.46^{ab}	1.34^{e-h}	2.93^{a-c}	2.73^{a-e}
2.5	0	29.00^{c-f}	24.66^{d-f}	31.88^{b-e}	28.50^{de}	32.00^{a-e}	33.76^{a-e}	1.54^{d-h}	1.58^{d-h}	2.17^{c-h}
	2.5	27.66^{c-f}	29.55^{c-e}	32.00^{b-e}	29.67^{c-e}	34.50^{a-d}	34.00^{a-d}	1.42^{e-h}	2.39^{b-g}	2.21^{c-h}
	5	28.77^{c-f}	29.88^{c-e}	32.11^{b-e}	34.20^{a-d}	31.90^{a-e}	36.3^{a-c}	2.03^{c-g}	1.87^{c-h}	2.41^{b-g}
5	0	20.22^{ef}	27.99^{c-f}	30.66^{c-e}	26.50	33.33^{a-e}	34.83^{a-d}	1.35^{e-h}	1.95^{c-h}	2.17^{c-h}
	2.5	44.77^{ab}	37.22^{a-d}	37.55^{a-d}	38.20^{a}	32.33^{a-e}	35.33^{a-d}	2.75 $^{a-e}$	1.62^{c-h}	3.20^{a-c}
	5	39.00^{a-c}	44.77^{ab}	46.333^{a}	32.00^{a-e}	37.30^{ab}	38.66^{a}	2.43^{b-f}	3.61^{ab}	3.92^{a}
Mean		29.53	31.29	34.78	31.22	33.54	35.28	1.81	2.12	2.57
LSD				13.94			7.28			1.17
CV (%)				14.05			6.84			19.26

Means within column followed by the same letters are not significantly different at $P \leq 0.05$; LSD= Least significant difference; CV= Coefficient variation; NG = Number of grains; TSW = Thousand seed weight; GY = Grain yield.

Table 4.10. Interaction effects of combined application of lupine green manure, vermicompost and chemical fertilizers on straw yield biomass yield and harvest index of Wheat.in Mecha District, Northwestern Ethiopia during of 2023 main cropping season.

GM(t/ha)	VC(t/ha)	Parameters								
		SY(t/ha)			BY(t/ha)			HI (%)		
		Chemical fertilizers (kg)								
		0	50%	100%	0	50%	100%	0	50%	100%
0	0	2.74^{h}	2.95^{gh}	3.46^{e-h}	3.66^{h}	4.05^{gh}	5.15^{e-h}	22.73^{e}	24.43^{de}	29.94^{b-e}
	2.5	3.97^{c-g}	3.79^{d-h}	4.43^{b-e}	6.53^{c-g}	5.83^{d-h}	7.10^{b-e}	30.12^{b-e}	31.79^{a-d}	34.65^{a-c}
	5	3.19^{f-h}	4.59^{a-d}	4.43^{b-e}	4.54^{f-h}	7.52^{a-d}	7.16^{b-e}	27.23^{c-e}	36.05^{ab}	35.41^{ab}
2.5	0	3.37^{e-h}	3.41^{e-h}	3.94^{c-g}	4.91^{e-h}	4.99^{e-h}	6.12^{c-g}	28.86^{b-e}	29.53^{b-e}	32.85^{a-c}
	2.5	3.29^{f-h}	4.13^{b-f}	4.00^{c-g}	4.71^{f-h}	6.52^{b-f}	6.22^{c-g}	27.60^{c-e}	33.59^{a-c}	33.02^{a-c}
	5	3.84^{d-h}	3.67^{d-h}	4.16^{b-f}	5.87^{d-h}	5.54^{d-h}	6.57^{b-f}	31.93^{a-d}	31.13^{a-d}	33.89^{a-c}
5	0	2.93^{gh}	3.75^{d-h}	3.92^{c-g}	4.28^{gh}	5.70^{d-h}	6.09^{c-g}	27.59^{c-e}	30.95^{a-d}	32.95^{a-c}
	2.5	5.16^{ab}	3.47^{d-h}	4.41^{b-e}	7.91^{ab}	5.09^{e-h}	7.62^{b-e}	38.35^{a}	28.86^{b-e}	35.54^{ab}
	5	4.26^{b-f}	5.00^{a-c}	5.67^{a}	6.69^{b-f}	8.62^{a-c}	9.59^{a}	33.71^{a-c}	32.87^{a-c}	37.94^{a}
Mean		3.64	3.86	4.27	5.46	5.98	6.85	29.79	31.02	34.02
LSD				1.11			2.16			7.64
CV (%)				8.907			11.62			7.58

Means within column followed by the same letters are not significantly different at $P \leq 0.05$; LSD= Least significant difference; CV= Coefficient variation; SY = Straw yield; BY = Biomass yield; HI = Harvest index.

4.6. Correlations

Significant positive correlation of grain yield with all the yield and yield components were observed which indicating that grain yield could invariably increase by increasing those characteristics. Positive associations of grain yield with number of tillers produced per plant (r= 0.67^{**}), biomass yield (r= 0.93^{**}), harvest index (r= 0.92^{**}), spike length (r= 0.65^{**}), number of grains per spike (r=0.92^{**}), and thousand seed weight (r= 0.84^{**}) (Table 4.11). The result shows that the applied fertilizers have positive contribution to the economic yield. This result was supported by the recent findings of Firehiwot, (2014) who reported that strong significant positive correlation of grain yield with plant height, panicle length, panicle seed weight, straw yield and harvest index was observed on wheat.

Table 4.11. Correlations of Major agronomic Parameters

	PH	SL	NG	GY	TN	TSW	BY	HD	MD	HI	SY
PH	1										
SL	0.72**	1									
NG	0.58**	0.6**	1								
GY	0.61**	0.65**	0.92**	1							
TN	0.72**	0.88**	0.63**	0.67**	1						
TSW	0.51**	0.54**	0.65**	0.84**	0.55**	1					
BY	0.56**	0.61**	0.87**	0.93**	0.61**	0.80**	1				
HD	-0.45**	-0.62**	-0.63**	-0.63**	-0.65**	-0.46**	-0.62**	1			
MD	-0.29**	-0.34**	-0.37**	-0.35**	-0.40**	-0.22*	-0.32**	0.33**	1		
HI	0.58**	0.72**	0.92**	0.92**	0.67**	0.77**	0.84**	-0.63**	-0.33**	1	
SY	0.57**	0.59**	0.84**	0.93**	0.60**	0.82**	0.94**	-0.54**	-0.32	0.706**	1

Note: TN = tiller number, PH = plant height, SL = spike length, NG = number of grains spike^{-1}, BY = biomass yield, GY = grain yield, HD = days to 50% heading, MD = days to 90% maturity, HI = harvest index, SY = straw yield, TSW = thousand seed weight, *, and ** = significantly different at 5%, and 1%, respectively.

4.7. Partial Budget Analysis

The partial budget analysis was done to identify the economic benefits of the proposed and tested rewarding treatments. Yield from on-farm experimental plots was adjusted downward by 12.5%, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. The highest grain yield (3.92 t/ha) was recorded from the combined application of 100% recommended inorganic NPSB + urea combined and 5 t/ha LGM with 5 t/ha VC and the lowest grain yield (0.91 t/ha) was from the control treatment. The adjusted maximum and minimum grain yield were (3.43 t/ha and 0.80 t/ha) respectively, according to CIMMYT, (1988). An average market grain price of wheat was (Ethiopian birr 63 kg^{-1}), farm-gate price of NPSB and urea fertilizers were (Ethiopian birr 42 kg^{-1} and 44 kg^{-1}) respectively.

According to the partial budget analysis, the highest net benefit of (Ethiopian birr 199676.2 ha^{-1}) was obtained from the application of 5 t/ha VC + 5 t/ha LGM with 100% recommended chemical fertilizers, whereas the control treatment (plots without treatment) gave the lowest net benefit (57583.29 ha^{-1} Ethiopian birr) (Table 4.12). The dominant treatments were eliminated from further economic analysis. To identify treatments with the optimum return to the farmer's investment, the marginal analysis was performed on non-dominated treatments. The treatment having MRR below 100% was considered low and unacceptable to farmers thus eliminated (CIMMYT, 1988). The economic analysis further revealed that the application of 5 t/ha VC and 5 t/ha LGM with 50% recommended NPSB + urea fertilizers provided the highest marginal rate of the return (MRR) of 29465.6%.

Table 4.12. Economic analysis of LGM, VC and chemical fertilizers in terms of partial budget and marginal rate of return (MRR) for wheat production

Trt	GY (t/ha)	AGY (t/ha)	TVC (Birr)	GB (Birr)	NB (Birr)	MRR (%)
1	0.91	0.80	6014.756	63598.05	57583.29	
4	2.56	0.97	11059.76	161312	150252.2	1836.8
2	1.11	1.48	13305.76	75222.9	61917.14	-3932.9
10	1.54	2.24	13589.76	101475	87885.24	9143.6
7	1.35	1.79	16120.76	89777.25	73656.49	-562.1
5	2.04	2.33	18350.76	131507.1	113156.3	1771.2
13	1.43	1.17	18634.76	94621.95	75987.19	-13087.7
3	1.69	2.56	20596.76	110084.9	89488.09	688.1
11	1.58	2.39	20880.76	103967.1	83086.34	-2254.1
19	1.35	1.35	21165.76	88785	67619.24	-5427
8	2.93	1.38	23411.76	184877.1	146715.3	3521.6
16	2.03	1.90	23695.76	131117	107421.2	-13836
6	2.67	1.24	25641.76	169275.2	143633.4	1860.8
14	2.40	2.09	25925.76	152775	126849.2	-5909.9
22	2.76	1.93	26210.76	185278.1	161465.3	12146
12	2.18	1.78	28171.76	139772.3	111600.5	-2542.8
20	1.95	1.64	28456.76	126287.1	97830.34	-4831.6
9	2.74	2.11	30702.76	173232.9	142530.1	1990.1
17	1.88	1.18	30986.76	121532	90545.19	-18304.6
25	2.44	1.71	31271.76	155672.1	124400.3	11879
15	2.22	1.90	33216.76	142348.1	109131.3	-785
23	1.62	2.41	33501.76	106365.2	72863.39	-12725.6
21	2.17	1.42	35747.76	139244.9	103497.1	1363.9
18	2.42	2.80	38277.76	153977	115699.2	482.2
26	3.62	2.13	38562.76	225887	199353.5	29465.6
24	3.21	3.16	40792.76	174225.2	133432.4	-2970.5
27	3.92	3.43	45853.76	245207.3	199676.2	1302.5

GY = grain yield, AGY = adjusted grain yield, TVC = total variable cost, GB = gross benefit, NB= net benefit, MRR = marginal rate of return

Chapter 5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The integrated application of mineral fertilizers with vermicompost (VC) and Lupine green manure significantly improved soil properties and yield components of wheat. This integrated application of organic and inorganic fertilizer reduced soil bulk density, increases soil porosity, and increased soil nutrient levels of N, OC, P, K, and cation exchange capacity (CEC). Combined application of 5 t/ha Vermicompost and 5 t/ha Lupine green manure with 100 RCF yields the highest total nitrogen (0.29%). Application of 5 t/ha and 5 t/ha Lupine green manure with 100% RCF achieved the highest organic carbon (1.86%) and cation exchange capacity (28.7), while control plots record the lowest values. These improvements in soil physicochemical properties demonstrated the potential of this combined application approach to enhance soil fertility and productivity.

Moreover, combining chemical fertilizers with vermicompost and Lupine green manure improved the yield and yield-related traits of wheat. The combination of 5 t/ha and 5 t/ha Lupine green manure with 100% RCF resulted in the maximum grain yield (3922.5 kg ha^{-1}) and biomass yield (9599.2 kg ha^{-1}). In contrast, the control plots yield the minimum grain (914.9 kg ha^{-1}) and biomass (3661.6 kg ha^{-1}). Economically, the highest net benefit (199353.5 ETB ha^{-1}) recorded from the application of 5 t/ha vermicompost and 5 t/ha Lupine green manure and 50% recommended chemical fertilizers. This combined fertilizer application is feasible for farmers and reduces the cost of mineral fertilizer by improving soil nutrient levels. It could be concluded that, the integration of organic and inorganic fertilizers was better than inorganic fertilizer only.

5.2. Recommendations

Based on the results of this study, applying an integrated 5 t/ha VC + 5 t/ha LGM + 50% recommended chemical fertilizers improved the soil fertility and increased yield of wheat. However, the following research gaps are suggested for further research.

Further research should be conducted across multiple locations and years to validate the efficacy of this integrated approach.

Further study should be continued focusing more on the use of the combination of inorganic and organic manure in various ratio in order to identify the best combination that would result into sustainable production along with better soil fertility and environment-friendly conditions.

6. REFERENCES

Abedi T., Alemzadeh, A. & Kazemeini S. A. (2010). Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. *Australian Journal of Crop Science*, *4*(6), 384–389.

Adams A. M., Gillespie A. W., Dhillon G. S., Kar G., Minielly C., Koala S., Ouattara B., Kimaro A. A., Bationo A., Schoenau J. J. & Peak D. (2020). *Geoderma Long-term effects of integrated soil fertility management practices on soil chemical properties in the Sahel*. *366*(May 2019), 1–12.

Adediran O. A., Ibrahim H., Tolorunse K. D. & Gana U. I. (2015). Growth, Yield and Quality of Jute Mallow (*Corchorus olitorius* L.) as Affected by Different Nutrient Sources. *International Journal of Agriculture Innovations and Research*, *3*(5), 2319–1473.

Adugnaw Anteneh. & Dagnachew Asrat. (2020). Wheat production and marketing in Ethiopia : Review study Wheat production and marketing in Ethiopia : Review study. *Cogent Food & Agriculture*, *6*(1).

Agric E. (2013). *Long - term effect of organic and in organic fertilizers on rice (oryzasativa l.) – wheat (triticum aestivum l.) yield, and chemical properties of an acidic soil*. *49*, 382–394.

Alem Reda. and, Fassil Kebede. (2015). Agronomic performance of integrated use of organic and inorganic fertilizers on rice (*Oryza sativa* L.) in Tselemti District of North-Western Tigray, Ethiopia. *Journal of Environment and Earth Science*, *5*(9), 30–41.

Alem Reda. & Hagos Hailu. (2017). *Extensive Utilization of Inorganic Fertilizers in Ethiopian Agriculture and Its Possible Consequences on Soil Quality NPS fertilizer optimization with micronutrients for Barley (Hordeum vulgare L.) View project Crop Production View project*. *13*(4), 155–171.

Ali M. & Dhaked G. S. (2023). *Effects of organic manures and inorganic fertilizers on growth and yield of wheat (Triticum aestivum L .)*. *6*(1), 6–14.

Angus J. F. (2001). Nitrogen supply and demand in australian agriculture. *Australian Journal of Experimental Agriculture*, *41*(3), 277–288.

April M.-, Ahmad M. & Tripathi S. K. (2022). *Effect of Integrated use of Vermicompost, FYM and Chemical Fertilizers on Soil Properties and Productivity of Wheat (Triticum aestivum L .) in Alluvial Soil*. *11*(2), 101–106.

Aslam Z., Bashir S., Hassan W., Bellitürk K. & Ahmad N. (2019). *Unveiling the Efficiency of Vermicompost Derived from Di ff erent Biowastes on Wheat (Triticum*.

Atiyeh R. M., Subler S., Edwards C. A., Bachman G., Metzger J. D. & Shuster W. (2000). Effects of vermicomposts and composts on plant growth in horticultural container media and soil. *Pedobiologia*, *44*(5), 579–590.

Birhanu Bayeh. (2010). *Assessment of Bread Wheat Production, Marketing and Selection of N-Efficient Bread Wheat (Tritium aestivum L.) Varieties for Higher Grain Yield and Quality in North Western Ethiopia Assessment of Bread Wheat Production, Marketing and Selection of*

N-E.

Belay Yebo. (2015). *Integrated Soil Fertility Management for Better Crop Production in Ethiopia International Journal of Soil Science 10(1):1-16,2015*.

Biosci I. J., Shiferaw Nesgea., Heluf Gebrekidan., Sharma, J. J. & Tareke Berhe. (2012). *Influence of inorganic and organic nutrient sources on soil properties and rain-fed rice tissue nutrient content in Gambella , Ethiopia*. *2*(11), 146–165.

Bista B. & Dahal S. (2018). Cementing the Organic Farming by Green Manures. *International Journal of Applied Sciences and Biotechnology*, *6*(2), 87–96.

Bizowork Desta. & Yibekal Almayehu. (2020). Optimizing blended (NPSB) and N fertilizer rates for the productivity of Durum wheat (*Triticum turgidum* L . *var* . *durum*) in Central Highlands of Optimizing blended (NPSB) and N fertilizer rates for the productivity of Durum wheat (*Triticum turgidum*. *Cogent Food & Agriculture*, *6*(1).

Brar B. S., Singh J., Singh G. & Kaur G. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. *Agronomy*, *5*(2), 220–238.

Cheng Y., He K., Zheng M., Duan F., Du Z., Ma Y., Tan J., Yang F. & Liu J. (2011). *and Physics Mass absorption efficiency of elemental carbon and water-soluble organic carbon in Beijing , China*. 11497–11510.

Chimouriya S., Lamichhane J., Gauchan D. & Gauchan D. P. (2018). International Journal of Research Green Manure for Restoring and Improving the Soil Nutrients Quality. *Article in International Journal of Research*, *September*.

CIMMYT. 1988. From Agronomic data to Farmer Recommendations: An Economic work Book. Mexico, D.F: CIMMYT.

David G., Borcean A., Imbrea F. & Botoş L. (2014). *White Lupin (Lupinus Albus L.): A Plant Fit to Improve Acid Soils In South-Western Romania and an Important Source of Protein*. *46*(1), 198–202.

Demir Z. (2020). Communications in Soil Science and Plant Analysis Effects of Vermicompost on Soil Physicochemical Properties and Lettuce (*Lactuca sativa Var*.Crispa) Yield in Greenhouse under Different Soil Water Regimes Effects of Vermicompost on Soil Physicochemical. *Communications in Soil Science and Plant Analysis*, *0*(0), 1–18.

Deshmukh N. J. (2022). *Effect of Bio-fertilizers & Chemical fertilizers on productivity & quality parameters of Wheat : A Review*. *10*(8), 640–643.

Dey D., Nath D. & Jamatia P. B. (2015). *Effect of raised bed planting method of maize under sandy loam soil of West Tripura*. *1*(7), 561–563.

Ding X., Han X., Liang Y., Qiao Y., Li L. & Li N. (2012). *Soil & Tillage Research Changes in soil organic carbon pools after 10 years of continuous manuring combined with chemical fertilizer in a Mollisol in China*. *122*, 36–41.

Ding Z., Kheir A. M. S., Ali O. A. M., Hafez E. M., Elshamey E. A., Zhou Z., Wang B., Ge Y., Fahmy A. E. & Seleiman M. F. (2021). *A vermicompost and deep tillage system to improve saline-sodic soil quality and wheat productivity*. *277*(August 2020).

Efthimiadou A., Bilalis D., Karkanis A. & Froud-williams B. (2010). *Combined organic / inorganic fertilization enhance soil quality and increased yield , photosynthesis and sustainability of sweet maize crop*. *4*(9), 722–729.

Fageria N. K. (2007). Green manuring in crop production. *Journal of Plant Nutrition*, *30*(5), 691–719.

Fantu Nisrane Bachewe., Guush Berhane., Minten B. & Alemayehu Siyum Taffesse. (2017). *Agricultural Transformation in Africa ? Assessing the Evidence in Ethiopia*. *xx*.

Fazily T. (2020). *Impact of Integrated Nutrient Management on Wheat Productivity and Sustaining Soil Fertility : A Review*. *3*, 235–241.

Firehiwot Getachew. 2014. Effect of vermicompost and inorganic N and P fertilizers on growth, yield, and quality of bread wheat (*Triticum aestivum* L.) in eastern Ethiopia MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

Fresew Belete., Nigussie Dechassa., Adamu Molla. & Tamado Tana. (2018). Effect of nitrogen fertilizer rates on grain yield and nitrogen uptake and use efficiency of bread wheat (*Triticum aestivum* L.) varieties on the Vertisols of central highlands of Ethiopia. *Agriculture & Food Security*, 1–12.

Garc C., Pascual I., Antol M. C., Polo A. & Sa M. (2007). *Effect of water deficit on microbial characteristics in soil amended with sewage sludge or inorganic fertilizer under laboratory conditions*. *98*, 29–37.

Gedefa Sori. & Dagne Chimdessa. (2022). *Integrated Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties and Bread Wheat Production in Gechi District , Western Integrated Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties and Bread Wheat Produc*. *September*.

Getachew Alemayehu., Agegnehu Shibabaw., Enyew Adgo, E., Asch, F., & Freyer, B. (2022). *Recovery of Soil Health and Crop Productivity of Degraded Cultivated Land of Northwest Ethiopian Highlands*. *32*(1), 1–29.

Getachew Agegnehu., Beek C. L. Van & Bird M. I. (2014). *productivity and soil chemical properties in the highland tropical Influence of integrated soil fertility management in wheat and tef productivity and soil chemical properties in the highland tropical environment*. *November*.

Getachew Agegnehu. & Bird M. I. (2014). *Influence of integrated soil fertility management in wheat and tef productivity and soil chemical properties in the highland tropical environment*. 532–545.

Getachew Agegnehu., Nelson P. N. & Bird M. I. (2016). Soil & Tillage Research Crop yield , plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on Nitisols. *Soil & Tillage Research*, *160*, 1–13.

Gete Zelleke., Getachew Agegnehu., Dejene Abera. & Rashid S. (2010). *Fertilizer and Soil*

Fertility Potential in Ethiopia. *July*.

Girma Chala. (2020). *Evaluation of Potassium Fertilizer on Yield and Yield Components of Potato under Irrigation on Nitisols in Central Highlands of Ethiopia*. 21–27.

Girma Fana., Haile Deressa., Reta Dargie., Mengistu Bogale., Seyfudin Mehadi. & Firehiwot Getachew. (2012). *Grain Hardness , Hectolitre Weight , Nitrogen and Phosphorus Concentrations of Durum Wheat (Triticum turgidum L. var. Durum) as Influenced by Nitrogen and Phosphorus Fertilisation*. *20*(10), 1322–1327.

Gomez A. A. & Wiley J. (1984). Second Edition / I. *Statistical Procedures for Agricultural Research*, *6*, 1–678.

Hammad H. M., Khaliq A. & Ahmad A. (2011). *Influence of Different Organic Manures on Wheat Productivity Influence of Different Organic Manures on Wheat Productivity*. *January 2016*.

Han S. H., An J. Y., Hwang J., Kim S. Bin & Park, B. B. (2016). The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (*Liriodendron tulipifera* Lin.) in a nursery system. *Forest Science and Technology*, *12*(3), 137–143.

Haile Hasana., Sheleme Beyene. & Alemayehu Kifilu. (2023). Influence of Phosphogypsum Amendments on the Performance of Wheat (*Triticum aestivum* L.) and Chemical Properties of Sodic Soil of Alage , Central Rift Valley of Ethiopia. *Journal of Soil Science and Plant Nutrition*, *23*(3), 3888–3903.

Jackson K., Changade N. M., Sukul P., Meetei T. & Bijilaxmi Y. (2019). *Efficacy of organic and inorganic fertilizer on soil properties , growth and yield attributes of wheat crop*. *7*(6), 2942–2947.

Joshi R., Vig A. P. & Singh J. (2013). *Vermicompost as soil supplement to enhance growth , yield and quality of Triticum aestivum L .: a field study*. *Suthar 2009*.

Kasem Adem., Diriba-Shiferaw G. & Ejigu D. (2023). Effects of Combined Application of Organic and Inorganic Fertilizers on Growth, Yield and Grain Quality of Bread Wheat (*Triticum aestivum* L.) Varieties. *Journal of Global Agriculture and Ecology*, *15*(4), 13–28.

Kayeke J., Sibuga P. K., Msaky J. J. & Mbwaga A. (2007). Green Manure and Inorganic Fertiliser As Management Strategies for. *African Crop Science Journal*, *15*(4), 161–171.

Khan M. A., Chattha M. R., Awan M. Z., Anjum A. S., Imran M., Muhammad S., Khan S. & Kasana M. I. (2013). Comparative Efficiency of Organic and Inorganic Fertilizers on Growth and Yield of Wheat in Rainfed Conditions. *Int.J.Biol.Biotech*, *10*(4), 577–580.

Knight P. (1914). Green Manures. *Bulletin of Miscellaneous Information (Royal Gardens, Kew)*, *1914*(1), 21.

Kumar A., Prakash C. H. B., Brar N. S. & Kumar B. (2018). *Potential of Vermicompost for Sustainable Crop Production and Soil Health Improvement in Different Cropping Systems*. *7*(10), 1042–1055.

Kumar D., Singh S., Singh J. & Singh S. P. (2015). Influence of organic and inorganic fertilizers on soil fertility and productivity of wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, *85*(2), 177–181.

Kumar G. & Niwas R. (2022). *Effect of organic and inorganic fertilizers on growth and yield of wheat (Triticum aestivum L .)*. *11*(7), 1005–1009.

Kumar N., Chandra B. L. & Srivastva A. K. (2011). *In-situ green manuring for enhancing productivity , profitability and sustainability of upland rice*. 369–377.

Kumar P., Singh S. & Kaur H. (2019). *Effect of organic and inorganic fertilizers on plant uptake , protein synthesis and productivity of pearl millet-wheat sequence under semi-arid inceptisols*. *7*(6), 437–443.

Lenin M. & Ravimycin T. (2013). *The Effects of Different Levels of Vermicompost (Vc) on the Nutrient Contents of (Arachis Hypogaea L.) Under Arbuscular Mycorrizha Fungi (Amf) (Gloumus Intraradices) Application*. *1*(2), 37–45.

Lim S. L., Wu T. Y., Lim P. N., Pui K. & Shak Y. (2014). *The use of vermicompost in organic farming : overview , effects on soil and economics*. *August*.

Lin S., Pi Y., Long D., Duan J., Zhu X., Wang X. & He J. (2022). *Impact of Organic and Chemical Nitrogen Fertilizers on the Crop Yield and Fertilizer Use Efficiency of Soybean – Maize Intercropping Systems*.

Longa C. M. O., Nicola L., Antonielli L., Mescalchin E., Zanzotti R., Turco E. & Pertot I. (2017). *Soil microbiota respond to green manure in organic vineyards*. 1547–1560.

Lupinus, L. (2012). *Plant Guide*.

Mall R. K., Gupta A. & Sonkar G. (2017). Effect of Climate Change on Agricultural Crops. In *Current Developments in Biotechnology and Bioengineering: Crop Modification, Nutrition, and Food Production*. Elsevier B.V.

Marinari S., Masciandaro G., Ceccanti B. & Grego S. (2000). *In ¯ uence of organic and mineral fertilisers on soil biological and physical properties*. *72*, 9–17.

Mclenaghen R. D., Randhawa P. S., Condron L. M. & Di H. J. (2004). Increasing phosphate rock availability using a lupin green manure crop. *Super Soil, 3rd Australian New Zealand Soil Conference*, *December*, 5–9.

Mekonnen Workineh., Samuel Feyissa. & Ayele Akuma. (2020). Effect of Organic and Inorganic Fertilizers on Selected Soil Properties Yield of Bread Wheat (*Triticum aestivum* L) in Lume District East Shoa, Ethiopia. *Academic Research Journal of Agricultural Science and Research*, *8*(5), 432–446.

Mintesinot Desalegn. (2022). *Review on the Integrated Use of Organic and Inorganic Fertilizers on Production and Soil Fertility in Ethiopia*. *12*(3), 9–24.

Molla Hadis., Gashaw Meteke. & Wassie Haile. (2018). *Response of bread wheat to integrated application of vermicompost and NPK fertilizers*. *13*(1), 14–20.

Muslic D. R. & Gogic M. (2015). *Nitrogen fertilizer influence on wheat yield and use efficiency* *under different environmental conditions*. *75*(March).

Negessa Gadisa. & Abdisa Mekonnen. (2021). *Effect of Integrated Application of Vermicompost and N Fertilizers on Quality Parameters of Wheat (Triticum aestivum L .) Varieties in Welmera District , Central Ethiopia*. *17*(5), 378–385.

Negessa Gadisa. & Tesfaye Wakgari. (2021). *Influenced of Organic and Chemical Source Fertilizer on Soil Physicochemical Properties and Nutrient Concentration of Nitisol in Welmera District , Central Ethiopia*. *17*(4), 295–307.

Nigus Demelash. & Wondimu Bayu. (2014). *Current and residual effects of compost and inorganic fertilizer on wheat and soil chemical properties*. 357–367.

Noureldin N. A. & Saudy H. S. (2013). Grain yield response index of bread wheat cultivars as influenced by nitrogen levels. *Annals of Agricultural Sciences*, *58*(2), 147–152.

Okubay Giday. (2019). Effect of type and rate of urea fertilizers on nitrogen use efficiencies and yield of wheat (Triticum aestivum) in Northern Ethiopia Effect of type and rate of urea fertilizers on nitrogen use efficiencies and yield of wheat (*Triticum aestivum*) in Nor. *Cogent Environmental Science*, *5*(1).

Papini R., Valboa G., Favilli F. & Abate G. L. (2011). Agriculture , Ecosystems and Environment Influence of land use on organic carbon pool and chemical properties of Vertic Cambisols in central and southern Italy. *"Agriculture, Ecosystems and Environment," 140*(1–2), 68–79.

Patra D. D., Anwar M. & Chand S. (2000). *Integrated nutrient management and waste recycling for restoring soil fertility and productivity in Japanese mint and mustard sequence in Uttar Pradesh , India*. *80*, 267–275.

Ram M., Davari M. R. & Sharma S. N. (2009). *Direct , residual and cumulative effects of organic manures and biofertilizers on yields , NPK uptake , grain quality and economics of wheat (Triticum aestivum L.) under organic farming of rice-wheat cropping system*. *Mishra*, 16–30.

Rotar I., Kadar R., Deac V., Vidican R. & Anamaria M. (2020). *Assessing Wheat Response to N Fertilization in a Wheat – Maize – Soybean Long-Term Rotation through NUE Measurements*.

Sahlemedihin Sertsu. & Taye Bekele. (2000). Procedures for soil and plant analysis. *Technical Paper*, *74*, 110.

Sarwar G., Schmeisky H., Hussain N., Muhammad S., Ibrahim M., & Safdar E. (2009). Improvement of Soil Physical and Chemical Rice-Wheat Cropping System. *Pakistan Journal of Botany*, *41*(5), 2403–2410.

Sawyer B. (2013). *Agricultural production in Ethiopia : Results of the 2012 ATA Baseline Survey Nicholas Minot*. *April*.

Sidahmed I., Tahir A., Mohamed E., Elbashier E., Ahmed M., Ibrahim S., Sefyan A., Saad I. & Abdalla O. S. (2020). *Genetic Gain in Wheat Grain Yield and Nitrogen Use Efficiency at Different Nitrogen Levels in an Irrigated Hot Environment*. *2020*.

Simachew Bantigegn Wassie. (2020). Natural resource degradation tendencies in Ethiopia : a review. *Environmental Systems Research*, 1–29.

Singh M. (2015). *Effect of organic and chemical fertilizers on growth of wheat and soil properties (Triticum aestivum) Submitted to the*. 1–58.

Singh R., Sharma R. R., Kumar S., Gupta R. K. & Patil R. T. (2008). Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (Fragaria x ananassa Duch.). *Bioresource Technology*, *99*(17), 8507–8511.

Talgre L., Lauringson E., Roostalu H., Astover A., & Makke A. (2009). Green manure as a nutrient source for succeeding crops. *Plant, Soil and Environment*, *58*(6), 275–281.

Taye Belachew. & Yifru Abera. (2011). *Effect of green manuring in combination with nitrogen on soil fertility and yield of bread wheat (Triticum aestivum) under double cropping system of Sinana-dinsho , Southeast Ethiopia*. *1*(1), 1–11.

Tesfaye Burju. (2018). *Review on : The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility*. *5*, 1–11.

Tesfu Mengistu., Heluf Gebrekidan., Kibebew Kibret., & Kebede Woldetsadik. (2017). The integrated use of excreta-based vermicompost and inorganic NP fertilizer on tomato (*Solanum lycopersicum* L .) fruit yield , quality and soil fertility. *International Journal of Recycling of Organic Waste in Agriculture*, *6*(1), 63–77.

Thalkar M. G. & Patil P. K. (2019). *Effect of Organic* and *Inorganic Fertilizers on Yield of Wheat Crop of Triticum Aestivum L* . *19*(1), 122–124.

Tilahun Amede., Gizachew Legesse., Getachew Agegnehu., Tadese Gashaw., Tulu Degefu., Gizaw Desta.,Kindu Mekonnen, K., Schulz, S., & Thorne, P. (2021). Short term fallow and partitioning effects of green manures on wheat systems in East African highlands. *Field*

Tolera Emamu., & Tesfaye Wakgari. (2021). *The Effect of Application of Vermicompost and NPS Fertilizer on Selected Soil Properties and Yield of Maize (Zea May L.) at Toke Kutaye , Ethiopia*. *7*(5), 247–257.

Tsegaye Bekele. (2019). Effect of Land Use and Land Cover Changes on Soil Erosion in Ethiopia. *International Journal of Agricultural Science and Food Technology*, *5*, 026–034.

Valeem E. E., Ibrahim M., & Al E. T. (2008). *Response of Wheat Growth and Yield to Various Levels of Compost and Organic Manure*. *40*(5), 2135–2141.

Walia M. K., Walia S. & Dhaliwal S. (2010). Long-term effect of integrated nutrient management of properties of typic ustochrept after 23 cycles of an irrigated rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) system. *Journal of Sustainable Agriculture*, *34*(7), 724–743.

Wassie Haile. (2012). Appraisal of Erythrina bruci as a source for soil nutrition on nitisols of south Ethiopia. *International Journal of Agriculture and Biology*, *14*(3), 371–376.

Wasson A. P., Richards R. A., Chatrath R., Misra S. C., Prasad S. V. S., Rebetzke G. J. & Kirkegaard J. A. (2012). *Traits and selection strategies to improve root systems and water* *uptake in water-limited wheat crops*. *63*(9), 3485–3498.

Witte C. (2011). Plant Science Urea metabolism in plants. *Plant Science*, *180*(3), 431–438.

Workineh Ejigu., Yihenew G. Selassie., Elyas Eyasu. & Eric S. (2022). Effect of integrated fertilizer application on soil properties and tef (Eragrostis tef [Zucc] Trotter) yield on Vertisols of Northwestern Ethiopia. *Journal of Plant Nutrition*, *45*(5), 761–774.

Xiao Z., Gu H., Wu H., Jing W., Zhu K., Zhang W., Gu J., Liu L., Qian X., Wang Z., Yang J., & Zhang H. (2022). *Effects of Planting Density , Levels , and Forms of Nitrogen Application on the Yield and Nitrogen Utilization of Wheat*.

Yihenew G.Selassie. (2015). *The effects of land use types , management practices and slope classes on selected soil physico-chemical properties in Zikre watershed ,*. 0–6.

Yilkal Tadele. (2015). White Lupin (*Lupinus albus*) grain, a potential source of protein for ruminants. *Research Journal of Agriculture and Environmental Management*, *4*(4), 180–188. http://www.apexjournal.org.

Zhao X., Yuan G., Wang H., Lu D. & Chen X. (2019). *Effects of Full Straw Incorporation on Soil Fertility and Crop Yield in Rice-Wheat Rotation for Silty Clay Loamy Cropland*.

7. APPENDICES

Appendix Table 1. Mean squares of ANOVA for 50% heading date (HD), 90% maturity date (MD), plant height (PH), spike length (SL) and tiller number (TN) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer.

Source of variation	D.F	HD	MD	PH	TN	SL
Replication	2	11.70^{**}	3.04^{ns}	36.52^{ns}	0.07^{ns}	0.14^{ns}
LGM	2	136.92^{**}	10.45^{ns}	934.38^{**}	8.38^{**}	5.05^{**}
VC	2	230.70^{**}	51.34^{**}	2528.32^{**}	73.33^{**}	71.38^{**}
RCF	2	54.92^{**}	3.04^{ns}	955.61^{**}	4.94^{**}	11.04^{**}
LGM*VC*RCF	8	221.11^{**}	25.96^{**}	196.71^{*}	1.59^{**}	1.24^{**}
Error	16	1.64	3.64	50.96	0.20	0.15
CV		2.01	1.85	11.20	13.82	5.44

Where, D.F = degrees of freedom, ANOVA = Analysis of variance; CV = coefficient of variation, HD = heading date, SL = spike length, TN = tiller number, PH = plant height, MD = maturity date, ns, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.

Appendix Table 2. Mean squares of ANOVA for thousand seed weight (TSW), number of grains (NG), and grain yield (GY), straw yield (SY), biomass yield (BY) and harvest index (HI) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer.

Source of variation	D.F	TSW	NG	GY	SY	BY	HI
Replication	2	10.29^{ns}	75.53^{*}	479104.93^{*}	343527.16^{ns}	1453871.60^{ns}	38.95^{**}
LGM	2	17.85^{*}	197.15^{**}	2287149.38^{**}	2819297.53^{**}	10598393.83^{**}	59.26^{**}
VC	2	96.48^{**}	757.48^{**}	4926004.93^{**}	6161593.83^{**}	23293779.01^{**}	155.68^{**}
RCF	2	104.09^{**}	275.27^{**}	2834097.53^{**}	2988275.31^{**}	11806927.16^{**}	127.89^{**}
LGM*VC*RCF	8	27.38^{**}	73.81^{**}	885526.23^{**}	907629.01^{**}	3699101.23^{**}	25.33^{**}
Error	16	5.15	14.02	77907.25	109202.62	431827.6	2.77
CV		6.80	12.03	14.74	8.43	11.29	5.27

Where, D.F = degrees of freedom, ANOVA =Analysis of variance, CV = coefficient of variation, TSW= thousand seed weight, NG= number of grains, GY= grain yield, SY= straw yield, BY= biomass yield, HI= harvest index, ns, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.

Appendix Table 3. Mean squares of ANOVA (main and interaction) effects for days to 50% heading (HD), days to 90% maturity (MD), plant height (PH), tiller number (TN), spike length (SL) and thousand grain weight (TSW) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer.

Source	DF	HD	MD	PH	TN	SL	TSW
CF	2	54.92^{**}	3.04^{ns}	955.6^{**}	4.94^{**}	11^{**}	104^{**}
GM	2	136.92^{**}	10.45^{ns}	934.3^{**}	8.38^{**}	5^{**}	17.8^{ns}
Rep	2	11.7^{*}	3.04^{ns}	36.5^{ns}	0.07^{ns}	0.1^{ns}	10.2^{ns}
VC	2	230.7^{**}	51.34^{**}	2528.3^{**}	73.33^{**}	71^{**}	96.4^{**}
GM*CF	4	14.46^{**}	5.60^{ns}	230.7^{*}	2.12^{**}	0.3^{ns}	0.03^{ns}
VC*CF	4	35.9^{**}	7.43^{ns}	138.8^{ns}	0.05^{ns}	1.2^{**}	18.2^{*}
GM*VC	4	12.57^{**}	13.01^{*}	116.1^{ns}	2.05^{ns}	1.2^{**}	5.1^{ns}
GM*VC*CF	8	27.63^{**}	25.96^{**}	196.7^{*}	1.59^{**}	1.2^{**}	27.3^{**}
Error	16	1.64	3.64	50.96	0.20	0.15	5.1

Where, D.F = degrees of freedom, ANOVA = Analysis of variance; ns, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.

Appendix Table 4. Mean squares of ANOVA (main and interaction) effects for number of grains (NG), grain yield (GY), straw yield (SY), biomass yield (BY) and harvest index (HI) of wheat as affected by lupine green manure, vermicompost and recommended chemical fertilizer.

Source	DF	NG	GY	SY	BY	HI
CF	2	275.2^{**}	2834097.5^{**}	2988275.3^{**}	11806927.1^{**}	127.8^{**}
GM	2	197.1^{**}	2287149.3^{**}	2819297.5^{**}	10598393.8^{**}	59.2^{**}
Rep	2	75.5^{*}	479104.9^{*}	343527.1^{ns}	1453871.6^{ns}	38.9^{**}
VC	2	757.4^{**}	4926004.9^{**}	6161593.8^{**}	23293779^{**}	155.6^{**}
GM*CF	4	48.9^{*}	406549.3^{**}	228467.9^{ns}	995888.2^{ns}	26.3^{**}
VC*CF	4	129^{**}	465949.3^{**}	570586.4^{**}	2245240^{**}	8.5^{*}
GM*VC	4	147.8^{**}	532367.9^{**}	845214.2^{**}	3027579^{**}	21.8^{**}
GM*VC*CF	8	73.8^{**}	885526.2^{**}	907629^{**}	3699101.2^{**}	25.3^{**}
Error	16	14	77907.25	109202.6	431827.6	2.7

Where, D.F = degrees of freedom, ANOVA = Analysis of variance; ns, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.

Appendix Table 5. Mean squares of ANOVA for physicochemical properties of soil as affected by lupine green manure, vermicompost and recommended chemical fertilizer

Source of variation	D.F	BD	TP	pH	OC	TN	CEC	A.P	A.K
Replication	2	0. 003^{ns}	0.0007^{ns}	0.023 ^{ns}	0.006^{ns}	0.002**	0.46*	0.002**	0.009**
LGM	2	0.052**	0.010**	0.269**	10.03**	0.0002**	19.12**	17.24**	0.010**
VC	2	0.026**	0.009**	0.605**	2.37**	0.001**	9.46**	6.004**	0.008**
RCF	2	0.013**	0.001**	0.0148^{ns}	9.73**	0.0018**	119.71**	228.64**	0.008**
LGM*VC*RCF	8	0.016**	0.0037**	0.067**	0.17**	0.0007**	63.96**	21.95**	0.007**
Error	16	0.002	0.006	0.0108	0.012	0.0002	0.123	0.0001	0.0029
CV		0.12	1.41	2.07	14.34	2.15	1.52	0.07	3.27

Where, D.F = degrees of freedom, ANOVA =Analysis of variance, CV = coefficient of variation, BD = bulk density, TP; total porosity, PH = power of hydrogen, OC = organic carbon, TN = total nitrogen, CEC = cation exchange capacity, A.P= available phosphorus, A.K = available potassium, ns, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.

Appendix table 6. Treatment combination and arrangement

Treatment No	Treatment designation	LGM (t/ha)	VC (t/ha)	RCF (kg/ha) NPSB/Urea
1	GM0VC0CF0	0	0	0
2	GM0VC0CF1	0	0	50%
3	GM0VC0CF2	0	0	100%
4	GM0VC1CF0	0	2.5	0
5	GM0VC1CF1	0	2.5	50%
6	GM0VC1CF3	0	2.5	100%
7	GM0VC2CF0	0	5	0
8	GM0VC2CF1	0	5	50%
9	GM0VC2CF2	0	5	100%
10	GM1VC0CF0	2.5	0	0
11	GM1VC0CF1	2.5	0	50%
12	GM1VC0CF2	2.5	0	100%
13	GM1VC1CF0	2.5	2.5	0
14	GM1VC1CF1	2.5	2.5	50%
15	GM1VC1CF2	2.5	2.5	100%
16	GM1VC2CF0	2.5	5	0
17	GM1VC2CF1	2.5	5	50%
18	GM1VC2CF2	2.5	5	100%
19	GM2VC0CF0	5	0	0
20	GM2VC0CF1	5	0	50%
21	GM2VC0CF2	5	0	100%
22	GM2VC1CF0	5	2.5	0
23	GM2VC1CF1	5	2.5	50%
24	GM2VC1CF2	5	2.5	100%
25	GM2VC2CF0	5	5	0
26	GM2VC2CF1	5	5	50%
27	GM2VC2CF2	5	5	100%

GM = Lupine green manure, VC = Vermicompost, CF = Recommended chemical fertilizer

AUTHOR'S BIOGRAPHY

The author, Tiruneh Aschalew, was born on 5 February 1998 in Mecha District, North Gojam Zone, Amhara Regional State, Ethiopia. He accomplished his elementary education on 2013 at Ding primary schools. Then he completed his secondary and preparatory education on 2017 at Merawi secondary and preparatory school. After successful completion of his secondary and preparatory education, he joined Kebri Dehar University College of Dry Land Agriculture and graduated with a Bachelor of Science degree in Plant Science in January 2021. After graduating with BSc. degree, he was employed by Kebri Dehar University as a Graduate assistant lecturer level and he is an employee of Kebri Dehar University still now. He joined the school of graduate studies of Bahir Dar University in October 2022 to pursue his Master of Science degree in Agronomy.