EVALUATION OF DIFFERENT ORGANIC FERTILIZERS ON GROWTH AND YIELD OF BREAD WHEAT (*Triticum aestivum L.*) AT KULUMSA, CENTRAL ETHIOPIA

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Evaluation of Different Organic Fertilizers on Growth and Yield of Bread Wheat (*Triticum aestivum L.*) at Kulumsa, Central Ethiopia

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APPROVAL SHEET

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DEDICATION

This thesis manuscript is dedicated to my Father, Mr. Zewde Haile and my mother, Mrs. Elfinesh Hunde, whom paved the way towards for my education and nursing me with peace and love, and whom has been reasons for my success next to God.

STATEMENT OF THE AUTHOR

First of all, I certify that this thesis is my original work and that all references to materials used in its creation have been properly cited. This thesis is deposited at the University Library and will be accessible to borrowers in accordance with the library's policies. It was submitted to partially fulfill the requirements for an MSc degree at Dilla University. I hereby sincerely declare that this thesis is not being submitted for credit towards any degree, diploma, or certificate at any other university.

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BIOGRAPHICAL SKETCH

The author was born on January 31, 1992, in Killisa Village, which is located in the Oromiya National Regional State, Ethiopia. He attended his primary education at Kuyera Elementary School from 1999 to 2007, junior education at Bora Junior Secondary School in 2010, and senior education at Asella and Adama (Hawas) Secondary School from 2011 to 2013. In 2014, he joined Debre Tabor University and graduated with BSc degree in Plant Science in 2016. Soon after graduation, he was employed by the Ethiopian Biodiversity Institute, and served as a researcher for three years. Then in 2021, he joined the School of Graduate Studies at Dilla University to pursue his M.Sc study in Agronomy.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
Av.P	Available Phosphorus
BD	Bulk Density
BY	Biomass Yield
CE	Cation Exchange Capacity
CSA	Central Statistical Authority
CV	Coefficient of Variation
CIMMYT	International Maize and Wheat Improvement Center
FAO	Food and Agriculture Organization of the United Nation
GY	Grain Yield
HI	Harvest Index
LSD	Least Significant Difference
masl	Meters Above Sea Level
NDVI	Normalized difference vegetation index
NSP	Number of Kernels Per Spike
NT	Number of Tillers
OC	Organic Carbon
OM	Organic Matter
PEN	Physiological Efficiency of N
PEP	Physiological Efficiency of P
ppm	Parts per million (mg/kg)
PH	Plant Height
SL	Spike Length
SN	Number of Spike
TN	Total Nitrogen
TSP	Triple super phosphate
TSW	Total seed weight

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EVALUATION OF DIFFERENT ORGANIC FERTILIZERS ON GROWTH AND YIELD OFBREAD WHEAT (*Triticum aestivum L.*) AT KULUMSA, CENTRAL ETHIOPIA

ABSTRACT

The field experiment was conducted at Kulumsa Agriculture Research station, Kulumsa, Central Ethiopia, to evaluate the effects of commercial organic fertilizers and inorganic N nutrient in wheat cropping systems. The field experiment was conducted a factorial arrangement of two commercial organic fertilizers (Eco-Green, Mela-Organics) and vermicompost, each was tested with four supplementation levels of N (0, 50, 75 and 100%) of the recommended dose of fertilizer in the study area. arranged in a factorial combination laid out in a randomized complete block design (RCBD) with three replications. The results indicated that the highest grain yield (5.23 t/ha) was obtained from MO+100%N, which was statistically similar to that obtained under the VC+100%N (5.00 t/ha), followed by EG+100%N (4.22t/ha). The SPAD scores of 44.6 and 46.2 from VC+100%N and MO+100%N, respectively, recorded where the highest grain and biological yields produced treatments. Compared with chemical fertilizer alone, the application of Eco-Green or Mela-Organics in combination with N fertilizer at higher doses (75% or 100%) significantly increased wheat grain yield by 5-19%, increased biomass yield by 2.6-13.5%. However, sole application of either Eco-Green or Mela-Organics (0%N) and with 50% N level, resulted in grain and biomass yields lower than the conventional practice (CF), with the grain yield reductions ranging from -2.4% to -27.7% and biomass yield reductions from -9.3% to -20.9%. Similarly, neither the type of organic fertilizers nor the level of inorganic fertilizer supplementation had a significant impact on soil properties except for soil OC. Considering the economic benefit, farmers of the area might be advised to use these commercial liquid fertilizers: Eco-Green in combination with 75%N RDF to achieve comparable wheat yields while reducing chemical fertilizer costs by 25%, whereas Mela-Organics with 100%N. However, since the experiment was done once and only at one location, the research should be repeated involving several other varieties at different locations and over various seasons to reach a conclusive recommendation.

Keywords: Bread wheat, Commercial organic fertilizers, Eco-Green, Mela-Organic**,** Vermicompost

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1 INTRODUCTION

1.1 Background of the Study

Bread wheat (*Triticum aestivum L.*), also known as common wheat, is a prominent cereal crop that significantly contributes to the growth of the agricultural industry in general and the food security status of farm households in particular (Anteneh and Asrat, 2020). Ethiopia has been the largest wheat producer in sub-Saharan Africa since 2005 (Hodson et al., 2020). Wheat ranked 4th major crop next to teff, maize, and sorghum in area coverage (1.8 M ha), and total production (4.3 M tons) during the 2020/21 season (CSA, 2021). Wheat production revolutionized Ethiopia in the last two years 2023), particularly due to the government's push for wheat self-sufficiency and exports. Yet the country remains a net importer as the production is insufficient to meet the rapidly growing domestic needs. Wheat is sometimes seen as being significant simply as a source of energy (carbohydrate). However, it also contains large levels of other essential nutrients, such as proteins, fiber, and other ingredients, such as lipids, vitamins, minerals, and phytochemicals, which may support a healthy diet (Shewry and Hey, 2015).

Wheat production in Ethiopia is mainly rain-fed with low average yield of 2.54 t ha^{-1}, (Nigus et al., 2022). This is far below from research stations. Low productivity is constrained by several biotic (i.e., host plant resistance, parasitism, etc.) and abiotic (erratic rainfall, depletion of soil fertility) factors (Georgis, 2015; Mann and Warner, 2015) and other socio-economic challenges. Among the biotic factors: diseases like wheat rust (Nigus et al., 2022). One of the main causes of Ethiopia's low wheat productivity is declining soil fertility caused primarily by prolonged farming with limited sources of fertilizer applications and land degradation (Hailu et al., 2015). According to the past production trend, increasing the area of cultivated land is the best way to raise the output of most cereal crops, including wheat (Taffesse et al., 2017), but currently, as the available arable land is not enough for population growth, improvements are needed to produce high-quality and large quantities of products from small arable land. Poor quality of arable soils, non-return of nutrients taken out of the soil, especially micronutrients, and malnutrition in human societies are all caused by inadequate soils. Healthy soil and healthy plants always go hand in hand. Creating a healthy plant is advantageous to human health as well (Amjadian et al., 2021).

In an effort to overcome the declining soil fertility and chemical fertilizer effects, an agricultural management technique known as organic production keeps the soil, plants, and ecosystem in

their natural state. It is based on the use of organic fertilizers and non-synthetic insecticides that are found in nature (Gadisa & Mekonnen, 2021). Farming organically has many advantages over farming inorganically, including being more profitable. Organic farming improves soil fertility, prevents pollution, and manages pests and diseases without endangering the environment, resulting in crops that are more nutritious and more marketable (Yatoo et al., 2021). Chemical fertilization is one method that could be used to increase crop productivity, but because of the harm that unwise chemical use in agricultural systems caused to the soil, food, environment, and human health, chemical fertilization is also becoming more expensive in the twenty-first century.

1.2 Statement of the Problem

In Arsi zone, wheat is one of the major and widely cultivated cereal crops. It's part of the larger Arsi-Bale wheat belt, which stretches across the southeastern part of the country. In 2020/21 harvested volume of wheat production reported for the Oromia, Amhara, and SNNP regions, has increased by about 2.19%, 1.99%, and 1.11% above the regions' post-harvest estimates from the previous year 2019/20 (CSA, 2021). Despite this, wheat-producing smallholder farmers are struggling with high cost of inorganic fertilizers, which is further exacerbated by nutrient-mining practices in cereal monoculture system. On top of that, due to cereal monoculture nutrient-mining practices and leaching losses, the soils of the Arsi/Bale highlands are primarily deficient in organic matter, nitrogen, and phosphorus, which attributed to low crop yield and quality (Abegeja et al., 2022). Recent studies (Erkossa et al., 2022; Muluneh et al., 2022) stressed the necessity of raising awareness of smallholder farmers toward the use of organic fertilizer technologies. Liquid organic fertilizers produced from agricultural wastes are becoming increasingly popular alternative strategy for crop production (Alemayehu et al., 2022; Phibunwatthanawong & Riddech, 2019).

So far, the use of liquid organic fertilizers in Ethiopia is at an infant stage, and very few have emerged as a commercial production. Eco-Green and Mela-Organics are among the commercial liquid organic fertilizer products available in local markets at Adama and the surroundings, produced by a private-based company. Now these companies are expanding their products customer base mainly for vegetable, flower, and fruit commercial farms. A recent research on malt barley at Bale highlands showed that Eco-Green would be promising when combined with the recommended dose of synthetic fertilizers (Abegeja et al., 2022). On the other hand, Mela-

Organics has emerged currently, which is prepared from water hyacinth *(Enboch)* and other green plants by Mela-Organics Liquid Fertilizer PLC at Adama, Ethiopia.

These commercial organic products, such as Mela-Organics and Eco-Green have already been in use, however, very little is known about the products, and no data were found comparing the performance of this commercial product (Mela-Organics) with those of farm-made fertilizers (vermicompost) that are commonly practiced. So far, there has not been any scientific effort to elucidate the effect of Mela-Organics on the yield of wheat in the proposed area. Since the composition of organic fertilizers, particularly the C/N ratio, as well as their level of decomposition, is key factors that affect their performance and hence have different effects on rhizosphere soil biochemistry and nutrient availability. Therefore, there is an imperative need to evaluate the commercial product as well as locally available organic fertilizer sources for their chemical fertilizer-replacing value, particularly for cereals, for which the present study was proposed.

1.3 Objective of the Study

1.3.1 General Objective

The overall objective of this study was to evaluate the effect of different organic fertilizer sources (Mela-Organics and Eco-Green as commercial and Vermicompost as farm-made) and supplementation dose on the yield of wheat under vertosols of Kulumsa area.

1.3.2 Specific Objectives

- ✓ To evaluate the effect of different organic fertilizers, chemical fertilizer, and their combinations on yield, and yield-related attributes of bread wheat under rain-fed condition.
- ✓ To evaluate the effect of organic fertilizers applied with or without chemical fertilizers on selected physicochemical properties of soil at the study area.
- ✓ To investigate the economic feasibility of different organic fertilizer.

2 LITERATURE REVIEW

2.1 Origin and Domestication of Wheat

Inter-Asiatic center includes the interior mountains of Asia Minor, Iran, Syria, Palestine, Trans-Jordania, Afghanistan, inner Asia, and northwestern India. The native crops include the origin of wheat, rye, and fruit trees. An unbroken line from present-day cultivated crops can be traced back to wild forms. About 15% of the important cultivated plants for the world originated here (Hummer & Hancock, 2015). One could say that bread wheat was formed from its diploid and tetraploid progenitors through a cycle of "diverge-and-merge" speciation events (Levy, 2022). Durum wheat did not develop exclusively in West Asia. According to archaeological evidence, naked emmer arrived in Ethiopia around 5,000 years ago (Tidiane et al., 2019) from National Research Council. 1996. *Lost Crops of Africa: Volume I: Grains*. Today, emmer wheat, also known as aja in Ethiopia, accounts for approximately 7% of total wheat production (Tidiane et al., 2019). According to recent molecular data (Kabbaj et al., 2017), Ethiopian farmers replicated what had previously been accomplished in West Asia by deriving durum wheat anew through further domestication of emmer. This new origin of the same crop gave rise to a subspecies known as *T. turgidum ssp. aethiopicum or abyssinicum* (Tidiane et al., 2019).

2.2 Constraints of wheat production in Ethiopia

Ethiopia is Africa's second-largest wheat producer next to Egypt (Shikur, 2022). But yields remain significantly lower than the global average due to a variety of production constraints among these, wheat rust diseases, the high costs of fertilizers, shortage of improved seeds and high seed prices predominantly mentioned constraints (Netsanet et al., 2017). This survey was conducted on three consecutive zones: Arsi, Bale, and West Shewa. The findings revealed that almost all sampled farmers (96%) in the three zones regarded wheat rusts as the most significant production constraint. High fertilizer prices were the second most important constraint in the surveyed zones (93%).

Another research was done in the highlands of Eastern Ethiopia. As the result reveals Farmers identified diseases (primarily rusts), a lack of arable land, a lack of improved varieties, and the high cost of inorganic fertilizers as the major wheat production constraints (Nigus et al., 2022).

Now a day the cost of inorganic fertilizer and its hazard on the environment becomes a series issue.

In Ethiopia, farmers have been using only urea and di-ammonium phosphate for more than 15 years. This leads for limitation of nutrients other than nitrogen and phosphorus (Hailu et al., 2015). Most soils in the tropical region including Ethiopia are highly weathered and infertile due to lower organic matter content caused by inadequate fertilizer use, complete removal of crop residues, continuous cropping systems, climate and soil types, lack of proper cropping systems and soil erosion and continuous cultivation (Aleminew & Alemayehu, 2020). In addition to soil fertility degradation, biotic and abiotic factors are cause for reduction of wheat production, Rusts (Puccinia spp.), Helminthosporium, septoria (Septoria tritici), tan spot (Pyrenophora tritici repentis), fusarium (Fusarium spp.), as well as smuts, take-all, and root rots are important wheat diseases from biotic and from abiotic soil acidity, erosion, poor soil fertility, water-logging, and pre-harvest sprouting. Such constraints are most common in highlands of Ethiopia (Tadesse et al., 2022).

Climate change and rainfall variability is creating a problem with crop production constraints in the rain-fed agricultural production system in the highlands of Ethiopia. Physical properties of the soil coupled with the unfavorable soil-rainfall relationship limit increased crop production on vertisols (Bedane et al., 2022).

2.3 Organic fertilizer as plant nutrient source

Fertilizers made exclusively from natural, plant, or animal-derived basic ingredients are known as organic fertilizers. When soil organisms like helpful bacteria and fungi break down the fertilizer pellets, nutrients in organic fertilizers like nitrogen, phosphorus, and potassium are released. By nourishing the soil, increasing its productivity, and simultaneously preventing it from being eroded away, the organic fertilizers contribute to the soil structure's sophistication (Abegeja et al., 2022). By researching its efficient management, the potential of these biomass waste sources as organic fertilizers has been assessed. Due to a lack of space, a large portion of these biomass wastes are incinerated or dumped in landfills. If properly managed, the valuable nutrients found in the biomass wastes can be put to good use. They can be processed to remove pathogens and then used to fertilize soil because they have high organic matter content. Organic

matter must mineralize over a longer period of time than chemical fertilizers do. This time for mineralization will be influenced by the soil's characteristics, moisture content, and temperature (Tejada et al., 2014).

2.3.1 Vermicompost as nutrient source

Vermicompost is a type of Organic Fertilizer. It is derived from composting organic waste by using various species of earthworms. Vermicomposting is the term for composting in which the earthworms in the compost pile aid in the process. Earthworms and other microorganisms transform organic materials through a non-thermophilic process that produces rich soil fertilizers with significantly higher microbial activity and nutrient availability, as stated (Chala & Gurmu, 2017). Vermicomposting fertilizer is a well-known method to improve the health of damaged soils (Hafez et al., 2020). Productive soils can be degraded for different reasons, possibly through repeated use of chemical fertilizers (Abebe et al., 2022). However, it can be amended through organic matter. In addition to maintaining yield quantity and quality, organic fertilizers have positive effects on soil structure and nutrient availability. They can also be less expensive than synthetic fertilizers. Utilizing organic ingredients that are environmentally and human health-friendly can improve fertility (Ayyobi et al., 2013). According to research carried out by Fikru and Fikreyohannes (2019) on garlic crop declared that, the application of 2.5 t ha^{-1} vermicompost has the highest marginal rate of return (204.36%), while 7.5 t ha^{-1} has the lowest marginal rate of return (168.87%).Therefore, it is reasonable to assume that, over a short period of time, the use of high doses of VC fertilizers can yield a higher economic return than the administration of low doses. However, the experiment's findings showed that despite greatly increasing in response to the application of VC fertilizer, growth, quality, and economic return did not achieve their optimal levels. Hence, if the rates of the VC fertilizers had been raised, it is possible that much higher growth characteristics, quality, and economic return of the garlic may have been acquired. The maximum growth, quality, and economic return of garlic were therefore achieved with the application of 7.5 t VC ha^{-1} fertilizer as it delivered the highest net benefit cost, according to the study's findings.

2.3.2 Liquid fertilizers as nutrient source

Liquid organic fertilizers play a great role in agriculture by nourishing the soil, increasing its productivity, and simultaneously preventing it from being eroded away. As researches carried

out on citrus shows, the source of liquid organic fertilizers influenced nitrogen partitioning among soil N pools as well. When compared to vegetal-based organic fertilizer, animal-based fertilizer resulted in a higher concentration of N present in the ammonium fraction on the July sampling event due to a greater supply of ammonium-N form. Because of the nitrification of ammonium-N given, the nitrate-N content in plants supplied with vegetal-based fertilizer was higher at the conclusion of the cycle (Legaz and Qui, 2016). According to the final conclusion of this finding, Liquid organic fertilizers can successfully replace mineral fertilizers in citrus tree nutrition management under drip irrigation because they increase soil chemical fertility, reduce excessive nitrate-N concentrations, boost plant growth, and C fixation in the plant. Furthermore, these fertilizers would allow not only for a reduction in chemical consumption, but also for the re-use of agricultural residues and animal dung, providing them great value. Most people believe that organic fertilizers release nutrients slowly and are rich in trace elements. Compared to chemical fertilizers, they are safer substitutes (Shaji et al., 2021). According to research by (Abegeja et al., 2022) on Eco-Green organic liquid fertilizer rates on malt barley, the outcome of their findings reveals that maximum mean grain yield (4220 kg ha^{-1}) and total biomass yield (7055 kg ha^{-1}) were recorded for 80 l ha^{-1} Eco-Green organic liquid fertilizer.

2.3.3 Combined use of fertilizer sources for better performance

Different authors (Dalvi et al., 2020; Gadisa & Mekonnen, 2021) mentions that appropriate nutrient management techniques should be used in conjunction with organic resources technology to demonstrate the improvement in agriculture. Organic and inorganic fertilizers can be used together to boost economic yields and Soil quality (Ejigu et al., 2021; Li et al., 2022; Yang et al., 2024). Total N stocks were greatly enhanced when chemical fertilizer and manure (NPKM and NPKM+) were applied together as opposed to NPK (by an average of 26.2% and 40.4%, respectively) (Gai et al., 2018). This finding declares that when organic and chemical fertilizers were applied together, wheat, maize, and rice yields improved by an average increment rate of 29% compared to when organic fertilizer was used alone and 8% compared to when chemical fertilizer was used alone.

Another research also carried out on wheat and urad (*Faciolus mungo)* plant revealed a positive effect of combining complementary resources in a way that minimizes the usage of artificial fertilizer and has a long-lasting effect (Bhati et al., 2017).The results of this investigation showed

that using vermicompost increased seed germination rates, allowing for more seeds to germinate and grow into plants. It also increased plant length, which provided more surface area for the development of leaves, flowers, and pods, as well as chlorophyll levels. The best results come from increasing the combined use of bio fertilizer; organic fertilizers by themselves are insufficient to support the necessary crop production (Han et al., 2016). The greatest strategy for obtaining increased crop yields and economic viability is the integrated application of chemical fertilizer and locally accessible soil fertilizers (Chala, 2019). The finding also addresses that potential synergies can be achieved by combining technical solutions with farmers' knowledge and training farmers and development agents on integrated soil fertility management approaches in order to address soil fertility issues.

3 MATERIALS AND METHODS

3.1 Description of the Study Area

This experiment was conducted during the main cropping season of 2023/24 at Kulumsa Agricultural Research Center (KARC). The Research Center is located in Arsi Administrative Zone, Oromia National Regional State, at about 170 km south of Addis Ababa. Geographically, Kulumsa is situated at 8º00' to 8º 02' N latitude and from 39º 07' to 39º 10' E longitude, at an altitude of 2200 meters above sea level. The area is known as one of the major wheat-producing regions in the country (Belete and Shimelis, 2022). Kulumsa is the major wheat production area in Ethiopia, particularly within the Arsi/Bale wheat belt. The KARC Research Center holds a national mandate for wheat crop research and serves as one of the Wheat Centers of Excellence for East Africa.

Kulumsa and its surroundings receive a mean annual rainfall of 840 mm; it has a unimodal rainfall pattern. The Length of growing period is (LGP) 120- 135 days. The mean maximum and minimum temperatures of the area are 22°C and 10.5°C, respectively (KARC metrological station, 2017). The dominant soil type of the area is vertisol, characterized by a clay loam soil texture (KARC, 2017).

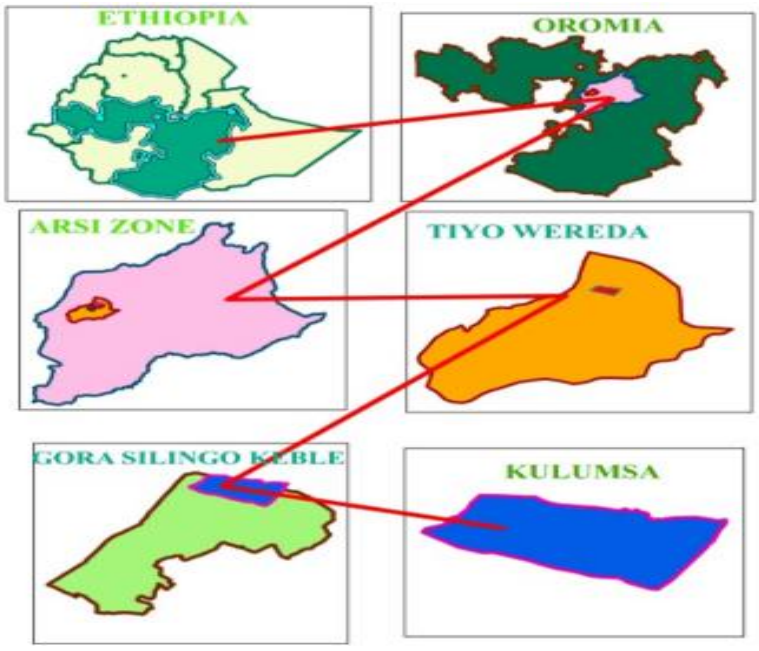


Figure 1: Location map of the study area (**Source:** (Dobocha Goda, 2022).

In Arsi zone Tiyo wereda land uses for different purposes; The Katar, Kulumsa, Gonde, Dosha, and Walkesa rivers are among them rivers found in Tiyo. According to a survey of the land in this woreda, 40% is arable or cultivable (32% is planted with cereals), 23.1% is pasture, 8.7% is forest, and the remaining 28.2% is swampy, mountainous, or otherwise unusable. The Woreda was a wheat belt in the Arsi zone. Wheat, malt, and food barley, faba bean, and field pea are the most common crops cultivated in the area (Guye & Uppal, 2018).

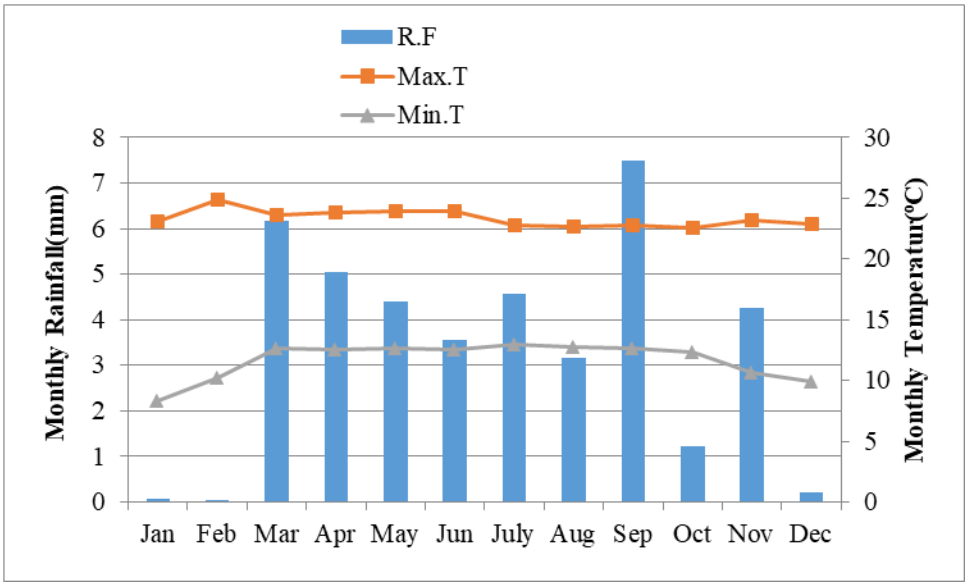


Figure 2: Rainfall and Temperature Distribution (2023) at the study area

3.2 Experimental Materials

A bread wheat variety (*Boru*), which was released in 2020 by KARC for medium to highland wheat-growing agro ecology, was used as a test crop. *Boru* is a well-adapted variety in the range of altitude 2050-2780 masl with a yield of 4.0-6.0 t/ha. The variety showed relative resistance to stem, yellow, and leaf rust as compared to other wheat varieties under production at highland wheat-growing agro-ecologies, and is known for its relatively higher protein content (14.37%) (Alemu et al., 2022).

In this experiment, Mela-Organics and Eco-Green were used as sources of commercial-based organic fertilizers, whereas vermicompost obtained from KARC was used as a local farm-made organic source counterpart for comparison of both commercial products. Mela-Organics is a liquid form of fertilizer, produced by a private company (Mela Organics PLC. Adama), which is

a recently introduced fertilizer product made from *water hyacinth (Enboch)* and other green plants.

3.3 Treatments and Experimental Design

The experiment involved a factorial combination of three types of organic fertilizers (Eco-Green, Mela-Organics, and vermicompost) and four N supplementation levels (0%, 50%, 75%, and 100%) based on the recommended N fertilizer rate commonly practiced in the study area. In addition, absolute control and conventional fertilizer practice treatments were included for comparison and for nutrient use efficiency determination. The experiment was arranged in a randomized complete block design (RCBD) with three replications. Treatments and their combinations were randomly assigned to experimental units within each block. Details of the treatment structure are presented in Table 1.

Table 1: Treatments and their combinations with N fertilizer doses used in the study.

Organic fertilizer types	**N fertilizer (% RDF)**			
	0	50	75	100
Mela-Organics (MO)	MON0	MON50	MON75	MON100
Eco-Green (EG)	EGN0	EGN50	EGN75	EGN100
Vermicompost (VC)	VCN0	VCN50	VCN75	VCN100

Mela-Organics and Eco-Green = which are commercial liquid organic fertilizers; the application rate of both is 40L/ha. RDF=recommended dose of fertilizer which is commonly practiced in the study area (i.e., Conventional practice): 0, 50, 75 and 100 refers to full dose and half dose of the recommendation, respectively.

3.4 Experimental Procedures and Crop Management

The experimental field was prepared using a tractor and was ploughed twice (disked and harrowed). After leveling, the layout was designed to account for the slope and soil fertility variations. The field selected was based on land under wheat cultivation in the preceding year to avoid residual effects of legumes. The plot size of 3 m x 4 m (12 m^2), which accommodates 20 rows per plot with 20 cm row spacing. The space between plots and blocks was 0.4 m and 1 m, respectively. Bread wheat (variety Boru) was sown at a seed rate of 150 kg/ha with a suggested row spacing of 20 cm.

The two commercial liquid organic fertilizers (hereafter referred to as Eco-Green and Mela-Organics) tested in this study were purchased from a local agrochemical input vendor. Detailed information on the chemical characteristics, nutrient levels of both organic products, and their producing companies is provided in Appendix Table 1. Both commercial fertilizers resulted in similar soil N and P increments despite marked differences in their N and P contents. The Mela-Organics solution was prepared according to the producer's procedure: i.e., 1 L Mela-organics dissolved in 40 L of water. The prepared quantity of solution was applied manually in 2 splits: at 30 days after sowing and 3 weeks after the first spray by manual hand sprayer (knapsack). Similarly, Eco-Green was determined according to the product information, with a mixing ratio of 1:20 Eco-Green to water, and applied similarly. The application rate of Eco-Green and Mela-Organics is 40 L/ha, which is the middle rate suggested by both liquid organic fertilizer producers and research reported by Eshetu et al. (2022).

Vermicompost was obtained from KARC. Its application rate was determined based on its N content and applied a week before sowing, and uniformly spread to the plot area and immediately incorporated into the soil. For the plots receiving inorganic fertilizers, N (urea as a source of N) was applied in two splits (at planting and at 30 days), while full doses of P as TSP and NPS were applied just at planting. Commonly practiced fertilizers for wheat production at Kulumsa are 200 kg urea/ha and 150 kg/ha TSP which corresponds to 92 kg N/ha and 69 kg P/ha, respectively.

Weed control, time and frequency, and all relevant agronomic practices were applied consistently to every plot as per the area recommendation. From twenty rows per plot, 16 inner rows of each plot were considered for the crop-related data collection, leaving the outermost two rows from both sides of the plots to reduce the border effect.

3.5 Data Collection

3.5.1 Crop-related data

For each plot, sixteen inner rows were used as harvestable rows for all crop-related data collection, leaving the outermost two rows on each side to minimize border effects. The measured parameters of wheat crop include plant height, leaf length, leaf width, leaf area, SPAD chlorophyll content, as well as yield and yield components such as the number of tillers per

plant, total tillers per plant, productive tillers per plant, number of grains per spike, thousand-grain weight (g), above-ground dry biomass (t/ha), and grain yield (t/ha). Phenology-related data, including the number of days to 50% emergence, 50% heading, and physiological maturity, were also recorded. Details of the measurements for each parameter are given below.

i. **Crop phenology:** Days to 50% emergence were recorded by counting the number of days from sowing to 50% emergence. Days to 50% heading were determined by counting the number of days taken from the date of 50% emergence to 50% heading. Days to physiological maturity were recorded when 90% of all plants per plot lost chlorophyll and turned yellow. This was determined on a visual basis.

ii. **Plant height (cm):** Plant height was determined from the base to the tip of the spike (awns excluded) of 16 randomly selected plants from the net plot area at the physiological maturity.

iii. **Leaf Area:** Leaf area of flag leaves (cm) was measured from 16 randomly selected plants from the net plot areas. It was calculated as length× maximum width× 0.68.

iv. **Chlorophyll content and** greenness (NDVI): The leaf Chlorophyll content was recorded using SPAD Chlorophyll Meter (Model: SPAD-502 plus). The measurements were made on two fully-expanded leaves per plant at two locations per leaf. The same procedure was repeated for three randomly selected plants in each plot (Reported values represent the mean of twelve measurements per plot). Normalized Difference Vegetative Index (NDVI) value was measured using a Green Seeker Handheld Crop Sensor. Both SPAD and Green Seeker NDVI data were collected at the booting growth stage of wheat, critical period of the beginning of the heading stage.

v. **Number of tillers per plant**: The number of tillers per plant was determined from 16 randomly pre-tagged plants per plot at heading. The number of productive tillers was determined at maturity by counting all spikes producing seeds of 16 plants per net plot.

vi. **Number of grains per spike**: the number of grains per spike was the mean number of grains per spike computed as an average of 16 randomly taken spikes from the central unit area, threshed, and grains were counted using an electronic seed counter.

vii. **Aboveground biomass:** the aboveground dry biomass (t/ha) was measured from plants harvested from the net plot area after sun drying for 4 days and converted into tons per hectare.

viii. **Grain yield**: grain yield (t/ha^{-1}) was taken by harvesting and threshing the seed yield from the entire net plot area, adjusted to 12.5% moisture content and expressed in ton per hectare using the following formula Mulvaney and Devkota,(2020).

$$\text{Grain Yield} = (\text{Harvest yield}) * \frac{[(100\% - \text{Harvest moisture }\%)100\%]}{[100\% - \text{Standard moisture }\%\ 100\%]} \ldots\ldots\ldots (\text{Eq } 1)$$

ix. **Thousand-grain weight (g)**: thousand-grain weight (g) was determined based on the weight of 1000 grains sampled from the grain yield of each treatment by using an electronic seed counter and weighed with an electronic balance.

x. **Harvest index (%)**: The harvest index (HI) was calculated as the ratio of dry seed yield to above-ground dry biomass yield (Regmi et al., 2021), using the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield t ha}^{-1}}{\text{Biological yield t ha}^{-1}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots (\text{Eq } 2)$$

3.5.2 Soil sampling and analysis

Prior to planting, ten subsamples representing the experimental area were collected in a zigzag pattern at a depth of 0–20 cm to create a one kg composite sample. The composite samples were air-dried, ground, and passed through a 2 mm sieve for laboratory analysis of the following soil physicochemical properties. Soil particle size was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was measured in water at a soil-to-water ratio of 1:2.5 (Reeuwijk, 1992). Organic carbon content was analyzed using the volumetric method (Walkley & BlacK, 1934). Total N was analyzed by the micro-Kjeldahl digestion method with sulfuric acid (Jackson, 1958), and Available phosphorus was determined by (Bray & Kurtz, 1945) method.

3.6 Economic Analyses

Partial budget analysis of grain yields was conducted to evaluate the economic feasibility and profitability of each organic application when combined with inorganic N rate, using the CIMMYT procedure (CIMMYT, 1988). The average wheat yield was adjusted downward by 10% to account for the difference between the experimental yield and the expected yield of farmers using the same condition. Gross field return of yield was calculated based on the market price during the crop harvesting season, which was 60 ETB/kg as obtained from local markets. The partial budget analysis, employed considering various parameters: gross field benefit, total variable cost (TVC), net benefit, and marginal rate of return (MRR). A dominance analysis procedure was conducted to identify potentially profitable treatments, which involved ranking the treatments in ascending order based on their TVC, from the lowest to the highest.

3.7 Statistical analyses

Data were subjected to the analysis of variance using the PROC GLM procedure of SAS software (Version 9.3, SAS Institute Inc.), which employs the method of least squares to fit general linear model. The effects of specific factors, namely organic fertilizer type and N fertilization dose, were tested, excluding the control group dataset, and the results were expressed as mean values. To explore significant differences between the means of treatment groups, least significant difference (LSD) test was conducted at a 5% probability level.

Whenever necessary, the percentage changes in different crop parameters from the conventional fertilizer practices was compared as:

Percent change (% increase/decrease) = [(TreatmentX - CF) / CF] ×100

Moreover, correlation analysis was performed through the simple correlation coefficient between soil properties, pH, Total N, Available P and Organic C, crop growth, and yield-related parameters. Linear regressions were performed for individual organic fertilizer types to distinguish the fertilization dose, following the REG procedure of SAS.

4 RESULTS AND DISCUSSION

4.1 Initial Soil Properties of the Experimental Site

The soil analysis results of the experimental site, prior to treatment application, are summarized in Table 2. The surface soil (0-30 cm) had a clay texture with particle distribution of clay (50.83%), silt (32.29%), and sand (16.88 %). The soil pH (H_2O) was 6.01, which indicates a acidic reaction based on the ratings by Hazelton and Murphy (2016). The pH of the experimental soil falls within preferred range (pH 6.0 - 7.0) for optimal nutrient availability and microbial activity (Dewangan et al.(2023).

Soil organic carbon (OC) and total nitrogen (N) content were 1.28% and 0.19%, respectively (Table 2). Both OC and total N values fall within the "low" range according to the ratings by Tekalign (1991). The available P content was 19.35 mg/kg, which can be rated as “high” based on the rating by Tekalign (1991). Similarly, a previous soil description report of the KARC site by EIAR (2003) identified three major soil types Eutric Vertisol, and Vertic Luvisola, and Vertic Cambisol; all the soil units generally have acidic surface soil reaction, and low in the available P, Zn and Cu contents.

Table 2: Selected physicochemical properties of the experimental site before planting

Soil property	**Value**	**Rating**	**Reference**
pH (1:1.2)	6.01	Moderately acidic (5.6–6.5)	–
Total N (%)	0.19	Low (0.1–0.2)	Murphy et al. (2007)
Available P (ppm)	19.35	High (18–25)	Bulletin (n.d.)
Organic C (%)	2.48	high (>1.99)	Murphy et al. (2007)

4.2 Effect of Treatments on Growth and Physiological Traits

4.2.1 Plant height

The plant height differed significantly ($p \leq 0.001$) by the of organic types and fertilizer rates as well as their interactions (Appendix Table). The mean tallest plants (83.6 cm) and shortest (73.5 cm) were recorded from application of MO+100%N (but was statistically at par with VC+100%N) and MO+0N%, respectively (Table 4). The plant height increased consistently with the increase in the N supplementation levels for each organic fertilizer. It might be due to better availability of nutrients during the growth period from synergy of fertilizer. The result is in

agreement with Alemayehu et al. (2022) who reported that rice grown under liquid bio fertilizer in combination with half to full dose of recommended fertilizer resulted in 12-21% increase in plant height over the sole conventional fertilizer.

4.2.2 Leaf area

Flag leaf area was affected by different organic and inorganic fertilizers and by their interactions (Table 3). Leaf area is highly and significantly ($p<0.001$) influenced by inorganic fertilization. The highest leaf area was recorded from the treatment MO+100%N (27.20 cm^2), which was statistically par with VC+100%N plot. The lowest leaf area was recorded from VC+0%N (21.2 cm^2), which was statistically similar with MO+0%N.

Table 3: Interaction effects of different organic fertilizer types and N fertilizer rates on plant height, leaf chlorophyll content, and flag leaf area of wheat at Kulumsa, during 2023 main cropping season.

Organic type	N dose (%)	Plant height (cm)	Leaf chlorophyll (SPAD unit)	Flag leaf area (cm^2/plant)
EG	0	78.2 ^{ef}	43.9 ^{c}	25.8^{bc}
	50	80.3 ^{de}	45.1 ^{b}	24.1^{cde}
	75	81.8 ^{bcd}	45.6 ^{b}	25.7^{bcd}
	100	77.1 ^{f}	45.8 ^{b}	26.4^{ab}
MO	0	73.5 ^{g}	42.3 ^{d}	21.4^{f}
	50	77.2 ^{f}	45.3 ^{b}	22.1^{ef}
	75	77.6 ^{f}	44.9 ^{b}	23.9^{cde}
	100	83.6 ^{a}	46.2 ^{a}	27.2^{a}
VC	0	78.7 ^{ef}	43.1 ^{cd}	21.2^{f}
	50	80.1 ^{de}	45.4 ^{b}	23.6^{de}
	75	82.5 ^{abc}	45.5 ^{b}	25.4^{bcd}
	100	82.8^{a}	46.5 ^{a}	27.2^{a}
	LSD	2.311	1.0079	1.852
	N*O	***	***	**
	CV	1.69	1.17	10.80

*Chl: Leaf chlorophyll content in SPAD unit; EG: Eco-Green; MO: Mela-Organics; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of the conventional fertilizer (CF). Means in the column followed by the same letter are not significantly different at p<0.05. * Significant at p ≤ 0.05; ** significant at p ≤ 0.01; *** significant at p ≤ 0.001.*hlorophyll content

The leaf area under both Mela-organics and vermicompost fertilizers demonstrated a consistent increase with increasing rates of N fertilizer application; however it was inconsistent trend with

Eco-Green. The correlation matrix (Appendix Table 7) indicated that flag leaf area had positively and strongly correlated with phonological, physiological and yield traits: GFP (r=0.67, P<0.0001), SPAD chlorophyll (r=0.46, P<0.001), NDVI values (r=0.79, P<0.0001), AGD (r=0.68, P<0.001) and grain yield (r=0.66, P<0.0001). The result corroborates with Mouhamed and Ouda (2000) who showed the association between flag leaf area and the yield of the main spike was positively significant. According to Khan et al., (2022), this could be due to the high availability of nutrients and crop capacity to absorb nutrients from both organic and synthetic fertilizers could all contribute to the larger leaf area. As the flag leaf area increased, simultaneously the grain yield was increased (5.23 ton/ha) and (4.14 t/ha) respectively, which indicated that the positive correlation between leaf area and yield.

The leaf chlorophyll content was significantly influenced by main effect of N rate ($p<0.05$) and interactions organic fertilizers types and N rate. The highest chlorophyll content (46.5 SPAD value) was recorded from the VC+100%N treatment, which was statistically par with MO+100%N plot. The lowest was recorded from VC+0%N treatment (43.1 SPAD value). However, sole application of organic treatments (Mela-Organics, Vermicompost, and Eco-Green) showed the lower SPAD value (Table 3).

Chlorophyll content is strongly linked to the N content in plants, and serves as a valuable indicator of photosynthetic activity and crop response to N fertilizer. SPAD Chlorophyll positively and strongly correlated with NDVI values (r=0.69, P<0.0001) (Appendix Table 7) indicating OAs different N-levels at varying levels chlorophyll content or N status of affected. Both leaf chlorophyll and NDVI values tended to increase with increasing N fertilizer levels for organics fertilizers types. SPAD and NDVI values have been widely used as the standard estimators of crop N status. Previous studies have used the SPAD readings to predict chlorophyll content or plant N status and yield of field crop (Oglesby et al., 2022).

The greenness (NDVI value) of the crop was highly significantly influenced by organic fertilizers types and N rate, but their interaction effect was not significant (Table 4). The NDVI value of the crop ranged from 0.63 to 0.73 (Table 5).



Figure 3: Pictures during measuring of leaf chlorophyll contents (**Right**) and NDVI/greenness (**Left**) of wheat using SPAD 502 and Green Seeker handheld devices.

Table 4. Main effects of the organic fertilizers types and N fertilizer rates on the spike length and NDVI value of wheat at Kulumsa, during 2023 main cropping season.

Treatment	NDVI value	Spike length (cm)
Organic type		
EG	0.7^{ba}	8.95^{ab}
MO	0.7^{a}	8.79^{b}
VC	0.7^{b}	9.09^{a}
LSD	0.015	0.246
N dose (%)		
0	0.68^{c}	8.61^{c}
50	0.7^{bc}	8.88^{bc}
75	0.7^{b}	9.12^{ab}
100	0.73^{a}	9.18a
LSD	0.018	0.018
CV	2.55	3.25

*EG: Eco-Green; MO: Mela-Organics; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of the conventional fertilizer (CF). Means in the column followed by the same letter are not significantly different at p<0.05 . * significant at p ≤ 0.05; ** significant at p ≤ 0.01; *** significant at p ≤ 0.001.*

Across the organic types, both Mela-Organics and Eco-Green produced the higher NDVI value, which were statistically at par. The highest NDVI (0.73) was recorded from MO+100%N,

followed by EG+75%N (0.72). This could be nutrient availability and it balance increased the greenness and healthiness of the crop. As the NDVI values increased the crop become healthier (Abera et al. (2020), the NDVI indicates the degree of greenness, the value ranges from 0.00 to 0.99.

4.2.3 Number of tillers

Number of tillers is one of the most important agronomic parameters to be considered for enhancing productivity. Number of plant tillers measured at two different stages plant growth at vegetative tillering stage and at heading stage. At both stages, the plant tiller was no significant treatment effect at any level of significant test (Table 5). Although, the use of organic fertilizer with different levels of inorganic fertilizer enhanced total tiller to be productive tiller more than conventional and unfertilized. For instance, EG+N75% (4.08), MO+N75% (4.11), VC+N75% (4.11), UC (3.40), CF (4.17) total tillers and productive tillers (3.17), (3.00), (3.02), (2.50) and (2.98) treatments respectively. The result is supported by Harbi et al.,(2021) who reported that important nutrients for organic compound forms like proteins, lipids, and carbohydrates can be more readily available and absorbed when liquid organic fertilizer is added.

4.3 Yield and Yield Components

4.3.1 Grain yield, total biomass yield and harvest index

The grain yield and total biomass yield of wheat was significantly ($P \leq 0.05$) influenced by the interaction effect of organic types and fertilizer rates (Appendix Table 3). Significantly highest (5.23 t/ha) grain yield was recorded under Mela-Organics with 100%N (MO+100%N), whereas the lowest (3.18 t/ha) was obtained from the VC+0%N plot. Across the treatments, Eco-Green + N50%, Eco-Green + N75%, Mela-Organics + 75N%, and vermicompost + N75% equally exhibited the grain yields which were at statistically par with the conventional fertilizer plot (Table 5).

With increasing N dose, the grain yields were higher by 44, 68, 65 and 63% for Eco-Green, 37, 45, 73 and 105% for Mela-Organics, and 25, 60, and 86% for vermicompost soil fertilizers compared to the unfertilized control (Figure 4). However, only the higher N doses with Eco-Green or Mela-Organics fertilizers demonstrated a yield increase of 5.5-19% over the conventional practice. At 0%, 50%, and 75% N substitution levels, all organic fertilizer

treatments (except for Eco-Green at 75% N) resulted in grain yields lower than the conventional practice (CF), with the reductions ranging from –2.4% to –27.7% (Figure 5). This indicates the necessity of N supplementation for both commercial organic fertilizers.

Under fully organic condition (0%N), Eco-Green and Mela-Organics performed relatively better grain yield than vermicompost. Compared with their respective sole application, the difference in grain yields among N supplementation rates were larger in Mela-Organics (5.4%-49.4%) than in Eco-Green (12.8%-16.9%). Within the same organic type, N supplementation at high dose resulted in significantly ($p < 0.05$) higher grain yield when compared with lower fertilization rates. The grain yield obtained from the Eco-Green combined with 50%N application was higher than that reported by (Abegeja et al., 2022) for malt barley, where a high rate of Eco-Green application (80 L/ha, double the rate used in the present study) in which the maximum grain yield of 4,220 kg/ha and total biomass yield of 7,055 kg/ha were reported.

The correlation matrix showed that the grain yield was positively and strongly correlated with leaf chlorophyll content ($r = 0.78$, $p < 0.0001$), agronomic N efficiency ($r = 0.54$, $p < 0.001$), productive tillers ($r = 0.44$, $p < 0.005$), leaf area ($r = 0.66$, $p < 0.0001$), and total seed per spike ($r = 0.67$, $p < 0.0001$) (Appendix Table 7), indicating that the observed yield response was attributable to the nutrient supplied from N and the organic fertilizers, which increased dry matter accumulation and yield by enhancing productive tillers, leaf area, and total seed per spike. Moreover, a separate regression analysis (Figure 7) indicates a strong, linear relationship between leaf chlorophyll content and grain yield ($r^2 = 0.98$, 0.84 and 0.90, respectively for Eco-Green, Mela-Organics and vermicompost; $p < 0.0001$) total biomass yield ($r^2 = 0.97$, 0.88 and 0.98, respectively for Eco-Green, Mela-Organics and vermicompost; $p < 0.0001$), provide evidence that the wheat yield response for each organic fertilizers was due largely to available N supplied by N. This evidences that both commercial liquid organic fertilizers (Eco-Green or Mela-Organics) cannot stand alone, and can be beneficial for crop productivity when applied at a dose that guarantees the nutrient (N) requirements of the crop.

The total biomass yield of wheat was highly significantly ($p < 0.001$) influenced by the application of different organic fertilizers and inorganic fertilizer treatments (Appendix Table 3). The highest total biomass yield (11.82 t/ha) was recorded under Mela-Organics + N100% application (Table 4), followed by Eco-Green + 100%N (10.58 t/ha), Eco-Green + 75%N (10.62

t/ha), and vermicompost + N75% (10.8 t/ha), vermicompost + N50% (10.68 t/ha), all these were statistically par each other. Whereas, the lowest total biomass yield (8.23 t/ha) was recorded from the Mela-Organics + 0%N.

Table 5: Grain yield, total biomass yield and harvest index of wheat as influenced by the interaction effect of different organic fertilizers types and N rates.

Organic type	**N dose (%)**	**Grain yield (t/ha)**	**AGB (t/ha)**	**Harvest index (%)**
EG	0	3.67 ^{de}	9.17 ^{cd}	40.07^{bcd}
	50	4.29 ^{bcd}	9.45 ^{cde}	45.50 ^{a}
	75	4.22 ^{bcd}	10.62 ^{abc}	39.57 ^{cd}
	100	4.14 ^{abc}	10.58 ^{abc}	38.84 ^{abc}
MO	0	3.50 ^{de}	8.24 ^{e}	42.67 ^{abcd}
	50	3.69 ^{de}	8.89 ^{de}	41.37 ^{abcd}
	75	3.87 ^{de}	9.56 ^{bcde}	40.50 ^{bcd}
	100	5.23 ^{a}	11.82^{a}	44.33 ^{abc}
VC	0	3.18 ^{e}	8.23 ^{e}	38.71 ^{d}
	50	4.07 ^{cd}	10.68 ^{abc}	38.20 ^{d}
	75	4.74 ^{abc}	10.80 ^{abc}	44.20 ^{abc}
	100	5.00^{ab}	11.18^{ab}	44.86^{ab}
LSD (0.05)		0.789	1.696	5.200
N rate		***	***	Ns
Organic type		ns	ns	Ns
N*Organics		*	*	**

*AGB: Aboveground biomass; EG: Eco-Green; MO: Mela-Organics liquid fertilizer; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of the conventional fertilizer (CF); Means in the column followed by the same letter are not significantly different at p<0.05. * significant at p ≤ 0.05; ** significant at p ≤ 0.01; *** significant at p ≤ 0.001.*

Combined application Eco-Green with N fertilizer at the rates of 0, 50, 75, and 100% of N rates resulted in mean grain yield advantages of 37%, 43%, 59% and 59%, respectively relative to the unfertilized control, with Mela-Organics, increased by 24%, 33%, 43% and 77%, respectively over the unfertilized control (Figure 4). The total biomass yield followed more or less similar trends as grain yield among treatments. However, no significant differences in total biomass yield observed among the EG+50N%, EG+75%N, and EG+100%N, MO+75%N, VC+50N%, treatments. Birru and Abageja, (2025) reported significantly increase in grain yield, and biomass yield with Eco-Green application at 60 L/ha.

Harvest index calculated as the percentage ratio of grain yield to aboveground dry biomass yield was significantly ($P \leq 0.01$) influenced by the interaction effect of organic types and N rates (Table 6). Significantly the highest (45.5%) harvest index was recorded from EG+100%N, followed by MO+100%N (44.33%) and VC+50%N (44.20%) respectively. Whereas the lowest (38.20%) was obtained from the plot treated with VC+50%N. The trend was inconsistence across the treatments as the rate of inorganic fertilizer increased the harvest index were either increased or decreased. The correlation matrix (Appendix Table 7) shows that harvest index and grain yield has positively and strongly correlated ($r=0.57$, $p<0.0001$). The result was in agreement with Saeed et al.(2020), who state that as the HI and grain yield are positively correlated, an increase in grain yield also raised the harvest index.

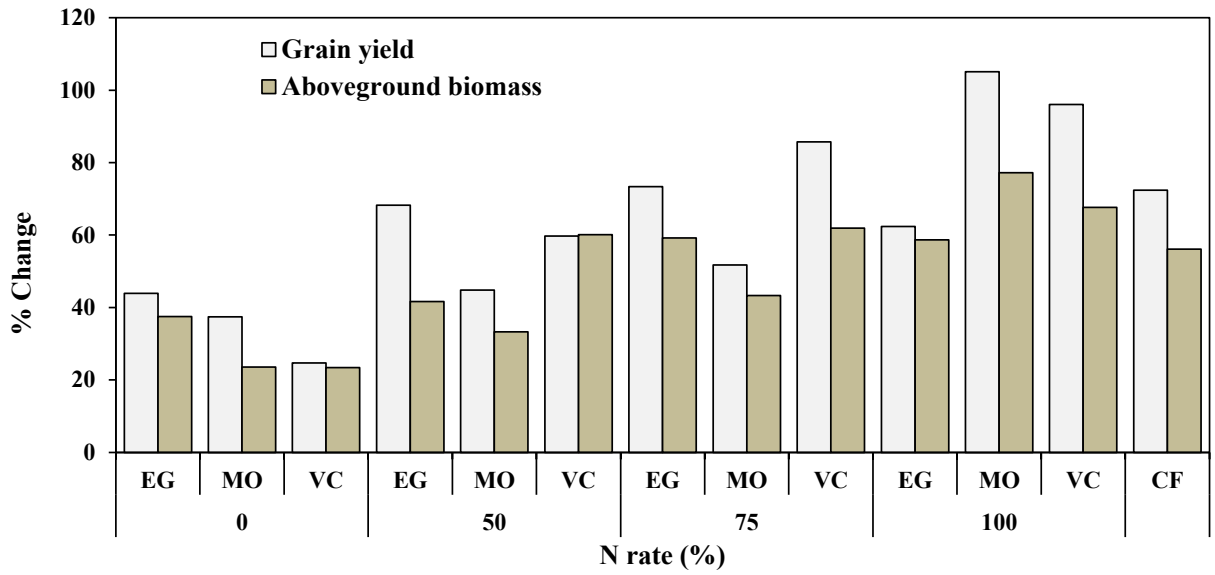


Figure 4: Percentage increase in grain yield and total biomass yield over the unfertilized control in response to applied organic fertilizers types and N rates at Kulumsa, during 2023 main cropping season.
EG: Eco-Green; MO: Mela-Organics liquid fertilizer; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of the conventional fertilizer (CF).

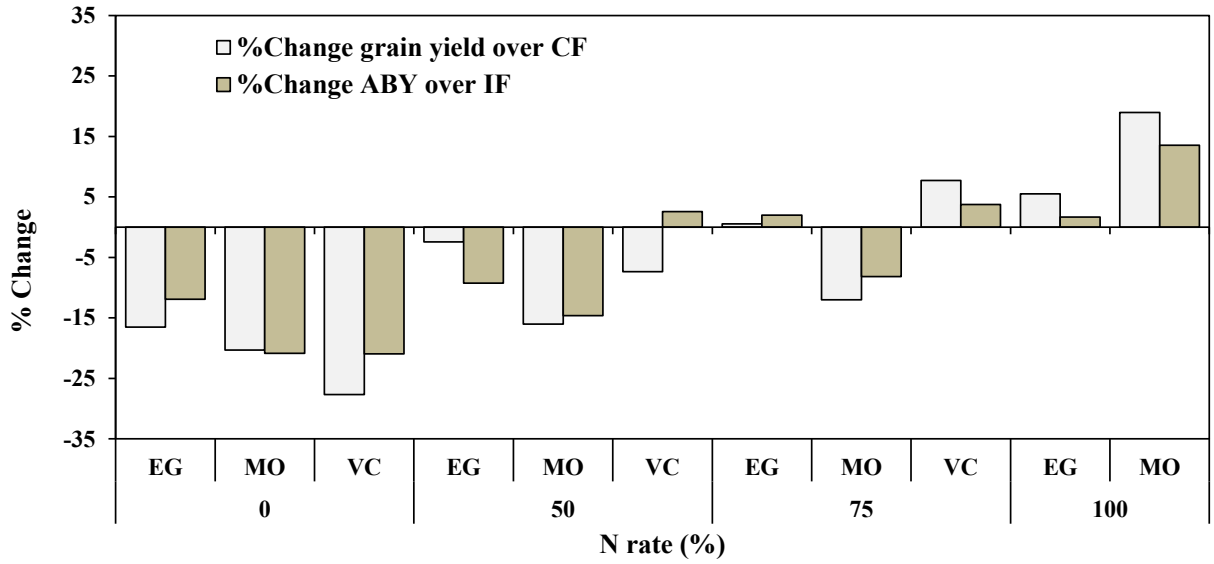


Figure 5: Percentage change (increase/decrease) in grain and total biomass yield of wheat over the conventional fertilizer practice (CF) in response to applied organic fertilizers types and N rates at Kulumsa, during 2023 main cropping season.
EG: Eco-Green; MO: Mela-Organics liquid fertilizer; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of the conventional fertilizer (CF).

4.3.2 Spike length, number of spikelet's per spike, and seeds per spike

The results show that spike length of wheat was not influenced by organic types and their interactions, but was influenced by N rates ($p \leq 0.01$). The maximum spike length (9.18 cm) was obtained from N rates 100% (Table 6).

The number of spikelet's per spike and seeds per spike were significantly influenced by main effect of the organic fertilizers types and N fertilizer rate ($p<0.05$) and their interactions. The maximum number of spikelet's per spike (18.46) was obtained from the plot treated with VC+50%N, followed by plots treated with MO+100%N (18.29) and EG+75N% (18.06). The highest total seed per spike was obtained from VC+75%N (58.67), followed by MO+75%N (57.33), MO+50%N (57.00), respectively. The smallest total seed per spike was recorded from EG+0%N (40.67).

When compared the sole application of either Mela-Organics or Eco-Green, there is no significant difference observed (49 and 48), total seed per spike was recorded, respectively but total seed per spike obtained from VC+0%N (52.33) was higher than both organic fertilizers.

Similarly, research on barely crop by Birru and Abageja, (2025) reported the highest spike length, number of seeds per spike, and number of tillers from plots where Eco-Green was applied at 60 L/ha.

Table 6: Number of total and productive tillers, spike length, number of spikelet's per spike, and seeds per spike of wheat as influenced by the interaction effect of different organic fertilizers types and N rates.

Organic type	N dose (%)	Total tillers	Productive tillers	Spike length (cm)	Spikelet per spike	Total seed per spike
EG	0	4.27	3.39	8.78	16.94^{h}	48.00^{g}
	50	4.09	2.98	9.00	17.44^{fg}	54.33^{e}
	75	4.08	3.17	9.12	18.06^{bcd}	55.00^{cde}
	100	3.90	2.96	8.89	17.75^{def}	54.67^{de}
MO	0	3.71	2.52	8.27	15.94^{g}	49.00^{g}
	50	3.94	2.94	8.76	17.59^{efg}	57.00^{ab}
	75	4.11	3.00	8.91	17.54^{efg}	57.33^{ab}
	100	4.27	3.27	9.24	18.29^{bc}	56.67^{bc}
VC	0	3.92	3.00	8.76	17.25^{gh}	52.33^{f}
	50	3.94	3.29	8.87	18.46^{b}	56.33^{bcd}
	75	4.11	3.02	9.33	17.92^{cde}	58.67^{a}
	100	6.31	3.50	9.11	18.48^{a}	56.00^{bc}
LSD		-	-	-	0.02	2.12
N rate		ns	ns	**	***	***
Organic type		ns	ns	ns	***	***
N*Organic		ns	ns	ns	***	*

*EG: Eco-Green; MO: Mela-Organics liquid fertilizer; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of N fertilizer (CF); Means in the column followed by the same letter are not significantly different at p<0.05. * Significant at p ≤ 0.05; ** significant at p ≤ 0.01; *** significant at p ≤ 0.001.*

The correlation matrix showed that the total seed per spike was positively and strongly correlated with leaf chlorophyll content (r = 0.86, p < 0.0002), spike length (r = 0.76, p < 0.0001), spikelet per spike (r = 0.88, p < 0.0001), plant height (r = 0.77, p < 0.0001), Greenness (r = 0.61, p < 0.0001), Biomass yield(r=0.68,p<0.0001) and Grain yield (r=0.67,p<0.0001) (Appendix Table 7). Separate regression analysis (Figure 6) shows that strong linear relationship between total seed per spike and grain yield (r^2=0.95, 0.59 and 0.86) respectively for Eco Green, Mela organics and Vermicompost: p<0.001) biomass yield (r^2=0.90, 0.59 and 0.69) respectively for Eco Green, Mela organics and Vermicompost.

4.3.3 Nitrogen use efficiency

Agronomic efficiency more closely reflects the direct production impact of an applied fertilizer. In this study, the agronomic use efficiency N (AEN) of the crop was significantly ($P<0.05$) influenced by organic fertilizer types and N fertilizer (Table 7). Across the treatments, Eco-Green with lower N application dose (EG+50N%) resulted in highest (31.6 kg/kg) of agronomic N efficiency, which was 88.27% more than the conventional fertilizer practice (16.8 kg/kg) it might be due to the presence of other nutrients in (EG) which increases the overall nitrogen content of the mixture. Whereas with Mela-Organics (MO+100%N) produced AEN 24.3 kg/kg. Except for MO+75%N and EG+100%N treatments, application of organic fertilizer types (each individually and in combination with N fertilizer rates) were higher agronomic N use efficiency compared with the conventional fertilizer practice. In case of Eco-Green, AEN consistently decreased with N fertilizer supplementation rates. This could be due to variations in the nutrient composition or other factors that affect plant growth and crop yields.

Table 7: Agronomic nitrogen use efficiency and partial factor productivity (PFP) of nitrogen of wheat as influenced by different organic fertilizers and inorganic fertilizer supplementation doses.

Organics	N rate	AE_N (kg/kg)	PFPN kg grain/kg N
EG	50	31.63	78.03
	75	20.23	51.13
	100	14.47	37.63
MO	50	20.77	67.13
	75	16.00	46.90
	100	24.33	47.57
VC	50	27.67	74.03
	75	26.10	57.03
	100	22.27	45.40

As an indicator parameter for N utilization efficiency, AEN is around 35 kg/kg for maize production (Dobermann, 2007), however it can exceed 58 kg/kg in agricultural developed countries, through water and fertilizer utilization management practices (Wang et al., 2021). The findings of the present study that improvement in AEN over the conventional fertilizer practice could be due to the nutrient management from both organic and inorganic sources.

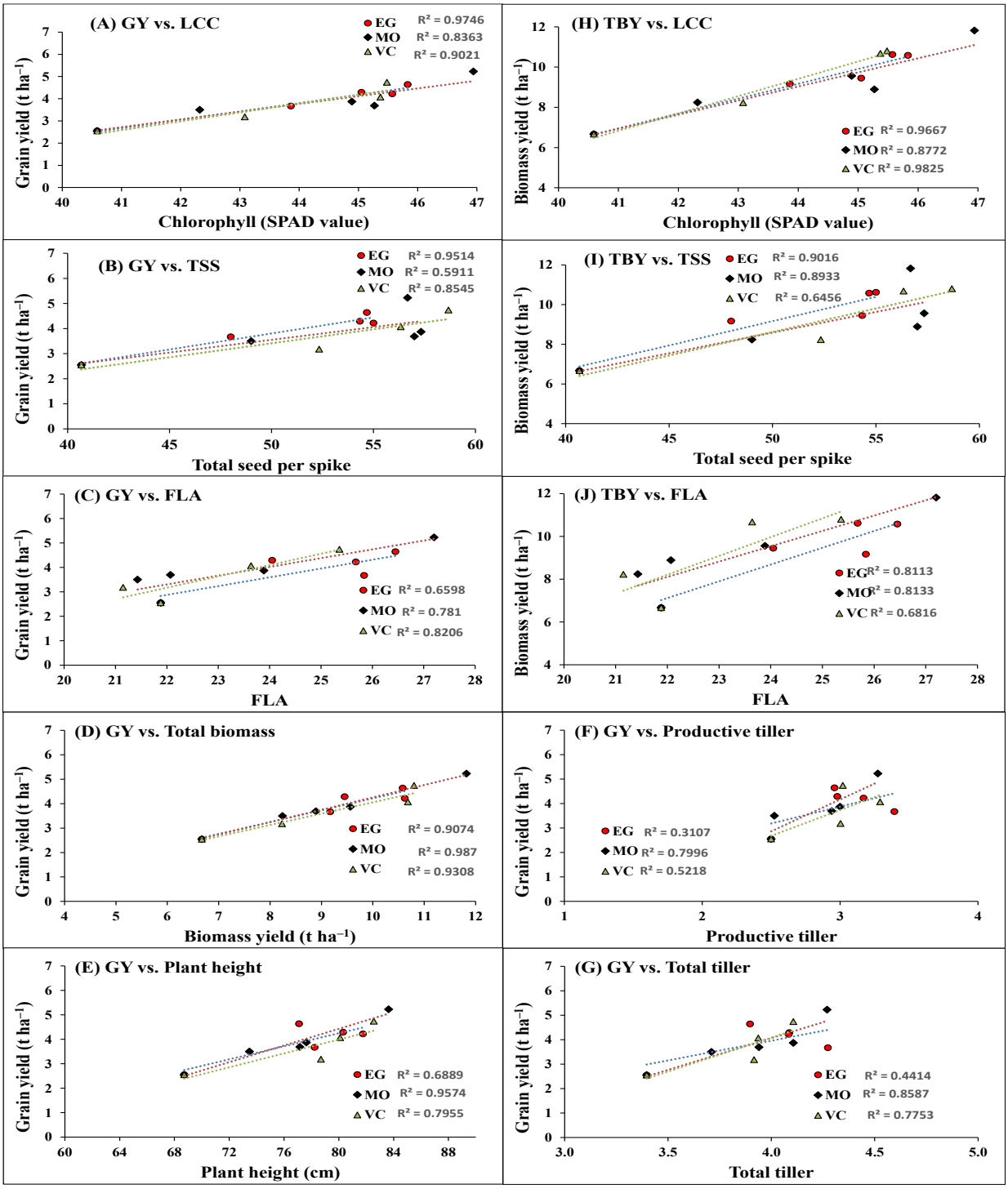


Figure 6: Relationship between grain yield with (A) leaf chlorophyll content, (B) total seeds per spike, (C) flag leaf area, (D) total biomass yield, (E) plant height, (F) number of productive tillers, and (G) total number of tillers; as well as the relationship between total biomass yield with (H) leaf chlorophyll content, (I) total seeds per spike, and (J) flag leaf area.

** Significant at p ≤ 0.05* (r^2 = 16-34)*; ** significant at p ≤ 0.01* (r^2 = 35-50)*; *** significant at p ≤ 0.001* (r^2 > 0.50); ns: not significant (r^2<16).

4.4 Effect of treatment on selected chemical properties of soil after harvesting

A selected chemical property of soil after-harvesting was evaluated, including pH, OC, total N, and available P (Table 8). The results indicated that only the main effect of the organic fertilizer types was significant (P<0.05) for soil pH, Available P, and total N, while soil OC and available P did not show significant effect. The result indicated relatively higher pH levels and total N contents for plots treated with vermicompost with different rates of N fertilizer (Table 8). The highest pH value 6.34 and 6.07 were recorded from plots treated with vermicompost (VC+75%N) respectively.

Table 8: Selected soil properties under different fertilizer treatments after harvesting of wheat crop.

Treatments	**pH** (H_2O)	**OC** (%)	**TN** (mg/kg)	**AvP** (%)
Organic type				
EG	5.99b	2.87	0.19b	18.71b
MO	5.92b	3.09	0.19b	18.58b
VC	6.16a	2.99	0.21a	21.5a
LSD	0.1346	ns	0.0116	2.6539
N dose				
0	6.12	2.9	0.2	20.52
50	6.04	3.11	0.2	19.54
75	6.02	3.02	0.2	19.53
100	5.91	2.91	0.19	18.79
LSD	ns	ns	ns	ns
CV	2.63	11.18	6.94	16.00

P_{av} = Available phosphorus. EG: Eco-Green; MO: Mela-Organics liquid fertilizer; VC: Vermicompost; N: Inorganic fertilizer; 0, 50, 75 and 100% of the conventional fertilizer (CF); Means in the column followed by the same letter are not significantly different at p<0.05.

Although vermicompost provided substantially higher total N compared to Mela-Organics and Eco-Green, thereby contributing to greater buildup of soil OC and total N, significant improvements in these parameters are generally not expected from a single-season application. This aligns with the findings of the present study and reinforces the understanding that measurable enhancements in soil OC and nutrient status typically require sustained and repeated

applications of organic inputs over multiple cropping cycles. The organic carbon levels do not show a significant difference it might be due to that the organic carbon in the fertilizer is quickly decomposed by soil microorganisms, which can result in a rapid release of nutrients and a quick uptake by plants.

One of the major challenges associated with commercial liquid organic fertilizers currently available in the local market is the lack of clearly defined modes of action. Most products do not specify whether their effectiveness is intended to be microbial-based, i.e., whether they contain beneficial microorganisms such as plant growth-promoting rhizobacteria or nutrient-solubilizing microbes. Product labels typically indicate only the nutrient content, which alone does not guarantee product quality or agronomic effectiveness. This is particularly problematic given that these fertilizers are applied in highly diluted forms and in small volumes, resulting in nutrient inputs that are substantially below crop requirements, regardless of how high the nutrient analysis may appear on the label.

4.5 Economic profitability of different organic fertilizers

Table 9 presented the partial budget analysis result. The highest mean net benefit (266311 ETB/ha) was recorded from the combined application of MO+100%N, followed by 225085, 220113, 214452, 208251, and 232432 ETB/ha for CF, EG+50%N, EG+75%N, EG+100%N, VC+75%N, respectively. The lowest net benefit was obtained from the unfertilized plot (137700 ETB/ha).

Higher marginal rate of return (MRR) was obtained from the application of MO+100%N (798.4%), EG+50%N (713.7%), sole inorganic fertilizer (698.2%0, and EG+0%N (676.9%). Both EG+50%N and MO+100%N provide positive returns on the added investment over unfertilized control, with EG+50%N being the more profitable choice in terms of marginal efficiency. This means for every 1 ETB spent on fertilizer, the farmer gets back ETB 7.1 and 7.9 ETB, respectively.

Based on CIMMYT (1998) guideline, a given management practice with high net benefit is generally considered acceptable when its MRR is above 100%. Accordingly, the partial budget analysis, combined application of Eco-Green with 50% N-fertilizer of RDF (EG+50%N) achieved a grain yield (3.86 t/ha) and the second-highest net benefit (220113 ETB/ha), along

with MRR of 713.7%, and was thus considered as agronomical optimal and economically feasible for wheat production in the study area. On the other hand, applying Mela-Organics only at higher N rate (MO+100%N) produced the highest net benefit (266311 ETB/ha) and a high marginal rate of return (798.4%) could be optionally used since it produced the highest grain yield (4.71 t/ha). Vermicompost at 5 t/ha (VC+75%N) resulted in a high net benefit (232432 ETB/ha) together with the MRR (402.6%) and better grain yield, therefore can be considered a viable option for profitable wheat production in the study area.

Table 9. Partial budget analysis of wheat grain yield as influenced by organic fertilizer types and N fertilizer rate, at Kulumsa, during 2023 main cropping season.

Treatments*	**GY adjusted (t/ha)**	**TVC (ETB/ha)**	**Gross field benefit (ETB/ha)**	**Net benefit (ETB/ha)**	**MRR (%)**
UC (- Control)	2.30	0	137700	137700	-
EG+0%N	3.30	7785	198180	190395	-
MO+0%N	3.15	8585	189000	180415	-
EG+50%N	3.86	11547	231660	**220113**	**713.7**
MO+50%N	3.32	12347	199260	186913[d]	d
CF (+Control)	3.96	12515	237600	**225085**	**698.2**
EG+75%N	3.80	13428	227880	214452[d]	d
MO+75%N	3.48	14228	208980	194752[d]	d
EG+100%N	3.73	15309	223560	208251[d]	d
MO+100%N	4.71	16109	282420	**266311**	**798.4**
VC+0%N	2.86	17885	171720	153835[d]	d
VC+50%N	3.66	21647	219780	198133[d]	d
VC+75%N	4.27	23528	255960	**232432**	**402.6**

GY adjusted=Grain yield adjusted by 10%; Wheat price 60 ETB//kg; ETB=Ethiopian birr; TVC=Total variable cost; MRR=Marginal rate of return; d=Dominated.

**Treatments arranged in ascending order based on their TVC.*

5 SUMMARY AND CONCLUSIONS

The field experiment was conducted at Kulumsa Agriculture Research station, Kulumsa, Central Ethiopia, during the main rainy season of 2023 (May-August), to evaluate the effect of commercial liquid organic fertilizers in wheat cropping system. Well-adapted bread wheat (variety, Boru), was used for planting. Factorial combinations of three organic fertilizer types in which two were commercially Mela-Organics (MO), Eco-Green (EG), and Vermicompost (VC) and four levels of N rates consisting of 0, 50%, 75% and 100% of RDF were laid out in a randomized complete block design with three replications.

The results indicated that the highest grain yield (5.23 t/ha) was obtained from MO+100%N, which was statistically similar to that obtained under the VC+100%N (5.00 t/ha), followed by EG+100%N (4.22t/ha). The SPAD scores of 44.6 and 46.2 from VC+100%N and MO+100%N, respectively, recorded where the highest grain and biological yields produced treatments. Compared with chemical fertilizer alone, the application of Eco-Green or Mela-Organics in combination with N fertilizer at higher doses (75% or 100%) increased wheat grain yield by 5-19%, increased biomass yield by 2.6-13.5%. However, sole application of either Eco-Green or Mela-Organics (0%N) and with 50% N level, resulted in grain and biomass yields lower than the conventional practice (CF), with the grain yield reductions ranging from –2.4% to –27.7% and biomass yield reductions from –9.3% to –20.9%. Accordingly, the observed poor agronomic performance at partial supplementation (50%N) or sole organic condition suggests that the commercial liquid fertilizers cannot stand alone can be beneficial for crop productivity when applied at a dose that ensures the nutrient (specifically N) requirements of the crop. This indicates the necessity of N supplementation for both commercial organic fertilizers.

The results on soil properties after-harvesting showed that only the main effect of the organic fertilizer types was significant for soil pH and total N, and available P. No notable differences were detected in soil OC by organic fertilizer types and N fertilizer rates and their interaction. Among the organic fertilizers, vermicompost performed higher soil pH and total N, and available P, indicating that vermicompost influenced short-term improvements in such soil properties compared to Mela-Organics or Eco-Green.

Considering the economic benefit, farmers of the area might be advised to use these commercial liquid fertilizers (Eco-Green) in combination with 75%N of the conventional fertilizer dose to

achieve comparable wheat yields while reducing chemical fertilizer costs by 25%. On the other hand, applying Mela-Organics only at higher N rate (MO+100%N) produced the highest net benefit and a high marginal rate of return could be optionally used since it produced the highest grain yield. Vermicompost at 5 t/ha combination with 75% N resulted in a high net benefit together with an acceptable MRR and better grain yield, therefore can be considered a viable option for profitable wheat production in the study area.

However, it would be early to draw recommendation, as the experiment was conducted at a single location for one growing season. Therefore, further research is necessary, encompassing various application rates of commercial liquid organic fertilizers (in addition to the dose recommended by the company), NPK rate studies, and multi-season, multi-location trials.

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7 APPENDICES

Appendix Table 1. Chemical properties of Mela-Organics and Eco-Green liquid fertilizer (as per the given product description)

Product name	**Mela-Organics**	**Eco-Green**	
Producing company	Mela Organics Liquid Fertilizer Production PLC.	Eco Green-Organic Liquid Fertilizers	
Chemical properties			
Mela-Organics	**Value**	**Eco-Green**	**value**
pH	6.59	pH	6.36
EC	6.22	EC	ND
TN(%)	5.91	TN (%)	12
P(mg/lt)	255.69	P_2O_5 (%)	4
K (mg/lt)	1367.07	Elemental P (%)	1.906
Mg (mg/lt)	329.99	Soluble K (%)	6
Ca(mg/lt)	1720.42	Elemental K (%)	4.98
SO4 (mg/lt)	641.99	Ca (%)	5
Na (mg/lt)	233.18	Fe (%)	2
Fe (mg/lt)	11.99	Mn (%)	0.5
Mn (mg/lt)	7.74	Zn (%)	0.05
Zn (mg/lt)	2.56	Cu (%)	0.05
Cu (mg/lt)	2.05		
Mo (mg/lt)	0.96		
B (mg/lt)	2.92		



Appendix Table 2: ANOVA (Mean square, F Value) for crop phenology

	Days to booting		**Day to heading**		**Days to maturity**		**Grain filling period**	
Source	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
N suppl	3.08	0.049	0.37	0.774	2.46	0.090	2.61	0.077
Organic type (O)	1.92	0.170	6.99	0.005	2.24	0.131	0.57	0.576
Rep	2.85	0.080	0.94	0.407	0.41	0.668	1.18	0.327
Org*N	3.46	0.015	2.66	0.043	1.91	0.125	1.53	0.214
CV (%)	1.20		2.42		4.28		8.58	

Appendix Table 3: ANOVA for growth and physiological traits

	PH		**TL**		**Gre**	
Source	**F Value**	**Pr > F**	**F Value**	**Pr > F**	**F Value**	**Pr > F**
N suppl (N)	23.54	<.0001	0.06	0.978	9.7	0.0003
Organic type (O)	21.51	<.0001	0.98	0.392	5.68	0.0102
Rep	1.5	0.246	1.32	0.287	4.46	0.0236
Org*N	12.66	<.0001	1.51	0.222	2.06	0.0999
CV (%)	1.69		3.50		2.56	

Appendix Table 4: ANOVA for growth and physiological traits

	CHC			FLA		
Source	Mean Square	F Value	Pr > F	Mean Square	F Value	Pr > F
N suppl (N)	19.94	71.43	<.0001	36.9	27.11	<.0001
Organic type (O)	0.61	2.2	0.1345	10.3	7.6	0.0031
Rep	1.22	4.38	0.025	3.2	2.33	0.1213
Org*N	1.13	4.06	0.0069	6.2	4.57	0.0037
CV (%)	1.17			4.74		

Appendix Table 5: ANOVA for Grain yield, aboveground biomass

		AGB		**GY**		**HI**	
Source	DF	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
N suppl (N)	3	14.48	<.0001	12.23	<.0001	0.85	0.482
Organic type (O)	2	1.37	0.2742	0.51	0.6101	0.49	0.619
Rep	2	4.7	0.02	0.57	0.5739	1.77	0.193
Org*N	6	2.07	0.0483	2.78	0.0361	3.66	0.011
CV (%)		8.85		11.55		7.19	

Appendix Table 6: ANOVA for yield attributing parameters

	Total tillers		Productive tillers		Spike length		Spikelet per spike		Total seed per spike	
Source	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
N suppl (N)	0.44	0.725	0.93	0.445	7.20	0.0015	85.1	<.0001	77.58	<.0001
Organic type (O)	0.14	0.872	1.84	0.182	3.12	0.064	42.8	<.0001	20.52	<.0001
Rep	4.09	0.031	0.73	0.494	2.60	0.097	5.2	0.0144	1.37	0.2758
Org*N	0.93	0.494	1.86	0.134	1.46	0.237	10.2	<.0001	2.48	0.0551
CV (%)	9.15		12.24		3.29		1.29		1.99	

Appendix Table 7: Correlation coefficients among various parameters soil properties, growth and yield attributes, and nutrient uptake of wheat

	DB	DH	DMs	GFP	PH2	TT	PT	NDVI	CHC	FLA	SL	SPS	TSS	ADB	GY
DB	1														
DH	0.55***	1													
DMs	-0.17ns	0.34*	1												
GFP	-0.38*	-0.01ns	0.94***	1											
PH2	-0.42**	-0.3ns	0.28ns	0.4*	1										
TT	-0.16ns	-0.04ns	0.32*	0.35*	0.43**	1									
PT	-0.15ns	-0.18ns	0.2ns	0.28ns	0.51**	0.79***	1								
NDVI	-0.49**	-0.19ns	0.51**	0.61***	0.81***	0.2ns	0.38*	1							
CHC	-0.48**	-0.31ns	0.39*	0.53**	0.8***	0.42*	0.47**	0.7***	1						
FLA	-0.31ns	0.06ns	0.66***	0.67***	0.44**	0.18ns	0.39*	0.79***	0.46**	1					
SL	-0.4*	-0.29ns	0.42*	0.56***	0.83***	0.29ns	0.35*	0.85***	0.77***	0.61***	1				
SPS	-0.55***	-0.43*	0.24ns	0.42*	0.85***	0.41*	0.46**	0.71***	0.89***	0.4*	0.79***	1			
TSS	-0.46**	-0.45**	0.25ns	0.43*	0.77***	0.33*	0.29ns	0.61***	0.86***	0.25ns	0.76***	0.88***	1		
ADB	-0.46**	-0.19ns	0.54***	0.65***	0.77***	0.36*	0.48**	0.83***	0.83***	0.68***	0.81***	0.81***	0.68***	1	
Gyf	-0.37*	-0.04ns	0.68***	0.74***	0.77***	0.42*	0.44*	0.8***	0.78***	0.66***	0.79***	0.71***	0.67***	0.9***	1
AE_P	-0.07ns	0.22ns	0.6***	0.58***	0.6***	0.27ns	0.34*	0.56***	0.61***	0.54**	0.53**	0.49**	0.45*	0.7***	0.91***
pH	0.08ns	-0.44*	-0.56***	-0.43*	-0.09ns	0.06ns	0.01ns	-0.26ns	-0.28ns	-0.4*	-0.02ns	-0.01ns	-0.01ns	-0.25ns	-0.34*
TN	0.17ns	-0.06ns	-0.35*	-0.35*	0.02ns	-0.21ns	-0.05ns	0.03ns	-0.23ns	-0.06ns	0.02ns	-0.11ns	-0.08ns	-0.09ns	-0.1ns

DB=Daysto booting,DH=Days to heading,DMs=Days tomaturity,GFP=Grain filling period,PH1=Plant height at tillering,PH2=Plant height at maturity,TT=Total tiller,PT=Productive tiller,TL=Total leave,NDVI =Grenneness,Vig=Vigorsity,CHC=Chlorophyll content,FLA=Flag leaf area,SL=Spike length,SPS=Spikelet per spike,TSS=Total seed per sike,ADB=Aboveground biomass,Gyf=Grain yield,HI=Harvest index,HLW=Hectolitre weight,TSW=Thousand seed weight,AEN=Agronomic nitrogen use efficiency,PFPN=Partial factor productivity of nitrogen,PFPP=Partial factor productivity of phosphorus,PH=power hydrogen,TN=Total nitrogen,OC=Organic carbon,AvP=Avaliable phosphorus.

Appendix Table 8: Phenological data of wheat at Kulumsa, during 2023 main cropping season, under different organic fertilizer types and N rates.

Organic type	N dose (%)	Days to booting	Days to heading	Days to maturity
EG	0	50.33	56.67	101.33
	50	50.33	57.33	99.00
	75	50.6	57.33	101.00
	100	49.00	55.33	100.00
MO	0	50.67	58.67	102.33
	50	51.00	56.33	98.67
	75	50.67	57.33	101.33
	100	49.67	58.00	104.67
VC	0	49.33	54.33	90.67
	50	50.00	55.00	97.00
	75	50.33	55.33	101.67
	100	50.67	57.33	101.00

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Appendix Picture 1: Pictures field experiment activities