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Research Article

# Evaluation of Organic Liquid Fertilizer "ECO-GREEN" on the Yield and Yield Components of Food Barley at Sinana District, Bale Zone, Oromia, Southeastern Ethiopia

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## Abstract

Organic fertilizers improve soil structure by enriching it, boosting productivity, and simultaneously preventing erosion. Nitrogen and phosphorus are key limiting nutrients in many soils. In the highland vertisols of Ethiopia, nutrient deficiencies, particularly of nitrogen and phosphorus, are common due to practices like monocropping and nutrient leaching. This study evaluates the effect of the organic liquid fertilizer "ECO-GREEN" on the yield and yield components of food barley in Sinana District, Bale Zone, Southeastern Ethiopia. The experiment, conducted during the 2018/2019 growing season, included six different levels of ECO-GREEN application (ranging from 0% to 5% of fertilizer diluted in water) and was carried out in three different locations: Robe Area, Jafera, and Sambitu. The results demonstrated that grain yield, plant height, spike length, seeds per spike, number of tillers, and biomass yield all significantly increased with the application of ECO-GREEN fertilizer, with the highest yield observed at 60 L/ha. However, higher fertilizer levels (80 L/ha and 100 L/ha) did not show further significant yield improvements. This study highlights the importance of optimal fertilizer application for improving barley production under the highland conditions of Ethiopia.

## Keywords

Eco-GREEN, Food Barley, Grain Yield, Organic Fertilizers, Bale Highland

## 1. Introduction

Poor soil fertility is a major constraint affecting barley yield in Ethiopia [1]. Integrated soil fertility management, which combines organic and inorganic nutrient sources, offers a viable solution to address soil fertility challenges and enhance crop productivity [2]. The insufficient application of nutrients and poor soil management practices have contributed to widespread soil fertility depletion in many developing countries, leading to reduced crop yields, including for food barley [3]. Studies have shown that the integrated use of organic and inorganic fertilizers is critical for addressing soil fertility issues and sustainably increasing crop yields [4]. Moreover, relying solely on either organic or inorganic fertilizers has been found insufficient for achieving sustainable productivity [5].

Organic liquid fertilizers are valuable in improving soil fertility as they provide organic matter essential for microbial

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activity. These fertilizers enrich the soil with humus, releasing nutrients at a slow and consistent rate that plants can efficiently use. Unlike synthetic fertilizers, organic options prevent nutrient over-concentration, as soil microbes regulate nutrient release. These fertilizers also encourage the activity of earthworms, which enhance soil aeration and structure [6]. Organic fertilizers, made from biodegradable materials, improve soil structure, enhance productivity, and protect against erosion. They also help retain soil moisture, which mitigates stress and improves overall soil health [7].

Long-term exclusive use of chemical fertilizers without incorporating organic matter has been shown to impair soil health and reduce yields [8]. Combining decomposed organic materials with plant growth-promoting bacteria can decrease reliance on synthetic fertilizers while improving environmental sustainability [9]. The integration of organic and inorganic fertilizers is therefore essential for replenishing soil fertility and increasing barley yields [10]. However, mineral fertilizers alone reduce soil biological activity and aggregate stability, making a combined approach more sustainable and cost-effective [11].

Organic fertilizers provide primary nutrients like nitrogen, phosphorus, and potassium, which are critical for plant growth and development. These nutrients improve microbial biomass, nitrogen fixation, and soil dehydrogenase activity, leading to better plant growth and yield [12-14]. Additionally, organic fertilizers enhance soil structure, water-holding capacity, and promote the production of plant growth regulators through microbial activity [15, 16]. Properly balancing organic and inorganic inputs is thus critical for sustaining agricultural productivity while minimizing environmental impacts [17].

Despite the recognized benefits of organic fertilizers, there is limited research on the effects of ECO-GREEN organic fertilizer, either alone or in combination with chemical fertilizers, in Ethiopia, including the Bale highlands. Furthermore, studies on the appropriate rates and timing of foliar nitrogen and organic liquid fertilizers for barley production are lacking in this region. This study was therefore initiated to evaluate the effects of ECO-GREEN fertilizer on food barley yield, soil properties, and to determine its optimum application rate under the highland conditions of the Sinana District.

## 2. Materials and Methods

### 2.1. Description of the Study Area

The experiment was carried out during the 2018/2019 growing season at three locations in Sinana District, Bale Zone, Southeastern Oromia: Robe Area, Jafera, and Sambitu. Robe Area is situated at a latitude of 7°06'N and longitude of 40°02'E, with an altitude of 2456 meters above sea level (m. a. s. l). Jafera lies at 7°04'N and 40°11'E, with an altitude of 2450 m. a. s. l, while Sambitu is located at 7°10'N and 40°05'E, with an elevation of 2407 m. a. s. l. The predominant soil types in these areas are Cambisols and Vertisols, with textures ranging from clayey to sandy loam. The district experiences a bimodal rainfall pattern, with peak precipitation occurring in April and September. The experimental sites have an average minimum temperature of 10.72°C, a maximum temperature of 21.98°C, and an annual total rainfall of 925 mm.

### 2.2. Experimental Design

The experiment was arranged in a randomized complete block design with three replications, using the "Robera" variety of food barley. Seeds were sown in rows, and six treatment levels of ECO-GREEN, including a control, were evaluated: T1 = Control (sole water), T2 = 1% (20 L/ha), T3 = 2% (40 L/ha), T4 = 3% (60 L/ha), T5 = 4% (80 L/ha), and T6 = 5% (100 L/ha). The ECO-GREEN to water ratio was maintained at 1:20, meaning 1 liter of ECO-GREEN was diluted with 20 liters of water. Treatments were applied at 15, 30, 60, and 90 days after emergence (DAE). Each plot measured 3 m × 3 m (9 m²), consisting of 15 rows, each 3 meters long and spaced 20 cm apart. The organic liquid fertilizer "ECO-GREEN" was applied either early in the morning or late in the afternoon to prevent ultraviolet rays from sterilizing the beneficial microorganisms in the fertilizer extract.

### 2.3. Data Collection

Agronomic parameters, including yield and yield components of food barley, were measured. These included plant height (cm), spike length (cm), seeds per spike (count), number of tillers (count), biomass yield (kg), and grain yield (kg).

### 2.4. Data Management and Statistical Analysis

The agronomic and soil data collected from various locations were organized using EXCEL software and analyzed through analysis of variance (ANOVA) using the lm model in R software version 3.4.4. The total variability for each trait was assessed using the LSD test model at a 0.05 significance level.

## 3. Results and Discussion

### 3.1. Yield and Yield Components

The table presents the effects of different levels of ECO-GREEN fertilizer application on several agronomic parameters of food barley, including grain yield (GY), plant height (PH), spike length (SPL), seeds per spike (SPS), number of tillers (NT), and biomass yield (BMY). The results are summarized as follows:

Grain Yield (GY): Grain yield increased significantly with ECO-GREEN application. The control (0 lit//ha) recorded the lowest grain yield (1595 kg/ha), while the highest yield (4929 kg/ha) was observed at 60 lit/ha. Higher application rates beyond 60 lit//ha (80 and 100 lit//ha) did not result in a further increase in yield, indicating that 60 lit//ha may be the optimal rate for maximum productivity.

Plant Height (PH): Plant height also showed a significant positive response to ECO-GREEN levels. The shortest plants (57 cm) were recorded in the control, while the tallest (85 cm) were observed at 60 and 80 L/ha. Similar to grain yield, increasing ECO-GREEN application beyond 60 lit//ha did not result in significant further height increases.

Spike Length (SPL): Spike length followed a similar trend, with the control having the shortest spikes (2.5 cm) and the 60 lit//ha treatment producing the longest (8.6 cm). The differences between 40 lit//ha, 80 lit//ha, and 100 L/ha were smaller, suggesting diminishing returns at higher rates.

Seeds per Spike (SPS): The number of seeds per spike showed a strong response to ECO-GREEN application. The highest number of seeds per spike (46) was recorded at 60 lit//ha, while the control produced the fewest seeds (21). Higher application rates (80 and 100 lit//ha) showed a decline compared to 60 lit//ha, suggesting potential adverse effects of excessive ECO-GREEN on seed development.

Number of Tillers (NT): The number of tillers was minimal (1tiller) in the control and increased significantly with ECO-GREEN application. The highest number of tillers (7) was recorded at 60 L/ha, but higher rates (80 and 100 lit/ha) showed a decline.

Biomass Yield (BMY): Biomass yield followed a pattern similar to grain yield, with the highest value (6653 kg/ha) recorded at 60 lit//ha. The control had the lowest biomass yield (2578 kg/ha) and higher rates (80 and 100 lit/ha) resulted in a slight decline compared to 60 lit/ha.

***Table 1.*** *Response of food barley to organic liquid fertilizer "ECO-GREEN" to yield and yield components barley.*

| ECO-Green Level (Lit/ha$^{-1}$) | GY (kg/ha$^{-1}$) | PH (cm) | SPL (cm) | SPS (No) | NT (No) | BMY (kg/ha$^{-1}$) |
|---|---|---|---|---|---|---|
| 0 (Control | 1595$^{e}$ | 57$^{c}$ | 2.5$^{d}$ | 21$^{d}$ | 1$^{f}$ | 2578$^{d}$ |
| 1 (20) | 2727$^{d}$ | 71$^{b}$ | 4.6$^{c}$ | 25$^{b}$ | 1.6$^{e}$ | 3829$^{c}$ |
| 2 (40) | 4056$^{c}$ | 72$^{b}$ | 6.5$^{b}$ | 26$^{c}$ | 3$^{d}$ | 4711$^{b}$ |
| 3 (60) | 4929$^{a}$ | 85$^{a}$ | 8.6$^{a}$ | 46$^{a}$ | 7$^{a}$ | 6653$^{a}$ |
| 4 (80) | 4293$^{bc}$ | 83$^{a}$ | 6$^{b}$ | 33$^{b}$ | 5$^{b}$ | 4649$^{b}$ |
| 5 (100) | 4309$^{b}$ | 75$^{b}$ | 6$^{b}$ | 31$^{b}$ | 4$^{c}$ | 4540$^{b}$ |
| CV | 7.22 | 10.4 | 16.78 | 7.2 | 21.96 | 13.09 |
| Mean | 3694 | 73.84 | 5.72 | 30.19 | 3.33 | 4438 |
| LSD (0.05) | 500 | 7.24 | 0.9 | 1.73 | 0.68 | 3866 |

GY= Mean Grain Yield (kg/ha$^{-1}$), PH=Plant Height (cm), SPL=Spike Length (cm), SPS=Seed per Spikelet (Number), NT=Number of Tiller (Number), BMY=Biomass Yield (kg/ha$^{-1}$)

## 3.2. Correlation Between Yield Components

The (table 2) presents the Pearson correlation coefficients among key agronomic traits of food barley, including plant height (PH), spike length (SPL), seeds per spike (SPS), number of tillers (NT), biomass yield (BMY), and grain yield (GY). Correlation coefficients range between -1 and 1, with values closer to 1 indicating a strong positive relationship. The results are interpreted as follows:

Plant Height (PH): Strong positive correlation with grain yield (r = 0.844), indicating taller plants tend to produce higher yields. High correlation with biomass yield (r = 0.782), suggesting plant height significantly contributes to biomass accumulation. Moderate to strong correlations with SPL (r = 0.633), SPS (r = 0.695), and NT (r = 0.669), showing its broad influence on yield components.

Spike Length (SPL): Strong correlation with grain yield (r = 0.824), indicating longer spikes are associated with higher yields. Very strong correlation with biomass yield (r = 0.867), highlighting its contribution to overall plant biomass. High correlations with seeds per spike (r = 0.814) and number of tillers (r = 0.814), suggesting its role in enhancing yield attributes.

Seeds per Spike (SPS): Strong positive correlation with grain yield (r = 0.817), showing that a higher number of seeds per spike contributes to improved yield. Very strong correlation with biomass yield (r = 0.897), implying a significant relationship between seed production and overall plant biomass. High correlation (r = 0.852), indicating that more tillers can contribute to increased seed numbers per spike.

Number of Tillers (NT): Strong positive correlation with grain yield (r = 0.807), demonstrating the importance of tiller number in yield determination. Moderate correlation with biomass yield (r = 0.765), suggesting tiller number plays a lesser role in total biomass compared to other factors. High correlations with SPL (r = 0.814) and SPS (r = 0.852), reflecting its contribution to overall yield structure.

Biomass Yield (BMY): Very strong correlation with grain yield (r = 0.934), highlighting biomass yield as a key determinant of grain production. Consistently high correlations with PH (r = 0.782), SPL (r = 0.867), SPS (r = 0.897), and NT (r = 0.765), indicating its dependence on multiple yield components.

Grain Yield (GY): Shows a very strong positive correlation with all other traits, particularly BMY (r = 0.934), indicating that biomass yield is the most influential factor for grain yield. High correlations with PH, SPL, SPS, and NT further demonstrate the integrated contribution of these traits to yield.

*Table 2. Pearson's correlation analysis between yield and yield components.*

| | PH | SPL | SPS | NT | BMY | GY |
|---|---|---|---|---|---|---|
| PH | 1.0000000 | 0.6333353 | 0.6954223 | 0.6689527 | 0.7816781 | 0.8446132 |
| SPL | 0.6333353 | 1.0000000 | 0.8143386 | 0.8142124 | 0.8669213 | 0.8244245 |
| SPS | 0.6954223 | 0.8143386 | 1.0000000 | 0.8518149 | 0.8968130 | 0.8167754 |
| NT | 0.6689527 | 0.8142124 | 0.8518149 | 1.0000000 | 0.7647384 | 0.8071668 |
| BMY | 0.7816781 | 0.8669213 | 0.8968130 | 0.7647384 | 1.0000000 | 0.9340985 |
| GY | 0.8446132 | 0.8244245 | 0.8167754 | 0.8071668 | 0.9340985 | 1.0000000 |

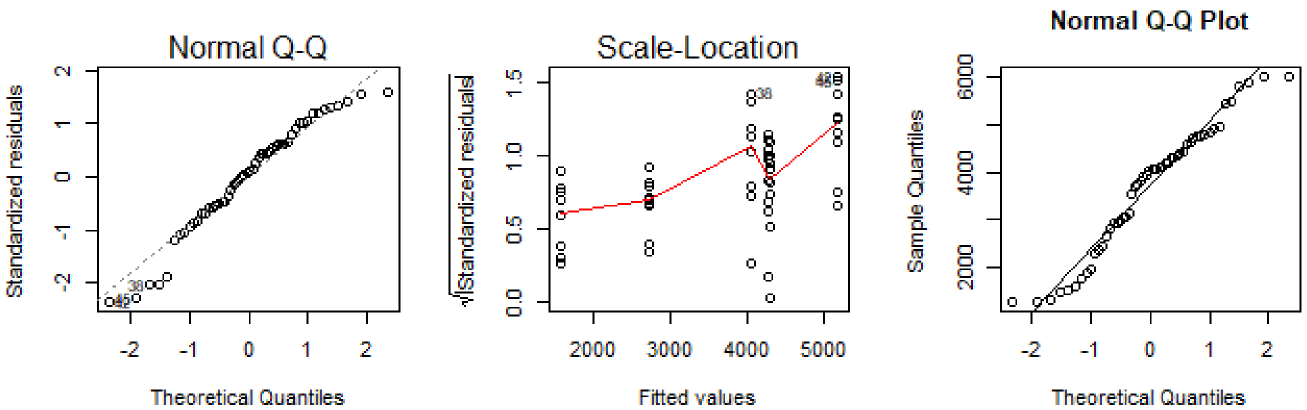


*Figure 1. Normality Tests of the data.*

This figure presents three diagnostic plots typically used to assess the assumptions and fit of a regression model: Normal Q-Q Plot, Scale-Location Plot. Each of these plots serves a specific purpose in evaluating model assumptions, particularly in linear regression.

Normal Q-Q Plot (left and right plot): This plot is used to assess whether the residuals of the model follow a normal distribution. In the Q-Q plot, if the points fall approximately along the reference line (diagonal line), it suggests that the residuals are normally distributed.

*Interpretation:* The points in this plot appear to align fairly well along the straight line, indicating that the residuals are approximately normally distributed. This is an important assumption for performing reliable statistical inference (like hypothesis testing) in linear regression.

Scale-Location Plot (middle plot): This plot is used to check the homoscedasticity assumption (i.e., constant variance of residuals). It plots the square root of the standardized residuals against the fitted values. In a well-behaved model, the points should be randomly scattered around a horizontal line with no clear pattern.

*Interpretation:* In this plot, the points seem to follow a somewhat random pattern and do not exhibit any clear trend or funnel shape. This suggests that the residuals do not display heteroscedasticity, which is a good sign for the model's validity.

Normal Q-Q Plot (right plot):

This plot is similar to the first one and provides a second look at the normality of the residuals. The purpose is to confirm the findings from the first plot.

*Interpretation:* The points on this plot also align closely with the diagonal reference line, further confirming that the residuals are approximately normally distributed.

Overall, these plots suggest that the regression model fits well, with normal residuals and constant variance, both of which are key assumptions in linear regression analysis. Both Q-Q plots suggest that the residuals are approximately normally distributed, which is a good indication for the validity of the regression model. The Scale-Location plot suggests no major issues with heteroscedasticity, meaning the variance of the residuals is consistent across the range of fitted values.

### 3.3. Interaction Between Treatments and Locations

An Interaction Plot is typically used to examine the relationship between two or more factors and their combined effect on a response variable. In this case, the mean grain yield (GY) is plotted across different locations and treatments (Figure 3). The interaction plot visually helps in understanding how the treatment effects vary across different locations and whether there's an interaction between location and treatment in determining grain yield.

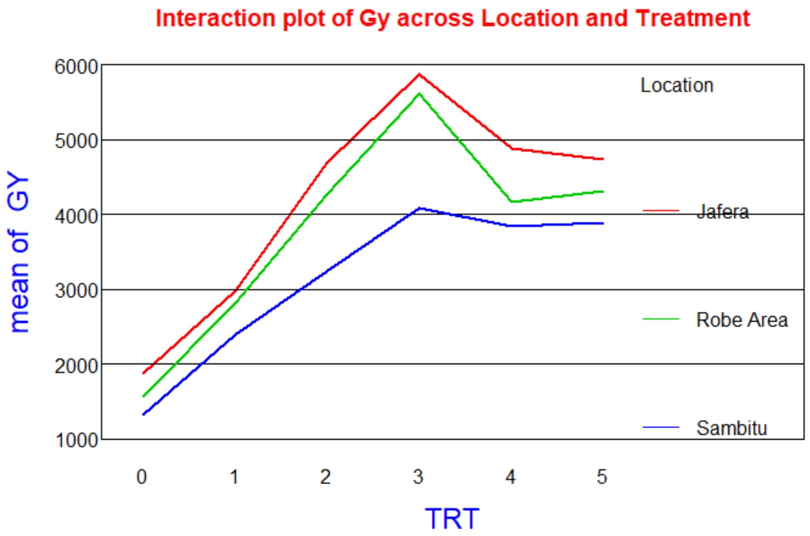


***Figure 2.*** *Interaction plot of mean grain yield across location vs treatments.*

The treatments show a consistent effect on grain yield across all locations. This indicates that location does not modify the treatment effect significantly. The plot could show a clear upward or downward trend in grain yield for each treatment regardless of location, suggesting that all locations respond similarly to the treatments. The treatments show different levels of effectiveness depending on the location. For instance, a higher application rate of ECO-GREEN might improve yields at one location, but might have little or no effect at another. This kind of result would suggest the need for more localized recommendations or adjustments in fertilizer application rates based on specific site conditions. If the lines converge or overlap, it might suggest that at certain levels of treatment, the differences in grain yield between locations are minimal, indicating a uniform response to the treatment across sites. The interaction plot serves as an essential tool in understanding how two factors, in this case, location and treatment, influence the response variable (mean grain yield).

It was noted that reparametrizing the model to include the intercept at treatment level 0 (control) revealed significant differences in mean grain yields across the treatment levels (Organic Liquid ECO-GREEN fertilizer) at all locations. The highest mean grain yields of 5700, 5500, and 4060 kg/ha were recorded at Jafera, Robe area, and Sambitu, respectively, on treatment level 3 (60 lit/ha) of ECO-GREEN. At this level (60 lit/ha), the mean grain yield was consistently higher across all locations, with Jafera exhibiting the highest yield potential, followed by Robe area. Sambitu had the lowest yields, likely due to moisture stress or drought. The lowest mean grain yields of 1950, 1700, and 1450 kg/ha were observed at Jafera, Robe area, and Sambitu, respectively, under the control treatment. In the control treatment, mean grain yields were lower at all locations. The mean grain yields for treatment levels 1 and 2 (20 lit/ha and 40 lit/ha of ECO-GREEN) were almost identical.

### 3.4. Yield Differences Across Treatment Levels

The results demonstrate that the application of Organic Liquid ECO-GREEN fertilizer had a noticeable impact on grain yields, with the highest yields occurring at treatment level 3 (60 lit/ha) (Figure 3). The higher fertilizer application likely improved nutrient availability and overall plant growth, leading to better yields. In the control (no fertilizer), showed lower grain yields. These results highlight the importance of fertilizer in improving productivity. Treatment levels 1 (20 lit/ha) and 2 (40 lit/ha) of ECO-GREEN fertilizer produced nearly identical mean grain yields. This suggests that the increase in fertilizer dosage from 20 to 40 liters per hectare did not significantly enhance yield compared to the 20 liter/ha treatment. This might indicate that there is an optimal range for fertilizer application, beyond which additional amounts do not yield proportional increases in grain production.

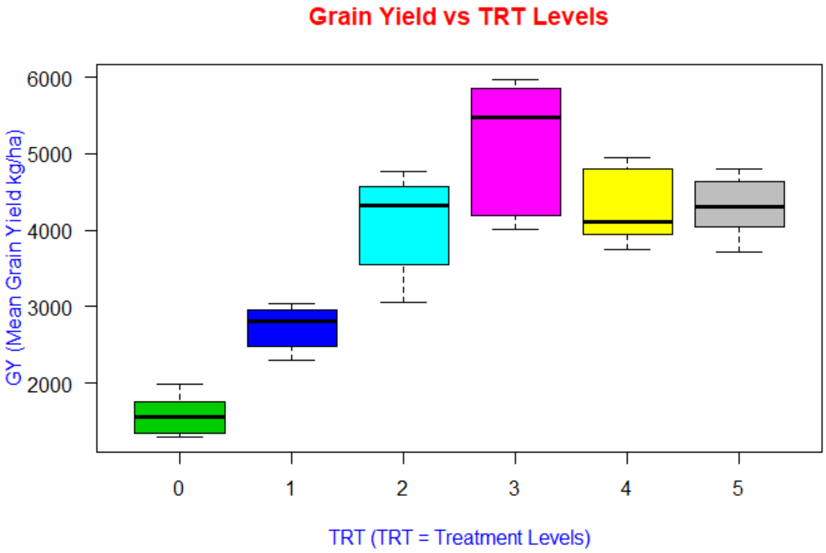


***Figure 3.*** *Box Plot of Mean Grain Yield vs Treatment.*

The box plot for treatment levels 1 and 5 is relatively short, indicating a high level of consistency in the mean grain yields across these levels. In contrast, the box plot for treatment level 3, as well as for other levels (0, 1, 2, 4, and 5), is noticeably taller, suggesting significant variation in yield responses between treatment groups. This indicates that the treatments produced quite different yield responses. Specifically, the highest mean grain yield was observed in treatment level 3, which showed a greater response compared to the other treatment levels (0, 1, 2, 4, and 5).

## 4. Conclusion and Recommendation

The application of ECO-GREEN fertilizer significantly improved all agronomic parameters compared to the control. The optimal rate for maximizing yield and yield components was 60 Lit/ha, beyond which diminishing returns were observed. This finding suggests that 60 lit/ha strikes a balance between nutrient availability and plant response, making it the most efficient rate under the study conditions. Effective fertilization practices, tailored to address specific nutrient deficiencies and crop requirements, are crucial for the economical and sustainable use of fertilizers in crop production. Based on the findings of this study, it can be concluded that the use of organic liquid fertilizer "ECO-GREEN" significantly improved both the yield and yield components of food barley compared to the control treatment. The results demonstrated that food barley productivity increased with the foliar application of "ECO-GREEN" organic liquid fertilizer, with the highest mean grain yield (4929 kg/ha) and total biomass yield (6653 kg/ha) achieved at a rate of 60 liters per hectare. This rate resulted in a 209% increase in grain yield and a 158% increase in biomass yield compared to the control. To address the current issue of unbalanced fertilizer application and soil degradation in the study area, it is important to adopt sustainable soil fertility management strategies, incorporate soil conservation practices, and avoid excessive use of unbalanced fertilizers. These actions will help improve soil health and increase crop productivity over time. Based on the results, the 60 liters per hectare application rate of "ECO-GREEN" organic liquid fertilizer is recommended as the most effective treatment for achieving higher grain and biomass yields. It is advised that this treatment be adopted by farmers in the study area. However, further research across multiple locations is needed to validate these findings and provide more robust recommendations.

Based on the results, the application of ECO-GREEN at 60 L/ha is recommended for achieving optimal barley yields in the Sinana District and similar highland regions. Exceeding this rate may not provide additional benefits and may lead to unnecessary costs. It is suggested that further studies explore the long-term effects of ECO-GREEN on soil health and its compatibility with other organic and inorganic fertilizers for more sustainable crop production. Research on the timing and frequency of fertilizer application should also be conducted to maximize efficiency. While the effects of ECO-GREEN were consistent across locations, site-specific factors such as soil type and moisture availability should be considered when applying fertilizers.

Farmers in areas prone to moisture stress, such as Sambitu, may need additional water management strategies to maximize yield potential. Given the positive results of ECO-GREEN on barley productivity, extension services should focus on educating farmers about the optimal use of organic liquid fertilizers to improve food security and agricultural sustainability in the Bale Zone.

## Abbreviations

| | |
|---|---|
| TRT | Treatment |
| GY | Mean Grain Yield ($kg/ha^{-1}$) |
| PH | Plant Height (cm) |
| SPL | Spike Length (cm) |
| SPS | Seed per Spikelet (Number) |
| NT | Number of Tiller (Number) |
| BMY | Biomass Yield ($kg/ha^{-1}$) |

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## Conflicts of Interest

The authors declare no conflicts of interest.

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