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FDRE TECHNICAL & VOCATIONAL TRAINING INSTITUTE

**SCHOOL OF GRADUATE STUDIES**

**FACULTY OF AGRICULTURE AND AGRO-PROCESSING TECHNOLOGY**

**DEPARTMENT OF FRUIT AND VEGETABLE PROCESSING TECHNOLOGY**

# EFFECTS OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH, YIELD, AND FRUIT QUALITY OF TOMATO *(Solanum lycopersicum)* UNDER GREENHOUSE CONDITIONS IN ADDIS ABABA, ETHIOPIA

**MSC THESIS**

**BY**

**ABIYOT GRUM TAMRAT**

**JUNE 2026**

**ADDIS ABABA, ETHIOPIA**

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A THESIS SUBMITTED TO FDRE TECHNICAL AND VOCATIONAL TRAINING INSTITUTE, FACULTY OF AGRICULTURE AND AGRO-PROCESSING TECHNOLOGY

FRUIT AND VEGETABLE PRODUCTION TECHNOLOGY PROGRAM

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FRUIT AND VEGETABLE PRODUCTION TECHNOLOGY

BY

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JUNE 2026

ADDIS ABABA, ETHIOPIA

# ADVISORS APPROVAL SHEET

This is to certify that the thesis entitled "Effects of Organic and Inorganic Fertilizers on Growth, Yield, and Fruit Quality of Tomato (*Solanum lycopersicum* L.) Under Greenhouse Conditions in Addis Ababa, Ethiopia" conducted by Abiyot Girum Tamrat ID No. TTMR 257/16. This work is submitted in partial fulfillment of the requirements for the Master of Degree of science in Fruit and Vegetable Production Technology. Having met the academic standards of the Department of Fruit and Vegetable Processing Technology, I recommend that the candidate be permitted to submit the thesis for final defense.

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## CERTIFICATION SHEET

Final approval and acceptance of thesis contingent up on the submission of its final copy to the council of graduate studies (CGS) through the Department Graduate Committee (DGC) of the candidate's major department.

I hereby certify that I have read this thesis under my direction and recommended that it be accepted as fulfilling the thesis requirement for the Degree of Masters of Science in Fruit and Vegetable Production Technology.

| Name of Major advisor | Signature | Date |
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| _____ | _____ | _____ |

# STATEMENT OF AUTHOR

Frist, I declare that this thesis is my original work and that all sources of material used for this thesis have been appropriately acknowledged. This thesis has been submitted in partial fulfillment of the requirements of MSc. degree at federal democratic republic of Ethiopia Technical and vocational training institute faculty of Agriculture and Agro-processing Technology and is deposited at the institute library to be made available to user rules of the library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief references from this are allowable without spatial permission for extended reference from or reproduction of this manuscript in whole in part may be granted by the head of the department of the dean of the school of graduate studies when in his or her judgment the proposed use of the materials is for scholarly interest. In all other instance, however, permission must be obtained from the author.

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# TABLE OF CONTENTS


Content Page

ADVISORS APPROVAL SHEET ..... i

CERTIFICATION SHEET ..... ii

STATEMENT OF AUTHOR ..... iii

ACKNOWLEDGMENT ..... iv

LIST OF TABLES ..... ix

LIST OF FIGURES ..... x

LIST OF APPENDIX ..... xi

LIST OF APPENDIX FIGURE ..... xii

ABBREVIATION AND ACRONYM ..... xiii

*ABSTRACT* ..... xiv

1. INTRODUCTION ..... 1

1.1. Background of the Study ..... 1

1.2. Statement of the Problem ..... 3

1.3. Objectives of the Study ..... 4

2. LITERATURE REVIEW ..... 5

2.1 Origin and Distribution of Tomato ..... 5

2.2. Ecology and Nutritional Importance of Tomato ..... 5

2.3. Nutrient Requirements for Tomato Cultivation ..... 6

2.4.1. Response of Tomato to DAP and Urea Fertilizers ..... 7

2.4.2. Growth Response of Tomato to DAP and Urea Fertilizer ..... 8

2.4.3. Yield and Quality Response of Tomato to DAP and Urea ..... 10

2.5. Phenological Response of Tomato to Eco-Green Fertilizer ..... 13

2.5.1. Effect of Eco-Green Fertilizer on Tomato Phenology ..... 13
2.5.2. Growth Response of Tomato to Eco-Green Fertilizer ..... 15
2.5.3. Yield and Quality Response of Tomato to Eco-Green Fertilizer ..... 16
2.6. Response of Tomato to garlic and onion peel powder ..... 20
2.6.1. Response of Tomato Phenology to Garlic and Onion Peel Powder ..... 20
2.6.2. Response of Tomato Growth to Garlic and Onion Peel Powder ..... 20
2.6.3. Response of Tomato Yield and Quality to Garlic and Onion Peel Powder ..... 20
2.7. Response of Tomato to Integrated Fertilization Application ..... 21
2.7.1. Phenological Response of Tomato to Integrated Fertilizer Application ..... 21
2.7.2. Growth Response of Tomato to Integrated Fertilizer Application ..... 22
2.7.3. Yield and quality Response of Tomato to Integrated Fertilizer Application ..... 24
3. MATERIALS AND METHODS ..... 28
3.1. Description of the Study Area ..... 28
3.2. Experimental Materials ..... 28
3.3. Treatments and Experimental Design ..... 30
3.4. Preparation of onion and garlic peel .....**Error! Bookmark not defined.**
3.5. Experimental procedures and management ..... 31
3.6. Data collection ..... 33
3.6.1. Soil data analysis ..... 33
3.6.2. Plant parameter data collection ..... 33
3.7. Statistical Analysis ..... 35
3.8. Economic Analysis ..... 35
4. RESULT AND DISCUSSION ..... 36
4.1. Soil and Onion-Garlic peel analysis before planting ..... 36

4.2. Phenological Parameters ..... 39
4.2.1. Days to First Flowering ..... 39
4.2.2. Days to 50% Flowering ..... 39
4.2.3. Days to First Fruit Setting ..... 39
4.2.4. Days to First Fruit Harvest ..... 40
4.3. Vegetative Growth Parameters ..... 41
4.3.1. Plant Height ..... 41
4.3.2. Stem Diameter (mm) ..... 42
4.3.3. Number of primary and secondary branches ..... 42
4.4. Fruit Morphology and Number ..... 44
4.4.1. Fruit Diameter (Major, Intermediate, and Minor) ..... 44
4.4.2. Total Fruit Number per Plant ..... 45
4.4.3. Fruit Volume ..... 47
4.5. Yield Parameters ..... 47
4.5.1. Marketable Fruit Yield ..... 47
4.5.2. Unmarketable Fruit Yield ..... 48
4.5.3. Total Fruit Yield ..... 49
4.5.4 Fruit weight ..... 50
4.5.5 Fruit Density ..... 51
4.6. Quality Parameters ..... 52
4.6.1. Fruit pH ..... 53
4.6.2. Total Soluble Solids (TSS°) °Brix ..... 53
4.6.3. Fruit color ..... 54
4.7. Partial Budget Analysis ..... 56

5. CONCLUSIONS AND RECOMMENDATIONS ..... 57

5.1. Conclusions ..... 57

5.2. Recommendations ..... 58

6. REFERENCE ..... 59

7. APPEDNIXXS ..... 72

# LIST OF TABLES

Table 1. Characteristics of Galilea F1 tomato variety ..... 29

Table 2: treatment level ..... 30

Table 3. Physical and chemical properties of the experimental soil and, onion and garlic peel before planting. ..... 38

Table 4: Effect of Fertilizer Types on Phenological parameters of tomato ..... 40

Table 5: Effect of Fertilizer Types on growth parameters of tomato ..... 43

Table 6. Effect of Fertilizer Types on tomato fruit diameter ..... 44

Table 7. Effect of Fertilizer Types on tomato fruit volume and total fruit number per plant ..... 46

Table 8. Effect of Fertilizer Types on tomato fruit yield ..... 52

Table 9. Effect of Fertilizer Types on tomato fruit quality ..... 54

Table 10. Effect of Fertilizer Types on Tomato fruit color ..... 55

Table 11. Partial Budget Analysis ..... 57

# LIST OF FIGURES

Figure 1 : Map of study Area ..... 28

Figure 2: Effect of Fertilizer Types on tomato Marketable fruit yield**Error! Bookmark not defined.**

Figure 3: Effect of Fertilizer Types on tomato Unmarketable fruit yield ..... 49

Figure 4: Effect of Fertilizer Types on tomato total fruit yield ..... 50

# LIST OF APPENDIX

Appendix 1: ANOVA Summary for Phenological parameters..... 72

Appendix 2: ANOVA Summary for Growth parameters ..... 72

Appendix 3: ANOVA Summary for Yield and Fruit Count..... 73

Appendix 4: ANOVA for Fruit Quality and Physical Parameters..... 74

# LIST OF APPENDIX FIGURE

Appendix figure 1: all over view of management activity of tomato production..... 75

# ABBREVIATION AND ACRONYM

| | |
|---|---|
| ANOVA | Analysis of Variance |
| C:N | Carbon-to-Nitrogen ratio |
| CEC | Cation Exchange Capacity |
| CV | Coefficient of Variation |
| EC | Electrical Conductivity |
| HARC | Holetta Agricultural Research Center |
| INM | Integrated Nutrient Management |
| LSD | Least Significant Difference |
| NPS | Nitrogen, Phosphorus, and Sulfur |
| pH | Potential of Hydrogen |
| PSB | Phosphate Solubilizing Bacteria |
| RCBD | Randomized Complete Block Design |
| RF | Recommended Fertilizer |
| TSS | Total Soluble Solids |
| USDA | United States Department of Agriculture |
| VAM | Vesicular-Arbuscular Mycorrhiza |

## *ABSTRACT*

*Tomato productivity in urban areas of Ethiopia, including Addis Ababa, remains below the global average due to declining soil fertility, high costs of inorganic fertilizers, and inadequate nutrient management practices. To address this challenge, a greenhouse experiment was conducted at FDRE technical and vocational training institute, in Yeka Sub-city, Addis Ababa, to evaluate the response of Tomato to organic and inorganic fertilizer application. The experiment was arranged in a randomized complete block design with three replications. The experiment consisted of eight fertilizer treatments: control, recommended inorganic fertilizer (RF), 50% RF + 381 kg ha$^{-1}$ onion-garlic peel powder, 25% Eco Green (EcoG) + 572 kg ha$^{-1}$ peel powder, 50% EcoG + 381 kg ha$^{-1}$ peel powder, 75% EcoG + 191 kg ha$^{-1}$ peel powder, 762 kg ha$^{-1}$ peel powder alone, and recommended Eco Green fertilizer. Results showed that the application of 50% RF combined with 381 kg/ha peel enhanced tomato growth by reducing the days to first flowering, 50% flowering, first fruit setting, and first fruit harvest by 46.5%, 40.4%, 41.68%, and 13.58% compared to the control, respectively. The recommended inorganic fertilizer and 50% RF + 381 kg ha$^{-1}$ peel powder produced statistically comparable marketable yields of 65.33 and 65.29 t ha$^{-1}$, respectively. In addition, tomato quality parameters including pH, total soluble solids, fruit density, shape, and size were significantly influenced by the use of organic and inorganic fertilizers. Partial budget analysis further revealed that 50% RF + 381 kg/ha peel provided the maximum net benefit of 1,705,731 Birr/ha with a marginal rate of return of 3064.2%. Overall, the combined application of onion-garlic peel powder with reduced rates of inorganic fertilizer improved tomato growth, yield, fruit quality, and economic returns, indicating its potential as a sustainable nutrient management strategy for greenhouse tomato production.*



*Keywords: Solanum lycopersicum, nutrient management, Onion-garlic peel powder, Eco Green,*

# 1. INTRODUCTION

## 1.1. Background of the Study

Tomato *(Solanum lycopersicum L.)* is one of the economically significant vegetables in the world in terms of production, consumption and economic value, producing annually a total of about 182.2 million tons on 4.73 million hectares worldwide (Wakene and Sharew, 2024). Apart from its significant economic contribution, tomato is a critical cornerstone of human nutrition. The fruit is rich in amino acids, fibers, minerals like iron and phosphorus and vitamins A, B and C (Lhamo *et al*., 2022; Liu *et al*., 2022). Tomato is a significant source of antioxidants, such as lycopene, beta-carotene and Vitamin C (ascorbic acid). Despite the variability among varieties and growing conditions, the fresh tomato fruit contains 21mg of ascorbic acid per 100g fresh weight, and through the antioxidant effect, lycopene and other carotenoids increase the nutritional value of the tomato fruit (Gemechu, 2019).

In Ethiopia, tomato is one of the economically significant commercial commodities produced under different agro-ecological conditions from 700-2200 meters above sea level (Beyene and Mulu, 2019). It is one of the main sources of income for more than 254,000 smallholder farmers (Gray, 2013). However, the status of national tomato production is characterized by a severe productivity gap. While the global benchmark for tomato yield spans from 23.7 to 70.8 t/ha, Ethiopian productivity remains strikingly low, averaging only 10-20 t/ha (Dzankovic et *al*., 2025). This low productivity is attributed to a combination of biophysical constraints, including irregular rainfall, heavy pest and disease pressures, severe depletion of soil organic matter, and suboptimal nutrient management practices. The low productivity can be linked to factors such as biophysical factors including uneven rains, presence of diseases and pests, extreme loss of soil organic matter, among others.

Urban agriculture has been identified as a crucial structural solution to the situation in rapidly growing cities such as Addis Ababa. In this city, food costs make up more than 70% of total income for households; hence, local farming makes these families economically resilient as it provides income and nutritious food at the same time (Tafese, 2014). Tomatoes are widely used in preparing typical Ethiopian sauces (wots) and salads, and prepared tomatoes are consumed in much higher amounts in metropolitan areas compared to any other vegetable(Wakene and

Sharew, 2024). Given the challenge of urban land shortage, polluted soil, and erratic weather, greenhouse pot production becomes a necessary tool.

Nutrient management plays a critical role in determining both the dynamics of the vegetative growth and ultimately the yield quality of the tomatoes. Tomato is a heavy feeder crop and requires consistent and balanced nutrient uptake to achieve optimal heights, leaf area coverage, stem diameter and effective photosynthesis to produce desirable yields. Moreover, fertilizer management controls fruit quality characteristics (Manga et *al*., 2024). The nutritional needs have been addressed through the use of inorganic fertilizers such as Diammonium Phosphate (DAP) and Urea. The application of these chemical fertilizers enables high availability of nitrogen (N) and phosphorus (P) nutrients for the plant. Nevertheless, current trends in sustainable agriculture are now exploring other sources of nutrients.

Eco-Green, specialized commercial liquid organic fertilizer has gained scientific prominence due to its rich content of readily bioavailable macro-and micronutrients, humic substance, fulvic substances, amino acids, and other bioactivate components that support plant growth. It also contains growth-promoting factors that stimulate root development and enhance nutrient uptake efficiency when applied as afoliar or soil drench Ateka *et al*. (2024). Because liquid organic fertilizers improve soil biological activity and nutrient availability while providing nutrients in easily absorbed forms, they are becoming more and more popular in sustainable crop production (Gao *et al*., 2023).

Concurrently, botanical bio-wastes like onion and garlic peel powders are also drawing scientific attention. Markets, homes, restaurants, and food processing operations produce large amounts of onion and garlic peels, which are frequently thrown away as waste, raising environmental issues. Nonetheless, these by-products are abundant in vital plant nutrients, such as calcium (Ca) magnesium (Mg), potassium (K), and other micronutrients that promote fruit development and plant growth. Furthermore, bioactive chemicals including phenolics, flavonoids and sulfer-containing compounds found in onion and garlic peels can boost soil biological activity, promote root development, improve nutrient uptake, and boost plant resistance to biotic and abiotic challenges ( Roshini *et al*., 2023; Shabir *et al*., 2022).

Relying solely on either synthetic or organic nutrients often falls short of achieving optimized, long-term yield targets. Consequently, the strategic combination of inorganic and organic

fertilizers provides a logical, sustainable framework. Integrated nutrient management aims to synchronize the immediate nutrient release of chemical fertilizers with the slower, sustained release of organic amendments. This approach maintains soil structural integrity, enhances microbial activity, increases fertilizer use efficiency, and avoids the nutritional deficiencies or toxicities common in monocultural feeding regimes. Therefore, onion and garlic peel powders were selected to evaluate their effectiveness as low-cost and environmentally friendly nutrient sources for improving tomato growth, yield, and fruit quality.

## 1.2. Statement of the Problem

Production of tomatoes in urban areas of Ethiopia is limited by a number of factors such as low fertility of the soil, improper use of fertilizers, and absence of good varieties that can be adapted to urban environments (Tesfay et al., 2018). An alternative system for the sustainable and economical management of soil is an integrated nutrient management system, which improves soil properties and increases soil fertility without having an adverse effect on the environment. This is because the continuous use of inorganic fertilizers alone leads to soil organic matter degradation, soil acidity or alkalization, soil deterioration, and environmental pollution (Li *et al*., 2025). Research findings from other countries indicated that the combined use of inorganic and organic fertilizers including onion and garlic peel significantly enhanced the response of tomato plants both in phonological, growath, yield and quality parameters ( Roshini *et al*., 2023) .

Generally, there is limited research in Ethiopia on the integration of organic and inorganic fertilizer types in urban agricultural systems, leading to a lack of evidence-based recommendations for urban farmers. Households and restaurants make extensive use of onions in different forms. Large amounts of onion and garlic peel waste are generated, yet it ends up being discarded. However, the use of inorganic and organic fertilizer resources including onions and garlic peel in tomato production has not been studied before within urban and rural agricultural setups. It is for this reason that the study becomes vital in reducing the cost of synthetic fertilizers, improving soil fertility, and ensuring efficient tomato production under the prevailing environment of Yeka Sub-City, Addis Ababa.

## 1.3. Objectives of the Study

### General objective

The general objective of the study was to assess how integrated nutrient management affects the growth, yield, and fruit quality of tomatoes in greenhouse conditions in Addis Ababa, Ethiopia.

### Specific objectives

- To investigate the effect of organic and inorganic fertilizer types and their combinations on growth and yield of tomato plants.
- To evaluate the effect of sole and combined application of organic and inorganic fertilizer treatments on tomato fruit quality attributes.
- To assess the economic feasibility and cost-effectiveness of the different fertilizer treatments associated with each application regime

# 2. LITERATURE REVIEW

## 2.1 Origin and Distribution of Tomato

The tomato *(Solanum lycopersicum L.)* belongs to the Solanaceae family of plants and its origins can be traced back to the Andean areas of South America comprising current day Peru, Ecuador, Bolivia, and Chile (Gatahi, 2020; Sudesh *et al*., 2024). Although wild ancestors originated in the South American mountains, the main area where it was domesticated and diversified is regarded as Mexico where early cultivation practices were employed before the plant became an internationally famous one (Ger *et al.*, 2024). Thus, the evolution of the plant began from its wild Andean relatives and continued through the process of domestication in Mexico that formed the genetic basis for further dispersal of the plant to other agro-ecosystems around the world.

With the discovery of the Americas by Spanish explorers, the tomato spread to Europe and thereafter reached different parts of the globe comprising tropical, subtropical, and temperate climates where it now represents a widely cultivated agricultural crop (Gatahi, 2020).Today, the tomato is among the most commercially important vegetable crops on Earth, being grown extensively in China that leads in production followed by countries like the USA, India, and Egypt (Ger *et al.*, 2024).

For tomato farming in Ethiopia, the leading states include Oromia (68%), Tigray (5%), and Somalia (4%) Wakene & Sharew, 2024). There is a smart choice in the location of tomato growing in the upper Awash Valley, Ziway, and Wondo-Genet regions since the altitude of these places is between 700 to 2,200 meters above sea level (Gemechu and Beyene, 2019).

## 2.2. Ecology and Nutritional Importance of Tomato

The tomato plant is a world-renowned crop that takes second place after potatoes on the list of horticultural crops based on international economic significance (Jat, And, et al., 2018). This plant demonstrates exceptional ecological adaptability in cultivation, prospering in various regions with different climate types such as tropical, subtropical, and temperate zones (Wakene & Sharew, 2024). As for Ethiopia, the crop grows well in mid-to-low-land areas with an altitude of 700 to 2000 meters above sea level in conditions of favorable environmental factors provided by rainfall within 700 and more than 1400 mm annually (Gemechu and Beyene, 2019)To promote their best physiological growth and development, the plants require slightly acidic soil

with pH from 6.0 to 6.8 (Islam *et al*., 2018). Nevertheless, the farmers need to keep in mind the fact that the yield might be limited by environmental stresses such as salinity, drought, and temperature changes (Lu *et al*., 2025).

Apart from being cultivated on a large scale, tomatoes are valued highly due to their nutritive value, which greatly contributes to human health and wellbeing (Lu *et al*., 2025).They are rich sources of necessary vitamins A, B, and C, as well as minerals, such as iron and phosphorus (Sabit, 2020). Notable are the powerful antioxidants present in tomatoes in the form of carotenoids, like lycopene and beta-carotene, and polyphenols, among others (Wakene & Sharew, 2024)These special compounds work through their ability to scavenge dangerous free radicals in order to protect body cells from any damage (Ger *et al*., 2024). There is clinical evidence that consuming tomatoes in any forms is associated with decreased chances of developing heart diseases, and high lycopene content lowers risks of some types of cancer, such as prostate and lung cancer (Gao *et al.*, 2023; Solanki *et al.*, 2017). It is a valuable blood purifying food, which stimulates gastric secretion (Jat *et al*., 2018).

## 2.3. Nutrient Requirements for Tomato Cultivation

A balanced combination of macronutrients, secondary, and micronutrients is crucial in tomato crop cultivation in order to ensure proper vegetative growth and improved fruit qualities. For instance, nitrogen is a basic element in the metabolic processes of plants and photosynthesis although the proportion needs to be kept under control in order to avoid blossom-end rot caused mainly by the deficiency of local calcium (Ramesh *et al*., 2023). The phosphorous nutrient accelerates maturity of tomato fruits and increases marketable production while potassium and boron contribute to the transport of sugar, fruit firmness, and improvement of such properties as titratable acidity and color (Jat, And, et *al*., 2018). In addition, the secondary and micronutrients like magnesium and zinc are important in cell wall formation and enzyme functions (Ramesh *et al*., 2023). Modern studies highlight INM as the best way because the interaction of organic manures like vermicompost or poultry manure and inorganic fertilizer has positive effect on the improvement of growth factors, productivity, and biochemistry including Total Soluble Solids (TSS), ascorbic acid levels, etc. (Li *et al.*, 2025).

## 2.4. Response of Tomato to DAP and Urea Fertilizer

### 2.4.1. Response of Tomato to DAP and Urea Fertilizers

**Days to 50% Flowering**

DAP application can considerably lower the period taken by the tomato plant to attain 50% flowering. As per Afrin (2022), tomatoes treated with the correct level of phosphorus using DAP attained 50% flowering in 36.4 days after transplanting (DAT), while in the control group, they did so in 44.8 DAT, reducing 18.7%.This speedup happens because phosphorus helps produce florigen and improves the root system's ability to support reproductive structures.

Nitrogen is important for growth, but too much urea can lead to luxury consumption and this causes the plant to stay in a vegetative state longer. According to Kabir (2021)high levels of urea (> 200 kg N/ha) caused 50% flowering after 49.

2 DAT, while a moderate nitrogen level (100 kg N/ha) resulted in flowering after 41.5 DAT. In a study by Soni *et al*. (2026), the minimum 50% flowering (38.5 DAT) was achieved where DAP was applied as basal dose and then top-dressed with urea in weeks 3 and 6. On the other hand, treatment with only urea but without DAPS resulted in 50% flowering after 46.3 DAT. This indicates that the phosphorus component of DAP is a physiological stimulus for flowering, which counteracts the extended vegetative effect of nitrogen.

**Days to 90% Maturity**

Interaction of Urea with DAP causes an effect that forces the plant to mature faster or slower. The main characteristic feature of Phosphorus is shortening the life cycle of the plant. Phosphorus stimulates earlier flowering and rapid fruit formation. As Regassa et *al* . (2016)have noted, application of DAP that contains not only phosphorus but also starter nitrogen shortened the time needed for maturity significantly. In the mentioned experiment, tomatoes with 150 kg/ha of DAP became 90% mature in 94.2 days, whereas control tomatoes without fertilizers were at this stage in 108.5 days. Reduction of this time period by about 14 days is caused by the ability of phosphorus to speed up translocation of photosynthesis from the leaves to fruits.

Kakabouki *et al*. (2024)have stated, the increase in the rate of Urea from 100 kg/ha to 250 kg/ha also increased days required for attaining 90% maturity. In other words, plants with high doses

of urea became 90% mature in 114.6 days that is 10.2 days more than in case of moderate doses of nitrogen. It happens because higher doses of nitrogen preserve higher auxin and cytokinin activity. This maintains the plant in a state of biomass growth, delaying the physiological death or senescence needed for final fruit ripening. (Bekunda *et al.*, 2022)found that a balanced application, specifically a 1:2 ratio of DAP to urea, led to an optimal maturity period of 98.4 days

### 2.4.2. Growth Response of Tomato to DAP and Urea Fertilizer

**Plant height**

Evidence has shown that the use of DAP (which contains initial phosphorus and nitrogen) together with urea (which provides high intensity nitrogen) enhances the growth of tomato plants. According to Kahsay *et al.* (2016)tomato plants provided with 150 kg/ha DAP and 100 kg/ha of urea attained a mean height of 112.4 cm at 90 days after transplanting (DAT). However, the control plants attained a mean height of 64.2 cm. This is an increase of 75% in the height growth due to nitrogen contribution towards cell division and phosphorus towards initial root development.

According to Alveno *et al*. (2024) tomatoes given 60 kg/ha $P_2O_5$ (from DAP) are 22.5% higher in height during the first 30 DAT than tomatoes lacking phosphorus. Chibi *et al.* (2015)state that the optimum height of tomato (134.6 cm) is attained through 120 kg/ha DAP and 180 kg/ha urea. However, after attaining this height, no further height development takes place as the plant focuses on its other developments like fruit and biomass development. Where the plant shifts energy from vertical growth to fruit production and biomass accumulation.

**Stem diameter**

The stem diameter of tomato plants that are more thick compared to thin stems can withstand fruit weight and prevent lodging of the tomato plants. This is attributed to the phosphorus present in DAP, which is considered crucial for the development of vascular tissues present in both xylem and phloem. Olagunju *et al*. (2023) discovered that tomato plants that were supplied with the rate of 100 kg/ha of DAP had an average stem diameter of 14.22 mm while the control plants had an average diameter of 8.54 mm. According to Ger *et al*. (2024), there was a considerable increase in stem diameter when the amount of urea increased from 0 to 150 kg/ha. Tomato plant

stem diameter increased from 9.1 mm for tomato plants that were supplied with no urea to 13.8 mm with the supply of 150 kg/ha urea. Tang et al. (2025),also discovered that tomato plants with 120 kg/ha urea and 100 kg/ha DAP application had the highest stem diameter of 15.65 mm.

In contrast, the average stem diameter of plants grown only with 120 kg/ha urea was only 12.30 mm. According to Nishat *et al*. (2021), as the amount of urea used to fertilize tomato increased from zero to 150 kg/ha, the diameter of the associated stems increased from 9.1 to 13.8 mm. However, the diameter of stems did not grow any thicker than 13.9 mm as long as more than 200 kg/ha was used on plants, indicating that nitrogen was no longer providing any positive benefit to lateral growth. Bisen *et al*. (2025), reported that the thickest stems (15.65 mm) occurred on plants that received both 100 kg/ha DAP and 120 kg/ha of urea; they were only 12.30 mm thick when urea alone was applied.

**Primary and secondary branch**

Branching patterns of tomato plants vary significantly with different rates of application of nitrogen-based fertilizers, i.e., urea and NPS, both of which affect primary branch numbers an indicator of vegetative growth as a function of amount of fertilizer applied. According to Begna (2018), the number of primary branches increases with higher rates of nitrogen fertilizer. The quantity of fertilizer applied to the soil has a measurable effect on the number of primary branches. Temesgen *et al.* (2025) found that plantings of 300 kg/ha produced the highest number of primary branches (8.68) while unfertilized control plots had the lowest number (3.33). Nitrogen levels also affect branch density. Beyene and Mulu (2019) found that the addition of 100 kg/ha of nitrogen to the soil increased the number of branches by 24.34% when compared to the control (0 kg N/ha).

Different combinations of fertilizers also influence the development of the secondary branches of tomato plants as well as the number of secondary branches on a plant for all of the treatments reported by Begna (2018) to be equivalent to the number of branches from the plants receiving Eco-Green fertilization. The highest number of secondary branches (3) occurred in the plants receiving only Urea while there were only two branches on those plants not treated with urea.

### 2.4.3. Yield and Quality Response of Tomato to DAP and Urea

**Fruit diameter**

The type and quantity of fertilizers affect the size of tomato fruit. A rate of 300 kg/ha of DAP resulted in wider tomato fruit size by 60.03 mm Temesgen *et al*., 2025). Recent studies involving nano-fertilizers produced positive results concerning the development and quality of fruits. According to research by Keerthana *et al*. (2024), using 75% of the recommended dose of urea and DAP abled the fruit to achieve its greatest diameter at 11.08mm.

**Fruit volume**

Fruit size and yield potential are highly dependent on the use of nitrogen and phosphorus fertilizer, specifically urea and DAP in tomatoes. These fertilizers are critical for enhancing vegetative, root, and fruit development, all critical components to producing high-yielding crops. Although increasing the amount of fertilizer generally increases fruit size, it will be affected by such variables as the type of fertilizer, how much of the fertilizer is applied, and the genetic characteristics of the tomato variety being grown (Sigaye, 2025).

In modern day farming practices, a common practice is to use DAP to enhance various characteristics of fruits. As Korane et *al*. (2025) noted that, higher application rates of DAP resulted in heavier average weights of fruits (68.6 g) when applied at 200 kg/ha. According to Temesgen et al. (2025) suggested that the application of NPS fertilizers also influenced the physical size of the fruit. He found that applying 300 kg/ha of NPS increased the width of the fruit to 60.03 mm, which was greater than when lower amounts were used.

**Fruit number**

Nitrogen mainly increases the number of clusters while phosphorus is necessary to effectively produce fruit (Beyene and Amare, 2019). Researchers across multiple experiments have concluded that mineral fertilizers (such as DAP and Urea) determine the overall prolificacy of tomato crops (Temesgen *et al.*, 2025). Mineral fertilization substantially enhances fruit production (compared to non-fertilized controls).

Beyene and Amare (2019) found that 100 kg/ha DAP and 150 kg/ha Urea resulted in 48.6 fruits per plant, or 151.8% increase from the control yield of 19.3 fruits. Similarly, Sabit (2020) found that tomato plants provided with 75% chemical fertilizer yielded the greatest quantity of fruit per

plant (35.1) and per cluster (3.89). Maximizing these parameters of growth and yield has been advised by Begna, (2018) to be through a comprehensive program of 200 kg/ha DAP, 300 kg/ha urea, and 400 L/ha eco-green. Marketable fruit are those that produce the standard size of fruit with no defects. A nutrient ratio like this is essential to produce this type of fruit; the highest marketable count of fruit at 38.4 per plant was with 100 kg/ha N and 92 kg/ha $P_2O_5$ and the number of marketable fruit is considerably decreased without phosphorus by producing undersized fruit and/or fruit with disorders (Ger et *al*., 2024). Marketable fruits to total number of fruit ratio of (86%) was highest when DAP 150 kg/ha and Urea 100 kg/ha were used. Urea application 250 kg/ha had an overall reduction in marketability ratio to 64% because many of the fruits were unmarketable due to cracking and small size (Kahsay *et al.*, 2016).

**Fruit yield**

Total yield of tomato varieties is significantly affected by the way nitrogen and phosphorus produce an interaction effect on the weight and cluster of tomatoes produced (Temesgen *et al*., 2025). Korane *et al*. (2025), found that 150 kg/ha of DAP plus 100 kg/ha of urea yielded a total yield of 54.8 t/ha (201% higher than the yield obtained from this crop produced under the control plot, which was only 18.2 t/ha). Ger et *al*. (2024) suggested that the yield of 38.183 t/ha was gained from 200 kg/ha DAP and 14.612 t/ha from the control. Marketable yield refers to the fruit that is free of pests, diseases, and physiological disorders and is very sensitive to fertilizer level (Temesgen *et al.*, 2025). Johnson (2025), reported a marketable yield of 46.5 t/ha using 120kg/ha of Urea and 92kg/ha of $P_2O_5$ and this indicated that Phosphorus increases the marketable ratio by strengthening cellular walls.

Blended and combined interactions include the impact of NPS at Jimma where 200 kg/ha NPS resulted in a profitable yield of marketable fruit of 15.383 t/ha (Ger *et al*., 2024). Sigaye *et al.* (2022) ratified that at an application rate of 250 kg/ha of Urea, unmarketable yield was as high as 8.4 t/ha due to sun-scald and cracking of the fruit, while at a balanced application rate of 100 kg/ha, unmarketable yield was only 2.1 t/ha.

**Fruit Weight**

Nitrogen application is a primary driver of tomato fruit mass, with efficiency varying greatly by formulation. Kabir (2021) showed that Urea Super Granule gave the highest single fruit weight (5.23 kg/plant) significantly superior to Frilled Urea (4.73 kg) and the unfertilized control (3.03

kg). Again, a mixture of 80% Urea Super Granule with 20% cow dung showed a good productivity of 4.61 kg per plant indicating the integrated organic-mineral regimes can maintain high productivity. In soils deficient in macronutrients, traditional Urea and Di-ammonium Phosphate (DAP) are the regional standard, but blended NPS fertilizers at 150 kg $ha^{-1}$ have achieved peak marketable fruit weights of 67.33 g, establishing it as a very effective substitute for DAP in improving commercial fruit size (Ger *et al*., 2024).

**Fruit density**

Despite the lack of empirical measurements of the density of fruits, diameter and fruit firmness have become the most important indicators of internal fruit compactness. As was found by Kabir (2021),100% nitrogen gave the highest fruit diameters (6.52 cm) and highest plot-level productivity (52.13 kg). Nevertheless, the application of urea with inhibitors (urea + NI + UI) improved the crop but had no impact on the fruit weight and, therefore, could be assumed to be aimed at increasing fruit numbers rather than their internal compactness. Fertilization with inorganic urea made fruit 6% softer than those treated with compost from tomato pomace, which indicated that chemical fertilizers favored rapid growth but not tissue density (Kakabouki *et al*., 2024).

**Fruit Quality (TSS and pH)**

The total soluble solids (TSS), reported in degrees Brix (°Brix), are used as a measurement of sweetness and flavor response. According to Keerthana *et al*. (2024), the maximum TSS was obtained from a combination of 75% of the recommended dose of nitrogen and phosphorus and two foliar applications of nano-diammonium phosphate (nano-DAP) at a rate of 0.7%, which produced a TSS of 5.52 °Brix; while the control group had a TSS of 4.22 °Brix. Furthermore, Shastri (2023) determined that TSS was maximized at 5.4 °Brix with 120 kg of urea per hectare and 80 kg of DAP per hectare, respectively.

Sugar-acid ratio determines how a product will taste qualitatively; Gebremedhin *et al.* (2024) found that balanced N and P applications kept the initial Tomato pH at 4.32 (an ideal processing pH) whereas control plants produced more acidic fruit (pH = 3.95). Fruit structural quality reduces the occurrence of puffiness and improves shelf life; the importance of P from DAP for development of thick pericarp walls and dense locular gel helps create fruit with increased structural quality. Ger et *al*. (2024), reported that controlling the density of their fruits was made

possible with a treatment of 100 kg of DAP and 150 kg of urea per hectare because the density of fruit increased from 0.88 g/cm³ in control plots to 1.04 g/cm³ using a DAP application rate of 100 kg/ha. Keerthana *et al*. (2024), demonstrated that fruits treated with 75% Nano-DAP applications produced the highest firmness of fruit (11.08 N), compared with the control (8.85 N). Those differences were attributed to the supportive functionality of phosphorus in energizing the movement of nutrients and nitrogen's contribution to biomass accumulation (i.e., provides structural support) when N and P were maintained in a balanced manner to prevent succulent and/or weak structures.

Kahsay *et al*. (2016) demonstrated that the application of Urea at a rate of 150 kg/ha with DAP at a rate of 92 kg/ha (both N & P sources) produced average individual fruit weights of 78.43 g, which represents an increase of 90 % relative to the control (41.25 g). Sabit, (2020), reported an average fruit weight of 94.3 g when applying 75% chemical and 25% organic fertilizer. Junior *et al.* (2024), demonstrated that balanced application of Urea and DAP resulted in lycopene levels of 5.85 mg/100g, while nitrogen-deficient plants produced lycopene levels of 3.20 mg/100g. So, through the use of DAP to promote carotenoid biosynthesis and the use of Urea to maintain healthy foliage, the conditions to protect fruits during ripening from sunscald (sunlight-induced Color degrades) are met.

## 2.5. Phenological Response of Tomato to Eco-Green Fertilizer

### 2.5.1. Effect of Eco-Green Fertilizer on Tomato Phenology

#### Days to 50% Flowering

The reproductive phase transition of a plant, measured by how many days it takes for 50% of flowers to bloom, is an important phenological measure of a plant's vigor and nutrition efficiency. Studies show that bio - organic fertilizers like Eco-green speed up this transition time significantly compared to traditional mineral fertilizers or untreated controls. A study done by Ateka et *al*. (2024), suggested that, tomato plants treated with standard dosage of Eco-green liquid fertilizer reached 50% flowering 34.25 days after transplanting versus 42.80 days for the untreated control group. Similarly, Bodale *et al.* (2021) noted that tomatoes grown with Eco-green had 50% flowering 33.8 days after transplanting which was nearly 12% faster than the traditional composted tomatoes which had a 38.4-day transition.

The liquid nature of eco-green fertilizer enables it to provide nutrients to plants in an immediately available form, therefore, overcoming the delays often associated with traditional soil-based organic fertilizers due to their slow rate of mineralization. The rapid availability of phosphorus and micronutrients (which are also important factors in the early stages of floral development) is enhanced when using a liquid fertilizer compared to using traditional fertilizers that rely on the longer timescales involved in receiving nutrients from solid organic fertilizers. The timing of flowering is also greatly affected by both the concentration of the bioorganic fertilizer used as well as the ratio of nutrients within the fertilizer. In Obaid *et al.* (2016) study, increasing the concentration of eco-green from 2mL/L to 6mL/L was found to reduce the number of days it takes for plants to achieve 50% flowering by a significant amount (31.50 days vs 37.10 days).

**Days to 90% Maturity**

The days for tomato plants to reach, 90% maturity represents the phenological growth stage where most of the fruit has reached the physiological red-ripe stage of development. The acceleration of the tomato ripening cycle is driven by specific bio-activators present in the Eco-green formula that accelerate the transition of tomato fruit from development (immaturity) to senescence (ripeness). Obaid et *al*. (2016), indicated that using Eco-green liquid organic fertilizer significantly shortened the tomato crop cycle, with plants treated with Eco-green fertilizer achieving 90% maturity after 88.45 days compared to 102.60 days of maturation for the plants in the control group using conventional, untreated organic fertilizers.

The efficiency of Eco-green's liquid delivery system is even more apparent when compared to traditional organic amendments. According to Ateka *et al*. (2024), Eco-green accelerated the time to 90% maturity in tomatoes by 12.5% due to the microbial components in Eco-green are believed to help degrade internal plant inhibitors, thus leading to earlier senescence of vegetative parts and making it possible for the plant to devote its physiological resources to fruit ripening. Eco-green treated tomatoes matured in 89.5 days compared to untreated plots that matured in 101.2 days. Zhang *et al*. (2024) found a dose-dependent response in Tomatoes, with a high Eco-green concentration (15 ml/L) resulting in 90% maturity in 86.20 days, compared to 91.80 days for a moderate concentration (5 ml/L).

### 2.5.2. Growth Response of Tomato to Eco-Green Fertilizer

**Plant height**

Eco-green fertilizers containing abundant essential macronutrients and plant growth-promoting regulators significantly promote the vertical growth of the tomato stem by accelerating cell elongation. Eco-green liquid organic fertilizer at 15 ml/L concentration resulted in 46% increase in vertical growth compared to untreated control (Taiwo & Oluwadamilola, 2020). The mean height of the treated plants was 76.45 cm at 42 days after transplanting (DAT) and 52.34 cm for control plants. This stimulation is due to the rapid absorption of nitrogen and growth hormones in the liquid formulation.

Murakami *et al.* (2021) also found that height responded linearly with the increase of Eco-green concentrations. Their data showed that at 45 DAT the dosage of 20 ml/L produced the plants of 94.20 cm while the lower dosage of 5 ml/L produced the height of 72.10 cm. The difference of 22.10 cm suggests that higher nutrient densities provide the necessary building blocks for the apical meristem to maintain high rates of cell division. Prasad et *al*. (2017), recorded the highest height of 88.50 cm in Eco-green treated tomatoes at peak vegetative phase. These results suggest that Eco-green can be used to supplement or replace chemical fertilizers to obtain a good stature of the plant. Begna (2018), reported that Eco-green alone (400 L/ha) produced a plant height of 63.66 cm. Mia *et al.* (2025), found that Tomato, which keep growing, hit a maximum of 142.6 cm at 60 days after transplanting with Eco-green growing around 12 cm per week during the mid-vegetative stretch.

**Stem diameter**

Stem diameter says a lot about a plant's health it shows how sturdy it is and how well it can move water and nutrients. When you use Eco-green liquid organic fertilizer, you see a real boost in tomato stem growth. This is due to the presence of auxins and minerals in this type of fertilizer that increases the activity of cambium leading to thickening of the stem. The average stem diameter for tomatoes when treated with Eco-green at 15 ml/L after 42 days was found to be 8.35 mm, whereas without treatment, the average stem diameter attained was 5.22 (Taiwo & Oluwadamilola, 2020) The stems increased from 2.4 mm after 14 days to 6.8 mm after 28 days.

That kind of progress means Eco-green doesn't just dump nutrients all at once (Manga *et al*., 2024).In the study by Mia *et al.* (2025), they saw stem thickness go up in a straight line as the dosage increased. Plants given the highest dose of 20 ml/L, ended up with stems 11.24 mm thick. For the lowest dose, 5 ml/L, stems measured just 7.15 mm. So, it looks like bumping up the Eco-green concentration helps plants hit the sweet spot for carbon-to-nitrogen balance, which makes a big difference when it comes to developing strong vascular tissue basically, what the plant needs to hold up big fruit loads.

**Primary and secondary branch**

Eco-green fertilizers kind of nudge the plant to stop focusing only on growing taller, and instead branch out to the sides (Nan *et al*., 2025). Skip the fertilizer, and honestly, the plant sort of drags its feet; you won't see much new growth until about day 28 (Mooy *et al*., 2019). By day 35, plants treated with eco fertilizer have about 6.5 branches each.

Nan *et al*. (2025), found that at 15 ml/L, tomato plants reached nearly 7.8 branches per plant by day 42, versus just 4.5 in the control group. Agron (2020), studied this too upping the dose from 5 ml/L to 20 ml/L gave plants 9.4 main branches instead of 6.2, which is a solid 51.6% increase. Therefore, giving your tomatoes the right blend of these eco-friendly nutrients really gives them the energy to grow fuller and bushier. Sabit (2020), showed that if you go with Eco-green alone at 400 L/ha, you still get a solid 21 branches per plant. Begna (2018), found that Eco-green did not bump up the number of main or side branches. Nan *et al.* (2025) noticed that, Eco-green can make a plant stronger overall, but the number of branches hits a ceiling set by the plant's genes. The fertilizer helps, but it can't outdo what the variety is actually programmed to do.

### 2.5.3. Yield and Quality Response of Tomato to Eco-Green Fertilizer

**Fruit volume**

Fruit volume, measured in cubic centimeters, gives you a clear idea of how much water and nutrients a tomato can hold and just how strong a sink it is for all that good stuff. Nan *et al*. (2025), showed that using Eco-green at 15 ml/L bumped up the average fruit volume to 58.42 $cm^3$. That's nearly 80% larger than the 32.55 $cm^3$ from the control group. This is because Eco-green boosts nutrient availability and encourages beneficial microbes in the soil, making everything work better beneath the surface. Another study by Luta *et al.* (2024)found a 36%

jump in fruit volume 61.5 $cm^3$ compared to the usual 45.2 $cm^3$. The bio-stimulants in Eco-green help the plant's hydraulic systems flow more efficiently, which means tomatoes end up with more water packed inside.

Eco-green contains humic acids and helpful bacteria that drive cell growth way beyond what synthetic fertilizers can manage. Mia *et al.* (2025)found tomatoes treated with Eco-green hit 64.20 $cm^3$, versus 52.15 $cm^3$ for those given only chemical NPK. These bioorganic tweaks strengthen the fruit's ability to build up water and biomass the real sink strength in action. Jatsiyah and Safruddin (2024), reporting that, bio-fertilizers had a bigger positive impact on tomato plant growth than traditional compost or manure. Therefore, it is pretty clear: switching to bioorganic fertilizers like Eco-green actually pays off in terms of bigger, better tomatoes.

**Fruit number**

That number of fruit depends a lot on hormones and the nutrients it gets from whatever fertilizer you use. Some studies show that eco-friendly fertilizers, especially those packed with organic extracts, actually help plants produce more fruits by getting the auxins and cytokinins balanced just right. Sigaye (2025), used 15 ml/L of Eco-green liquid organic fertilizer and saw plants crank out 32.55 fruits each that's a whopping 76.7% jump compared to the control group's 18.42 fruits. Fruit count is not just about numbers, though. It is closely linked to how heavy the total harvest is and how nutrients in the soil interact. Similarly, Begna (2018) observed that plots treated with NPS and urea (75) and Eco-green and urea (70) produced significantly higher numbers of marketable fruits compared to an organic-plus-urea control (65). Ateka *et al*. (2024), found that Eco-green treated plants produced 28.4 marketable fruits compared to only 12.2 in untreated plots. This shift represents an improvement in the marketable percentage from approximately 66% to 87%, likely due to reduced nutrient-related physiological stress.

The number of unmarketable fruits those that are small, cracked, or diseased drops when nutrients are released steadily. Gao *et al*. (2023), found that using the right amount of Eco-green fertilizer (20 ml/L) kept unmarketable fruit down to just 3.15 per plant. But when you overdose it with inorganic fertilizers, unmarketable fruit shoots up usually more than 7.5 per plant because the fast flush growth makes fruit crack. Eco-green seems to help the fruit skin stay elastic, which cuts unmarketable counts by over half compared to heavy chemical use.

**Fruit yield**

Fruit yield is not just about the total number it covers marketable, unmarketable, and overall production, and a lot of this depends on how you feed the plants. Begna (2018) reported that combining Eco-green with urea led to the highest marketable yield at 39 tons per hectare and Eco-green only gives unmarketable yield of 22 t/ha. Therefore, using both bioorganic and chemical fertilizers does not just boost size it makes a real difference in how much good fruit you get out of your fields. Bilalis *et al*. (2018), also found that, Tomato gives 150.3 t/ha of yield under organic fertilizer. Gao *et al*. (2023), also revealed that, organic plant fertilizer (Eco-green) increase yield of tomato by 35.78% when compared to the control group.

**Fruit weight and density**

The application of Bio-Green and specialized organic biostimulants exhibits a non-linear response, where moderate rates often yield superior results compared to high-dosage applications. Nan *et al.* (2025), reported that a moderate application of 0.75 liters of Bio-Green fertilizer combined with NPK (2.5 g) maximized both average good fruit weight (16.58 g) and total fruit weight (30.33 g). In contrast, increasing the Bio-Green dosage to 1 liter resulted in a significant performance decline, with weights dropping to 3.33 g, highlighting the risk of nutrient imbalance at excessive eco-green levels. These organic amendments provide a more stable nutrient release than fast-acting mineral fertilizers, thereby supporting the cellular expansion and carbohydrate accumulation necessary for superior fruit quality. Collectively, these findings suggest organic inputs are critical for refining the structural density and biochemical value of the final produce (Nan *et al.*, 2025).

**Fruit Quality (TSS and pH)**

Tomato quality is not just about one thing it is the weight, the chemical makeup, and how the fruit actually tastes. All these come down to what kind of nutrition the plant gets. On top of that, the bio-organic fertilizer outperformed the other types bio-chemical and bio-manure especially for improving sweetness, measured as soluble sugar (°Brix).

Sigaye (2025), found that tomatoes treated with 15 ml/L of Eco-green averaged 62.45 grams each way up from the 38.12 grams in the untreated plants, that’s a massive 63.8% jump. (Lu, Zhiwen, et al., 2025), showed that using the highest dose of their Eco-green fertilizer, boosted

fruit yield by 40.8% compared to not using any fertilizer at all. Gao *et al*. (2023), performed a meta-analysis and verified that organic fertilizers are generally effective in average TSS and soluble sugar. In terms of TSS, organic fertilizer produced a maximum TSS value of 3.7% compared to a TSS value of 2.3% from the unfertilized control (Sabit, 2020).

Total Soluble Solids (TSS/°Brix) say a lot about a fruit's sweetness and flavor, they are kind of the main event when it comes to quality. Gao *et al*. (2023), found that tomatoes treated with Eco-green hit a TSS of 5.12 °Brix, while the control group only managed 4.15. This indicates that organic fertilizers boost TSS by almost 12% compared to unfertilized groups. Mixing things up helps, too a blend using 75% chemical and 25% organic fertilizers gives 3.7% TSS, while control groups give 2.3% (Sabit, 2020). So, using organics really brings out the sweetness.

The chemical stability of tomato like pH and acidity really matters for both shelf life and that classic tangy flavor. Generally, the fruit pH in fresh tomatoes is always below 4.5. As noted by Choudhary *et al*. (2024), the fruit pH remained constant at 4.28 when using Eco-green treatment; this is slightly superior compared to the high and more basic pH of 4.65 in soils treated with excess amounts of inorganic fertilizers. In this case, eco-green fertilizer appears to regulate the tomatoes' acidity by keeping enough organic acids such as citric and malic acid. The fruit pH may be variable. While fruit pH can jump around, adding organic fertilizers also changes the soil pH. Lu *et al*. (2025), noticed that using more organic fertilizer tended to lower soil pH, and that shift can change how nutrients are available to the plants, which show up later in fruit quality.

Now, color and lycopene that is what catches people's eyes in the store. The organic pieces of Eco-green may actually help to start carotenoid production, leading to deeper red tomatoes. Sopha et al. (2020) indicated that tomatoes treated with 20 ml/L of Eco-green were 18 percent more colorful compared to tomatoes grown using regular chemical fertilizers. This implies that the use of this type of organic fertilizer promotes the growth of more lycopene content in tomatoes hence enhancing their appearance and possibly nutritional value. The author also reported that tomatoes getting a 20 ml/L dose of Eco-green were 18% more vibrant in color than tomatoes grown with regular chemical fertilizers. Therefore, it looks like this kind of organic approach helps tomatoes pack in more lycopene, making them look better and probably boosting their nutrition.

## 2.6. Response of Tomato to garlic and onion peel powder

### 2.6.1. Response of Tomato Phenology to Garlic and Onion Peel Powder

The phenological growth of tomato is made possible through the gradual provision of organic nutrients, with the creation of a stable 90-day flowering induction threshold but making sure that the transition into harvesting the fruits can be made effectively within 80 days from transplanting (Singh et *al*., 2020). Through three applications of aqueous garlic extract (AGE), tomato plants will be able to achieve the 50% flowering growth point, with the plant displaying optimum morphological characteristics because of high auxin content, which helps in achieving reproductive maturity (Hamza *et al*., 2024; Wewe, 2025).

This strategic management approach ensures the optimization of phenological timing through mineral-rich organic nutrient release and the establishment of robust physiological foundations necessary for reproductive maturity.

### 2.6.2. Response of Tomato Growth to Garlic and Onion Peel Powder

Growth parameters exhibit substantial vertical and structural development, with the integration of garlic and onion amendments driving plant height from a 47 cm baseline to a peak of 80.8 cm, representing a significant 71.9% increase in height (Temesgen et al., 2025). Peak construction robustness is best achieved through a combined 6% foliar and 20% ground application of garlic extract, yielding a maximum height of 98.00 cm and 12.55 primary branches compared to only 5.55 in unfertilized control groups (Ahmad, 2021). Furthermore, synergistic foliar sprays of 30 g $L^{-1}$ garlic and 25 g $L^{-1}$ onion extracts maximize lateral branching to an average of 14.44 branches per plant, providing the superior vegetative framework required for high fruit loads (Kouamé *et al.,* 2021). These recorded gains facilitate the maximization of structural erection through synergistic Allium applications and optimized nutrient availability across the plant canopy.

### 2.6.3. Response of Tomato Yield and Quality to Garlic and Onion Peel Powder

Marketable yield is significantly enhanced through optimize the plant's hormonal balance and stress response, reaching productivity levels between 42.76 t $ha^{-1}$ and 50.36 t $ha^{-1}$ by effectively mitigating losses from damping-off and blight by up to 92.64% (Korane *et al.,* 2025). Optimal

reproductive performance is further characterized by a fruit load of 11.62 fruits per plant with an average fruit weight of 84.07 g and a volume of 98.74 $cm^3$, while biochemical quality is simultaneously refined as Total Soluble Solids increase from a 6.65 baseline to 9.07°Brix (Hamza *et al*., 2024). While maturity-driven pH naturally rises from 4.23 to 4.63, post-harvest integrity is secured via a 90% reduction in seed borne fungal prevalence, preventing post-harvest decay and preserving the biochemical density of the fruit (Gao *et al*., 2023). Regarding quality, intensive garlic treatments significantly reduced fruit hardness to 12.74 $kg \cdot cm^{-2}$ compared to untreated controls which maintained a maximum density of 16.99 $kg \cdot cm^{-2}$ (Ahmad, 2021). Collectively, these organic inputs drive the refinement of biochemical quality and marketable yield via mineral-rich peel amendments and the implementation of effective protective frameworks.

## 2.7. Response of Tomato to Integrated Fertilization Application

### 2.7.1. Phenological Response of Tomato to Integrated Fertilizer Application

The integrated nutrient management strategy that includes the combination of inorganic nutrients such as urea and DAP with organic materials enhanced the phonological response of tomato plants. In this regard, enhanced days to first flowering in tomatoes was reported by Sabit (2020), where the application of 75% chemical fertilizer and 25% organic fertilizer resulted in the earliest flowering period of 51.1 days. It is faster than 100% chemical fertilizer use (54.1 days), the use of 50/50 chemical-organic fertilizer (54.7 days), and 100% organic fertilizer (56.0 days). Finally, the control (unfertilized) group had the latest period of 59.9 days. Moreover, (Nahar *et al.* (2021), state that the combination of 70% chemical fertilizer and 2 t $ha^{-1}$ of vermin compost leads to the reduction of the first flowering period to 27.33 days. The combination of garlic and onion peel powder along with compost has proven its positive effect on general growth and yields of other similar plants. Thus, it may be applied to trigger the flowering periods as well (Roshini *et al*., 2023).

Combined application of inorganic and organic fertilizer also enhance fruit setting in tomato. Since fruit setting depends on when flowering begins, fewer days to flower is a key sign of an earlier fruit set. Sabit (2020) showed that a mix of 75% chemical and 25% organic fertilizer resulted in the earliest flowering at 51.1 days. This significantly beat the unfertilized control,

which took 59.9 days. Khan et al. (2017), also support this faster reproductive timeline. They found that pairing full doses of NPK with 10 tons of compost improved the success and size of the fruit set. This shows that a balanced nutrient supply is vital for the change from flower to fruit.

Using garlic and onion peel powder with compost has shown to improve overall plant growth and nutrient uptake in related species. This provides the physiological foundation needed for a quick and efficient fruit set (Roshini *et al*., 2023). Together, combining easily available synthetic nutrients with the hormonal boost from organic liquids and botanical powders improves the plant's reproductive efficiency, shortening the time to the first fruit set.

The time to first fruit harvest in tomatoes is significantly reduced through integrated nutrient management. According to Sabit (2020), the shortest interval to first fruit picking was 94 days using ammonium sulfate combined with P and K, while a blend of 75% chemical and 25% organic fertilizer reduced flowering to 51.1 days compared to 59.9 days for the control. Collectively, the synergy between synthetic and organic inputs accelerates the transition to maturity, effectively shortening the days to first harvest and enhancing market productivity

### 2.7.2. Growth Response of Tomato to Integrated Fertilizer Application

#### Plant Height

Integrated Nutrient Management (INM) is the main factor for vertical growth. The highest plants are obtained from a chemical to organic ratio of 75% to 25% with an average of 95.7 cm, which is higher than the height of 78.4 cm in control groups (Sabit, 2020). In Ethiopian urban greenhouse settings, a combination of Urea and DAP with organic liquid fertilizer (Eco Green) and peel powder can increase plant height by 71.9% to a maximum of 80.8 cm by providing a constant supply of nutrients throughout the growth cycle, whereas the control group was 47cm (Temesgen et *al*., 2025). Tomato height has been recorded at 115.4 cm to 122.36 cm in INM plots, representing a 30.8% increase over the 88.2 cm observed in unfertilized or synthetic-only plots (Siddaling et *al*., 2017). This growth is further supported by liquid organic fertilizers like Eco Green, which enhance nutrient availability and ensure the plant reaches its full genetic height potential (Sigaye, 2025)

**Stem Diameter**

Stem growth appears to improve most under integrated nutrient management practices. (Lu, *et al.,* 2025) reported that combining conventional fertilizers with bioorganic fertilizers increased stem diameter to as much as 14.5 mm. In a similar study, Singh *et al*. (2020) found that applying 10.0 t/ha of poultry manure produced the highest stem diameter, reaching 0.91 cm at 60 days after transplanting (DAT). Hubert *et al.* (2024) observed that stem diameter at planting was greatest with 150:60:120 NPK + 375 kg/hm² organic fertilizer (4.85 mm). However, from 15 to 90 days after planting, the 450:180:360 NPK treatments performed better than the other treatments. By contrast, the control and 150:60:120 NPK + 75 kg/hm² organic fertilizer had the lowest values, measuring 4.11 mm at planting and 6.13 mm at day 15. Keerthana *et al.* (2024) also showed that applying 75% RDNP together with foliar sprays improved stem girth more effectively than synthetic fertilizers alone, which helped plants maintain the strength needed to carry heavier fruit loads.

**Number of Primary and Secondary branch**

Tomato plants produce more primary and secondary branches when nutrients are supplied through an integrated approach. Sabit (2020), reported that combining 75% chemical fertilizer with 25% organic fertilizer gave the best branching performance, with 28.6 branches per plant, compared with only 20.2 branches in the unfertilized control. A similar trend was observed by Siddaling et *al*. (2017), who found that applying 75% of the Recommended Dose of Fertilizers (RDF) together with biofertilizers such as Azotobacter, PSB, and VAM gradually increased the number of branches from 12.20 at 45 days after transplanting (DAT) to 19.20 at 135 DAT. In addition, garlic and onion peel powders mixed with compost have also been reported to promote vegetative growth in related species, indicating their possible role in improving primary and secondary shoot development (Roshini *et al.*, 2023). Overall, combining inorganic fertilizers like urea and DAP with organic liquids or botanical powders helps create a balanced nutrient supply that improves branching, strengthens plant growth, and ultimately supports higher fruit production (Gao *et al*., 2023; Khan *et al*., 2017)

### 2.7.3. Yield and quality Response of Tomato to Integrated Fertilizer Application

#### Fruit Diameter (Major, Minor, and Intermediate)

Fruit diameter is strongly influenced by integrated management yields the largest dimensions. Diameter and overall size of tomato fruits are significantly enhanced through integrated nutrient management, which combines inorganic fertilizers (such as urea and DAP) with organic amendments. According to (Jat *et al*., 2018), the application of 3.5 tons of poultry manure combined with 95N, 75P, and 55K kg/ha resulted in a maximum fruit diameter of 5.25 cm. Similarly, Sabit (2020), found that the highest fruit diameter was achieved using an NPK ratio of 350:200:250 kg/ha, while a treatment combining 75% chemical fertilizer with 25% organic cow dung optimized fruit length at 5.87 cm.

Using Eco Green and integrated vermin compost has been shown to produce a maximum fruit diameter of 42.87 mm, ensuring the fruit reaches its full genetic potential (Ramesh *et al*., 2023). The positive impact of combined inputs is further supported by Khan *et al.* (2017), who observed that the application of a full dose of NPK alongside 10 tons of compost produced the largest fruit size, as evidenced by the lowest number of fruits per kilogram (14). Although direct data on eco green liquid and garlic and onion peel powder for tomato diameter is limited, research on other crops suggests that these botanical powders significantly improve overall yield and growth parameters (Roshini *et al.*, 2023). Collectively, integrating inorganic nutrients with organic matter optimizes the physiological development of the fruit, leading to superior diameter compared to sole fertilization methods.

#### Fruit Volume

Fruit volume is strongly indicated by increases in fruit length, weight, and density under integrated nutrient management. According to Sabit (2020), the integration of 75% chemical and 25% organic fertilizer produced the largest fruit dimensions, with the longest fruits (5.87 cm) and the heaviest single fruits (94.3 g), compared to the unfertilized control, which yielded the shortest (3.65 cm) and lightest (83.1 g) fruits. This increase in size is further supported by Khan *et al*. (2017), who found that combining full doses of NPK with 10 tons of compost resulted in the highest fruit density (1.11 g/cm$^3$) and the largest overall fruit size, as evidenced by a minimum count of only 14 fruits per kilogram. The potential for organic liquids and botanical

powders to enhance these parameters is highlighted by (Sigaye, 2025), where the combination of 100% RNP and 60 L/ha of organic liquid fertilizer maximized marketable output, and by Roshini et *al*., (2023), who observed that compost integrated with onion and garlic peel powder significantly increased fresh weight in related crops. Collectively, integrating inorganic nutrients with organic supplements optimizes the physiological volume and density of the fruit by providing a balanced nutrient supply essential for maximum fruit expansion.

**Fruit density**

Integrated Nutrient Management (INM) significantly optimizes the physical determinants of fruit density through enhanced biomass partitioning and structural integrity. Despite the rareness of direct measurement of density (Zhang *et al*., 2024). proved that the synergetic effect of 4M+0.6N+Si led to an increase in fruit weight by 14.5% and dimensions up to 14.6%, while at the same time increasing fruit hardness, which serves as a marker of internal density, by 13.8%. Also, 50% application of farmyard manure along with 50% chemical fertilizers led to an average weight of 41.67 g, which indicates higher internal density in contrast to other systems (Patil *et al.*, 2021). The numeric data proves that the inclusion of silicon and organic matter stimulates cell growth and tissue density.

**Fruit weight**

Integrated Nutrient Management (INM) significantly optimizes tomato fruit weight, with organic amendments at 30 Mg $ha^{-1}$ increasing average mass to 77.50 g, a 35.96% gain over controls (Sholehkhuddin et *al*., 2023). Single fruit mass similarly improves by 14.5% when silicon is paired with high organic matter and reduced chemical nitrogen (Zhang *et al*., 2024). Furthermore, bio stimulants like bread yeast elevate weights to 74.00 g, while combined foliar and ground garlic applications achieve superior benchmarks of 84.07 g per fruit (Ahmad, 2024). These numerical gains demonstrate that integrating mineral-rich organic sources with precise bio stimulant applications effectively maximizes tomato fruit weight and final reproductive output.

**Fruit Number (Marketable, Unmarketable, and Total) per Plant**

Integrated nutrient management (INM), combining inorganic fertilizers such as urea and DAP with organic amendments, significantly increases the total and marketable number of fruits per tomato plant. Sabit (2020), shows that a combination of 75% chemical fertilizer and 25% organic fertilizer (cow dung) optimizes fruit production, yielding a maximum of 35.1 fruits per plant and 3.89 fruits per cluster, which substantially outperformed sole chemical applications (30.1 fruits) and the unfertilized control (22.3 fruits). Regarding marketable fruit numbers, Sigaye (2025), found that the integration of 100% recommended nitrogen and phosphorus (RNP) with 60 L/ha of organic liquid fertilizer produced the highest marketable output, whereas reducing the inorganic component to 50% RNP resulted in the lowest fruit counts, highlighting that a strong synthetic nutrient base is essential for fruits to reach marketable size (typically > 3.5 cm).

The efficacy of such integrated approaches is further supported by findings that combining Eco Green liquid with urea not only boosts marketable fruit numbers but also reduces losses from damping-off and early blight (Begna, 2018). Application of garlic and onion peel powder combined with compost has been shown to significantly enhance vegetative vigor in related species, suggesting a synergistic effect that supports higher fruit setting (Roshini *et al.*, 2023). Collectively, Nutrients from chemical sources and organic liquids fruits.

**Fruit Yield (Marketable, Unmarketable, and Total)**

Integrated nutrient management, which combines inorganic fertilizers such as urea and DAP with organic amendments, significantly optimizes tomato fruit yield. Regarding marketable yield, Sigaye (2025), found that combining 100% of the recommended nitrogen and phosphorus (R-NP) with 60 L/ha of organic liquid fertilizer produced the highest marketable output, noting that reducing R-NP to 50% led to a significant decline in production. Total yield is similarly enhanced through synergistic blends; for instance, a ratio of 75% chemical and 25% organic fertilizer resulted in a total yield of 93.2 t/ha (3.30 kg per plant), with a high of 35.1 fruits per plant (Sabit, 2020).

This is consistent with a broad meta-analysis indicating that organic fertilizers increase overall tomato yields by 42.18%, with animal-derived organic sources being the most effective at 50.53% (Gao et al., 2023). Conversely, imbalanced nutrient applications can increase unmarketable yields, which have been observed to peak at 7.30 t/ha (Korane *et al.,* 2025).

Application of 2g of garlic and onion peel powder combined with compost significantly improved vegetative fresh weight to 324.79 g in related crops, suggesting a potential for similar yield enhancements in tomatoes (Roshini *et al*., 2023). Collectively, integrating chemical fertilizers with organic liquids or plant-based powders outperforms sole applications, as the combination of readily available inorganic nutrients and soil-enhancing organic matter maximizes both the quantity and marketability of the harvest (Khan *et al.*, 2017).

**Fruit Quality (TSS and pH)**

The combination of synthetic and organic nutrients significantly enhances tomato fruit quality. Sabit (2020), shows that a combination of 75% chemical and 25% organic fertilizer gives a peak Brix percentage of 3.7% (compared with 2.3% in the unfertilized controls) and a maximum single fruit weight of 94.3 g. Gao *et al*. (2023), support this as they found that organic fertilizers increased Total Soluble Solids (TSS) by 11.86%. Plant-based amendments, such as garlic and onion peel powders, showed the greatest increase at 14.21% and were especially effective in acidic soils (16.67% increase). Regarding pH and acidity, the variety TLB 182 recorded a pH of 4.40 under 150% RDF (Sabit, 2020). The integration of botanical powders modulates the fruit acidity by enhancing the efficiency of nutrient uptake (Roshini *et al*., 2023).

In addition, INM results in the optimization of physical and nutritional characteristics such as fruit density of 1.11 g/cm³ and Vitamin C of 82.46 mg/100 (Khan *et al.*, 2017).Incorporation of extracts from the genus Allium also maintains these parameters since there is a reduction in fungal spoilage by more than 84% (Teka, 2013).. Overall, when urea and DAP are combined with eco-green liquids and botanical powders, a proper nutritional basis is formed to optimize TSS and pH.

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The study was conducted under greenhouse condition at Federal Technical and Vocational Training Institute (FTVTI) during the experimental period (August to March) in Yeka Sub-city, Addis Ababa. The area is located at geographic coordinates ranging from 9°01′00″ to 9°06′00” N and 38°46′00″ to 38°53′00″E. It is characterized by humid tropical climate with an average annual temperature of 15.9°C and 1,184 mm of rainfall (Ethiopian meteorological Institutes (EMI), 2023)

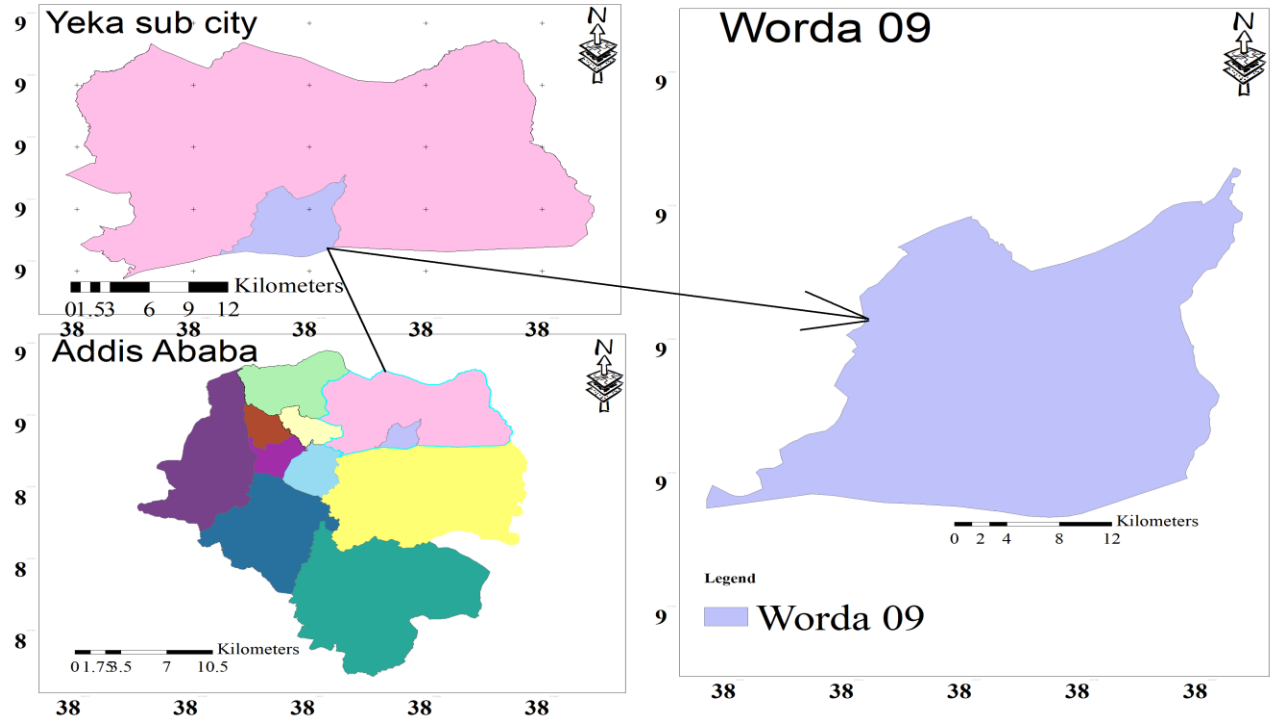



Figure 1 : Map of study Area

## 3.2. Experimental Materials

Galilea F1, a tomato variety hybrid *(Solanum lycopersicum L.)* was used for the study. Free seedlings of Galilea F1 were obtained from Ethio Veg Fru Plc, Ethiopia and the plants were uniform and healthy. The variety is identified based on its determinate nature of growth although local production guides sometimes classify the variety as semi-determinate because of its rapid

vegetative development (Beyene & Mulu, 2019). Tomato transplanting was done at 25-30 days after seedlings planting which coincided with 4-5 leaf stages (Martí et al., 2016).

In order to have uniformity across all experimental plots, only those seedlings which were effective, disease free, and uniform were selected. To increase the adaptability and survival rate after transplantation, toughening of seedling was done before hand by reducing watering and exposing the plants to field environment (Beyene & Mulu, 2019).

Table 1 Characteristics of Galilea F1 tomato variety

| Characteristic | Description |
|---|---|
| Breeder/Source | Hazera (distributed via Green life/MoA registered) |
| Growth habit | Determinate |
| Days to maturity | 75-90 days after transplanting |
| Fruit shape | Oval |
| Fruit size (weight) | 120g -180g per fruit |
| Fruit color | Deep red, glossy finish |
| Fruit firmness | Very high (excellent for transport) |
| Disease resistance | HR: *ToMV,* Verticillium wilt, Fusarium wilt, Bacterial speck; IR: Root-knot nematodes, Tomato spotted wilt virus, Powdery mildew |
| Yield potential | 60 - 80 tons/ha (600–800 qt/ha) |
| Shelf life | Long (approx. 14 - 21 days under ambient conditions) |
| Recommended altitudes | 700 - 2,000 m.a.s.l. (Highly adaptable) |

Source: MoA (2024).

Onion and garlic peel were purchased from local market (02 area). DAP and urea fertilizers were also purchased from the local market while Eco green liquid fertilizer was supported from the producing company free.

### 3.3. Treatments and Experimental Design

The experiment was conducted using a Randomized Complete Block Design (RCBD). With three replications and eight treatments compared to a completely randomized design (CRD), which presumes that every experimental unit is perfectly homogeneous, RCBD is thought to be more suitable. In reality, even in greenhouse settings, there are frequently small environmental gradients. RCBD improves precision and makes it easier to identify real treatment differences by considering these gradients through blocking. As a result, RCBD was determined to be the best experimental design for this study. The treatments include:

**Table 2: treatment levels**

| Treatment code | Treatment level |
|---|---|
| T1 | Control |
| T2 | 75 DAP + 381Urea kg ha $^{-1}$ |
| T3 | 38 DAP + 191Urea + 381 of onion and garlic peel kg ha$^{-1}$ |
| T4 | 15 lit Eco green + 572 onion and garlic peel kg ha$^{-1}$ |
| T5 | 30 lit Eco green + 381 onion and garlic peel kg ha$^{-1}$ |
| T6 | 45 lit Eco green + 191 onion and garlic peel kg ha$^{-1}$ |
| T7 | 762 onion and garlic peel kg ha$^{-1}$ |
| T8 | 60 lit Eco green fertilizers ha$^{-1}$ |

## 3.4. Preparation of onion and garlic peel

Onion and garlic peel collected from the local market were ground separately using laboratory mill after air dried for 2 days. The ground powder was mixed in 1:1 ratio and one kilogram of the sample was sent to Holleta Agricultural Research for chemical analysis. Standard procedure was also followed for chemical analysis of onion and garlic peel.

The soil used for the experiment was collected from topsoil layer (0-30 cm depth) of the African Leadership Excellence Academy (Aflex) compound.

After collection, all of the experiment pots were filled with properly mixed soil. A one-kilogram composite soil sample was created prior to planting by collecting representative subsamples from the soil prepared for each pot and carefully mixing them to create a consistent sample for analysis. Before planting, the experimental soil's chemical and physical characteristics were analyzed. Crumbs of soil were broken in to pieces and sieved. The collected samples were air-dried at room temperature on paper trays, ground and sieved using a 2mm sieve. Soil textural analysis (sand, silt and clay), total nitrogen (percentage), available phosphorus (ppm), available sulfur (ppm), soil pH, cation exchangeable capacity (Meq/100g soil) and organic carbon (percentage) were conducted at Holleta Agricultural Research Center following the standard procedures for each parameter.

## 3.5. Experimental procedures and management

The greenhouse experiment occupied a total net area of 53.71 m², measuring 13.1 m in length and 4.1 m in width. There was a buffer strip of 1.0m wide between each of the replication (block) and also between each plot of the block there were 0.5m wide pathways. There were 10 pots placed in two rows having 5 pots per row in each plot with 0.3m spacing between each plant and 0.7m spacing between each row. The capacity of the pot was 10 litres (20cm diameter). This soil sample was taken from the area of Holleta.

Ten pots were allocated as one experimental plot. 30 cm spacing was maintained between plants (from center of 1 pot to another) and 70 cm between rows. Seedlings of *Galilea tomato* variety were taken and then planted in pots in mid-July. Pots were arranged in the recommended spacing of 0.3 m between plants and 0.7 m between rows (Ger *et al.*, 2024).75 DAP + 381 Urea kg $ha^{-1}$ (RF), 38 DAP + 191Urea + 381 onion and garlic peel kg $ha^{-1}$, 15lit Eco green + 572 onion and

garlic peel kg $ha^{-1}$, 30lit Eco green + 381onion and garlic peel kg $ha^{-1}$, 45lit Eco green + 191onion and garlic peel kg $ha^{-1}$, 762 onion and garlic peel kg $ha^{-1}$, 60 lit Eco green fertilizers $ha^{-1}$ and control treatment (without fertilizer application) were applied to the assigned treatments. Recommended rate of DAP was applied during transplanting, while Urea fertilizer was applied one week after transplanting then after at 2, 4, and 8 weeks after transplanting. The mixed onion and garlic peel powder was incorporated three weeks after transplanting at the defined rates of the respective treatments. The initial application of Eco-Green liquid fertilizer was carried out three weeks after transplanting, with subsequent applications made twice at three-week intervals for the specified treatments.

All of the DAP fertilizer was applied in-ring around the seedlings during transplanting the seedlings while urea was applied to the respective treatments at 2, 4, and 8 weeks after transplanting. Onion and garlic peel powder was incorporated three weeks after transplanting at the defined rates of the respective treatments.

Eco-Green liquid fertilizer was applied initially at three weeks after transplanting, with repeated treatments every three weeks applied twice for the specific treatments accordingly.

Irrigation was applied uniformly to all plots based on crop water requirements, soil moisture conditions, and prevailing weather conditions. In order to ensure good seedling establishment, irrigation was given twice a day (morning and evening) during the early establishment stage. Subsequent irrigations were planned based on the soil moisture condition and plant growth stage. Subsequent irrigations were planned based on the soil moisture condition and plant growth stage. When infestations or disease symptoms occurred in the field, disease and pest management procedures were applied consistently across all treatments in accordance with the suggested tomato production methods. Agronomical practices such as weeding, staking, and keeping the field clean were continued throughout the growing period. The tomatoes were harvested when they changed color from green to pink, which signified their ripening stage(Beyene & Mulu, 2019).

## 3.6. Data collection

### 3.6.1. Soil data analysis

A 1 kg composite soil sample was collected and then air-dried the potting media at 21–27°C, crushed it with a porcelain mortar, and utilized 2 mm and 0.5 mm sieves to prepare for specific nutrient determination. After air-drying and sieving the media, the processed samples submitted to the Holleta Agricultural Research Center (HARC) Laboratory for professional analysis according to national protocols (Wogi *et al.*, 2021)

### 3.6.2. Plant parameter data collection

**Days to first flowering** was recorded from transplanting until 50% of the of the plants within a specific plot have begun to flower (Hailu *et al*., 2021).

**Days to 50% flowering** recorded from transplanting until 50% of the plants in a plot have produced flowers (Hailu *et al.*, 2021).

**Days to first fruit setting** was recorded from days of transplanting until the first plants in the center rows produced their initial fruit (Ger *et al.*, 2024).

**Days to first fruit harvest** was picked for analysis once their skin turned red, with multiple harvesting cycles carried out for each plot (Korane *et al*., 2025).

**Plant height (cm)** was measured in centimeters from the soil surface to the terminal bud on ten randomly selected plants per plot (Ger *et al.*, 2024).

**Stem diameter (mm)** was recorded using a caliper at heights between 3 cm above the soil surface and 10 cm above the root collar on ten randomly selected plants (Begna, 2018; Lu *et al.*, 2025)

**Branch number (primary and secondary)** was counted from ten randomly selected plants during the final harvest phase (Sharma *et al.*, 2023; Sudesh *et al.*, 2024).

**Fruit volume ($cm^3$)** was measured in cubic centimeters (cc) from representative mature samples to evaluate the physical expansion and development across treatment plots(Sharma *et al.*, 2023).

**Fruit density** was calculated by dividing the fruit's mass (average fruit weight in grams) by its volume (determined via water displacement) ( Shastri, 2023).

**Fruit diameter (major, minor, and intermediate)** was recorded at the widest part of the fruit using a digital vernier caliper, ensuring an accuracy of one decimal place for all major, minor, and intermediate dimensions

**Fruit number (marketable, unmarketable, and total) per plant** was recorded by summing marketable and unmarketable fruits harvested from the central rows to eliminate border effects, subsequently sorting them into marketable and unmarketable categories based on established quality and size criteria (Temesgen *et al*., 2025). Marketable fruits were defined as those exceeding 3.5 cm in diameter and free of visible damage, while unmarketable counts included all fruits categorized as undersized, bruised, physiologically disordered, or insect-damaged (Sigaye, 2025)

**Fruit yield (Marketable, Unmarketable, and Total**) was calculated as the sum of marketable fruits those exceeding a 3.5 cm diameter and free of defects and unmarketable fruits, which included those that were undersized, sunburned, or insect-damaged (Sigaye, 2025).

**Quality of tomato (TSS and pH)** was recorded by extracting juice from blended samples to determine pH and Total Soluble Solids (TSS). I measured the pH electrochemically using a digital pH meter calibrated with buffer solutions of 4.0 and 7.0, while TSS was determined using a digital refractometer with values expressed in °Brix (Rusu *et al.*, 2023; Teka *et al.*, 2013).

**Color:** Fruit surface color was measured using a special program written for this purpose by Pathare *et al*. (2013). The sample was analyzed for L, a, and b. Hue angle (h°), the qualitative attribute of colour, is used to define the difference between a certain colour and a grey colour with the same lightness, and was computed with the following equation (Mclerllan, 1994).

$$h° = \tan\text{-}1(b^*/a^{*-1})$$

The a*/b* ratio can be used to report the brightness of the red colour of the tomato fruit and its products (Saad *et al*., 2016).

## 3.7. Statistical Analysis

Data were subjected to two-factor Analysis of Variance (ANOVA) using statistix-10 software (version 10). Significant differences between treatment means were separated using the Least Significant Difference (LSD) test at a 5% probability level ($p < 0.05$).

## 3.8. Economic Analysis

A partial budget analysis was conducted following the (CIMMYT, 1988) framework. This involved calculating the total variable costs (TVC).

**Gross total fruit yield (kg/ha) (TFY): -** TFY is the total yield of each treatment.

**Adjusted yield (AjY): -** AjY is the total yield adjusted downward by 10% to reflect the difference with the yields that farmers could expect using the same treatments. Experimental yields are often higher; yields of farmers are adjusted by 10% less than that of the research results in economic calculations (CIMMYT, 1988).

**Gross field benefit (GFB):** GFB was computed by multiplying field/farm gate price that farmers receive for the tomato when they sale it as adjusted marketable yield. Sale price for tomato was considered at 30birr/kg.

**Gross field benefit (GFB) =** AjMY*Field/farm gate price of tomato

**Total variable cost (TVC): -** Total cost refers to the cost of the different fertilizers used for the experiment, preparation cost (for the peel), transportation cost, loading unloading and application cost. The costs of other inputs and production practices were considered the same or are insignificant among treatments. Price of eco-green = 400birr/Lt, urea = 92birr/kg, DAP = 92birr/kg, Onion peel =10 birr/kg, and garlic peel= 20birr/kg, preparation cost for the peel = 5birr/kg, transportation cost =3birr/kg each type of input, loading and unloading = 1birr/kg and application cost 5birr/kg were considered for the calculation of TVC.

**Net Income (NI) or Net Benefit (NB): -** was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).

Considering the local market sale prices of tomato (1kg = 30 birr)

$$NB = TR - TVC$$

**Marginal rate return (MRR):** is the measure of increasing in return by increasing input.

$$MRR = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Variable Cost}(\Delta TVC)}$$

Marginal rate of return (MRR %): is calculated by dividing change in net benefit by change in total variable cost and multiplied by 100%.

$$MRR\% = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Variable Cost}(\Delta TVC)} \times 100\%$$

**Dominance analysis** (identification and elimination of inferior treatments): is used to eliminate those treatments, which involve higher cost but do not generate higher benefits. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefit) is dominated treatment (marked as "D"). Identification of a candidate recommendation was from among the non-dominated treatments. That treatment gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers.

# 4. RESULT AND DISCUSSION

## 4.1. Soil and Onion-Garlic peel analysis before planting

Composite soil analysis before planting reveals that the soils employed in the experiment are made up of 72.5% clay, 14.5% silt, and 12.5% sand. Therefore, the soil type according to Rowell (2014) classification is clay.

The pre-planting composite soil sample analyses indicated that the soils used for the experiment contain 72.5 % clay, 14.5% silt, and 12.5% sand. Thus, the textural class of the soil is clay based on Rowell (2014) classification. The pH ($H_2O$) of the soil was 5.68 which is under the category of moderately acidic soil (Tekalign, 1991). According to FAO (2006), the preferable pH ranges for most crops and productive soils are from 4.01 to 8. Thus, the pH of the experimental soil is within the range for productive soils.

The experimental soil was found to have a CEC of 19.5 cmol (+) kg soil (Table 2). According to Landon (1991) top soils having CEC 15 - 25 mol (+)/kg are rated to have medium CEC. Thus, the soil of the study area has medium CEC, which is an indication of good agricultural soil.

The organic carbon and organic matter content of the experimental field was 0.41 and 0.71% respectively, which is very low according to the rating of (Tekalign, 1991). According to FAO (2012) low organic carbon and organic matter in the soil is due to removal of crop residual. According to Boix-Fayos *et al*. (2001) a threshold of 3-3.5% soil organic carbon had to be attained to achieve increases in aggregate stability. However, the Onion and garlic peels had very high Organic carbon (39.73%) and organic matter (68.5%) based on the rating of (Tekalign, 1991) (Table 2), these high rates reduce soil bulk density and compaction, and increases water holding capacity the soil. Soil organic matter provides an energy source for soil microbes and fauna, which are vital for decomposition and soil nutrient recycling.

Total nitrogen content and available phosphorus status of the experimental area were 0.94% and 4.80ppm soil, respectively (Table 2). The total nitrogen content was very high based on the rating of Tekalign (1991), while the available phosphorus was very low (Jones, 2001). The observed phosphorus deficiency of the experimental soil could be due to the combined effects of intensive nutrient mining and high fixation rates. However, the Onion and garlic peals had 1020ppm phosphorus, which is rated very high (Jones, 2001). This extraordinary phosphorus enhances primordial root architecture, and increases fruit set and development in horticultural crops.

Available sulfur value of the soil was also 14.27 ppm, which lies in low range (EthioSIS, 2014). This low in sulfur content of the soil may be due to continuous cultivation, which might be resulted from the intensive mining of sulfur from the soil, lack of using sulfur source mineral fertilizer, and poor use of organic fertilizers. Similarly, the content of sulfur in peels of garlic and onion was found very low (0.192ppm), which could be the delay in the analysis and volatility of the sulfur compound from the peel.

Table 3. Physical and chemical properties of the experimental soil and, onion and garlic peel before planting.

| Properties | Result | Rating | References |
|---|---|---|---|
| **1. Physical properties (%)** | | | |
| Sand (%) | 12.5 | | |
| Silt (%) | 14.5 | | |
| Clay (%) | 72.5 | | |
| Textural class | Clay | | Rowell (1994) |
| **2. Chemical properties** | | | |
| pH (1: 2.5 $H_2O$) | 5.68 | Moderately acidic | Tekalign (1991) |
| Organic carbon (%) | 0.41 | Very low | Tekalign (1991) |
| Organic matter (%) | 0.71 | Very low | Tekalign (1991) |
| Total Nitrogen (%) | 0.94 | Very high | Tekalign (1991) |
| Available Phosphorus(ppm) | 4.80 | Very low | Jones (2001) |
| Available Sulfur (ppm) | 14.27 | Low | EthioSIS (2014) |
| CEC (meq/100 g soil) | 19.05 | Medium | Hazelton and Murphy (2007) |
| **Onion and garlic peel analysis** | | | |
| Total Nitrogen (%) | 0.074 | Very low | Tekalign (1991) |
| Available Phosphorus(ppm) | 1020 | Very high | Jones (2003) |
| Available Sulfur (ppm) | 0.192 | Very low | EthioSIS (2014) |
| Organic carbon (%) | 39.73 | Very high | Tekalign (1991) |
| Organic matter (%) | 68.5 | Very high | Tekalign (1991) |

## 4.2. Phenological Parameters

### 4.2.1. Days to First Flowering

The time to first flowering was highly significantly ($p<0.001$) influenced by the fertilizer treatments (Appendix Table 1). The earliest flowering (47.0 days) was recorded in the Recommended Fertilizer (RF) and the 50% RF + 381kg Peel $ha^{-1}$ treatments (Table 3). In contrast, unfertilized control took nearly twice as long, reaching first flowering at 87.9 days. The rapid transition to flowering in Recommended fertilizer (RF) and integrated plots is due to the presence of phosphorus in DAP, which facilitates the production of florigen and enhances the root system capacity to support reproductive structures (Afrin, 2022). This supports the findings of (Sabit, 2020a), who observed that integrated nutrient management significantly accelerates the reproductive onset compared to unfertilized controls.

### 4.2.2. Days to 50% Flowering

The type of fertilizers used had a highly significant ($p<0.001$) impact on the number of days to 50% flowering (See Appendix Table 1). RF and 50% RF + Peel fertilizer combinations took the shortest time (58.0 days) while the control took the longest (97.33 days).The delay in the control group confirms that nutrient-deficient plants stay in a vegetative survival mode longer before shifting resources to reproduction. Phosphorus in DAP acts as a physiological trigger that counteracts the prolonged vegetative effects of nitrogen (Shubham *et al.,* 2025). onion and garlic peels are rich in bioactive phenolic compounds, specifically flavonoids like quercetin and organo sulfur compounds. These substances act as natural bio stimulants that optimize the internal hormonal balance. According to Sabit (2020), organic wastes from the Allium family contain precursors that stimulate the synthesis of auxins and cytokinins, which facilitate the transition from the vegetative to the reproductive phase.

### 4.2.3. Days to First Fruit Setting

The analysis of variance showed that time for initial fruit set of tomato was highly significantly ($p<0.001$) affected by type of fertilizer (Appendix Table 1). The 50% RF + 381kg Peel powder $ha^{-1}$ achieved the earliest fruit setting at 64.73 days, followed closely by the RF treatment at 64.97 days (Table 2). The control group took the longest (111.07 days). Earlier fruit setting is a

direct result of earlier flowering. As Islam *et al*. (2018) noted the integration of organic and inorganic sources increases nutrient availability, leading to enhanced reproductive production and better fruit setting success.

### 4.2.4. Days to First Fruit Harvest

The analysis of variance showed that days to first fruit harvest of Tomato was significantly ($p<0.01$) affected by type of fertilizer (Appendix Table 1). The 50% RF + 381kg Peel powder achieved the earliest harvest (123.67 days), while the 25% EcoG + 572 kg Peel powder was the most delayed (140.47 days) (Table 3).

Table 4: Effect of Fertilizer Types on Phenological parameters of tomato

| | **Parameters** | | | |
|---|---|---|---|---|
| **Treatments** | Days to first flowering | Days to 50% flowering | Days to 1st fruit setting | Days to 1st fruit harvest |
| Control | 87.90 $^{a}$ | 97.33 $^{a}$ | 111.07 $^{a}$ | 136.40$^{abc}$ |
| Rec Fertilizer (RF) | 47.00 $^{d}$ | 58.00 $^{c}$ | 64.97 $^{e}$ | 125.47 $^{d}$ |
| 50% RF + 381kg Peel ha$^{-1}$ | 47.00 $^{d}$ | 58.00 $^{c}$ | 64.73 $^{e}$ | 123.67 $^{d}$ |
| 25% EcoG + 572 kg Peel ha$^{-1}$ | 75.23 $^{b}$ | 82.67 $^{b}$ | 76.23 $^{d}$ | 140.47 $^{a}$ |
| 50% EcoG + 381kg Peel ha$^{-1}$ | 62.77 $^{c}$ | 73.00 $^{b}$ | 70.33 $^{de}$ | 128.30 $^{cd}$ |
| 75% EcoG + 191kg Peel ha$^{-1}$ | 69.60$^{bc}$ | 82.67 $^{b}$ | 100.10 $^{b}$ | 136.27$^{abc}$ |
| 762kg Peel ha$^{-1}$ | 63.34$^{bc}$ | 73.00 $^{b}$ | 75.67 $^{d}$ | 138.03$^{ab}$ |
| Rec EcoG | 67.43$^{bc}$ | 74.00 $^{b}$ | 88.77 $^{c}$ | 130.13$^{bcd}$ |
| Mean | 65.04 | 74.83 | 81.48 | 132.34 |
| LSD (0.05) | 12.42 | 10.42 | 9.09 | 9.358 |
| CV (%) | 10.91 | 7.95 | 6.37 | 4.04 |
| SE (Mean) | 4.09 | 3.43 | 3 | 3.085 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

Balanced fertilization shortens the ripening period by improving the movement of photosynthetic from leaves to developing fruits (Regassa *et al.*, 2016). The delay in the Eco-Green and Peel combination suggests that very high organic waste levels can maintain auxin activity, delaying the physiological senescence needed for final ripening (Kakabouki *et al*., 2024).

## 4.3. Vegetative Growth Parameters

### 4.3.1. Plant Height

The analysis of variance revealed that there was high significant ($p<0.001$) effect of Plant height on the different types of fertilizers used (Appendix Table 2). The highest plant was observed in the RF fertilizers which was 91.13 cm, statistically not different from 50% RF + 381kg Peel, which was 83.77 cm. The control had the shortest plant height, which was 46.00 cm (Table 4). The increase in height is due to nitrogen's function in cell division and phosphorus's role in early root development (Kahsay *et al.*, 2016).

The analysis of variance showed that Plant height was highly significantly ($p<0.001$) influenced by the different type of fertilizers (Appendix Table 2). The tallest plant (91.13 cm) was recorded in the RF fertilizers, statistically at par with 50% RF + 381kg Peel (83.77 cm). The control plant measured the shortest at 46.00 cm (see Table 4). This is due to the role of nitrogen in cell division and phosphorus in early root development development (Kahsay *et al.*, 2016)The combined application of treatments ensured a constant nutrient supply, which enabled the plant to develop its full genetic potential (Sigaye, 2025).

The control plant was the shortest at 46.00 cm (Table 4). This height increase is linked to Nitrogen role in cell division and Phosphorus contribution to early root development (Kahsay *et al.*, 2016). Integrated treatments provided a steady supply of nutrients, helping the plant reach its full genetic potential (Sigaye, 2025).

### 4.3.2. Stem Diameter (mm)

Stem diameter is the primary indicator for plant vigor and potential fruit yield. Fertilizer types had a significant (P<0.001) effect on stem diameter of tomato plant (Appendix Table 2). The highest stem diameter (11.53 and 10.43mm) were recorded from the treatment that received recommended fertilizer (RF) rate and 50% RF + 381kg peel $ha^{-1}$, respectively while the lowest (3.07mm) was from the control treatment (Table 4). Application of RF rate and 50% RF + 381kg peel $ha^{-1}$ treatments increase the stem diameter of tomato by 275.57 and 239.74% compared to the control treatment. The increase in stem diameter could be attributed to the readily availability of nutrients and moisturewhich promotes growth and thickness of tomato stem. The application of garlic peel to soil resulted to increase the water holding capacity of the soil up to 60% (Soliman *et al*., 2025). However, the very thin stem (3mm) observed from the control treatment is a significant indicator of nutrient stress. The result of this study was in agreement with Zuo *et al.* (2017) reported that healthy tomato plants entering the flowering phase typically have a stem diameter between 9.5 mm and 11.9 mm.

### 4.3.3. Number of primary and secondary branches

The number of branches of a plant is considered as a key indicator for a vegetative vigor and its potential for yield. The analysis of variance indicated that the type of fertilizers had a significant (P<0.001) effect both on the number of primary and secondary branches of tomato (Appendix Table 3). The highest numbers of primary branches (6.57 and 5.93) and secondary branches (6.70 and 6.17) were obtained from the RF rate and 50% RF + 381kg peel $ha^{-1}$, respectively (Table 4).

In contrast, the lowest numbers of primary branch (2.10) and secondary branch (1.3) was recorded from the application of 75% EcoG + 191kg peel $ha^{-1}$ and the control which is statistically at par with 762kg Peel $ha^{-1}$ and Rec Eco G treatments. Application of RF rate and 50% RF + 381kg peel $ha^{-1}$ improved number of primary branch of tomato by 212.86 and 182.38% and secondary branch by 415.38 and 374.6% in contrast to 75% EcoG + 191kg peel $ha^{-1}$ treatment and the control, respectively. The increased number of primary and secondary branches from the RF and 50% RF + 381kg peel $ha^{-1}$ could be attributed to the readily availability of nitrogen from urea/DAP combined with the bioactive compounds (like sulfur and phenolic acids) available in onion and garlic peel, which could trigger activation of axillary buds.

In line with the present results Roshini *et al*. (2023) reported the highest number of leaves and best overall growth performance of lettuce treated with a mixture of compost and onion/garlic peel fertilizer.

Table 5: Effect of Fertilizer Types on growth parameters of tomato

| Treatments | Parameters | | | |
|---|---|---|---|---|
| | Plant height (cm) | Stem diameter (mm) | No. of primary branch | No. of secondary branch |
| Control | 46.00 $^{d}$ | 3.07$^{d}$ | 2.47 $^{cd}$ | 1.30 $^{d}$ |
| Rec Fertilizer (RF) | 91.13 $^{a}$ | 11.53 $^{a}$ | 6.57 $^{a}$ | 6.70 $^{a}$ |
| 50% RF + 381kg Peel ha$^{-1}$ | 83.77 $^{a}$ | 10.43 $^{a}$ | 5.93 $^{a}$ | 6.17 $^{a}$ |
| 25% EcoG + 572 kg Peel ha$^{-1}$ | 69.73 $^{b}$ | 6.97 $^{b}$ | 4.27 $^{b}$ | 4.53 $^{b}$ |
| 50% EcoG + 381kg Peel ha$^{-1}$ | 54.43 $^{cd}$ | 4.70 $^{cd}$ | 3.70$^{bc}$ | 2.53 $^{c}$ |
| 75% EcoG + 191kg Peel ha$^{-1}$ | 51.27 $^{d}$ | 4.66 $^{cd}$ | 2.10 $^{d}$ | 1.40 $^{d}$ |
| 762kg Peel ha$^{-1}$ | 65.73$^{bc}$ | 5.63$^{bc}$ | 3.13$^{bcd}$ | 1.77 $^{cd}$ |
| Rec Eco G | 51.40 $^{d}$ | 4.40 $^{cd}$ | 3.30$^{bcd}$ | 1.57 $^{d}$ |
| Mean | 64.18 | 6.42 | 3.93 | 3.25 |
| LSD (0.05) | 11.46 | 2.13 | 1.25 | 0.8 |
| CV (%) | 10.2 | 18.97 | 18.13 | 14 |
| SE (Mean) | 3.78 | 0.7 | 0.41 | 0.26 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

## 4.4. Fruit Morphology and Number

### 4.4.1. Fruit Diameter (Major, Intermediate, and Minor)

Analysis of variance indicated that fertilizer type had a significant (P<0.001) effect on the major and intermediate fruit diameter of tomato. The results showed that treatments receiving recommended inorganic fertilizer rate (RF), 25% Eco G + 572 kg peel $ha^{-1}$, and 50% RF + 381kg peel $ha^{-1}$ produced significantly larger major and intermediate fruit diameters compared to the control (Table 5). The highest major and intermediate fruit diameters (56.67 and 55.10 mm) were recorded from the RF treatment, which was statistically similar with 25% EcoG + 572 kg peel $ha^{-1}$ (53.95 and 49.80 mm) and 50% RF + 381kg peel $ha^{-1}$ **(**53.23 and 52.77 mm**)**, respectively. In contrast, the control treatment recorded the lowest major and intermediate fruit diameters (34.47 and 31.60 mm). Recommended Fertilizer rate and 50% RF + 381kg peel $ha^{-1}$ increased major (64.4 and 54.4%) and intermediate (74.37 and 66.99%) fruit diameters respectively**,** compared to the control. This substantial increase on major and intermediate fruit diameter suggests that both full recommended inorganic fertilization and 50% substitution with organic amendments (garlic and onion peel powder) significantly enhance fruit size by boosting the net photosynthetic rate.

The highest major and intermediate fruit diameters recorded on RF treatment could be due to its attribute to the immediate availability of nitrogen and phosphorus nutrients which are critical for cell division and enlargement, which ultimately influence fruit development. Similarly, the comparable performance of 50% RF + 381kg peel $ha^{-1}$ indicates that integrating organic nourishment with inorganic fertilizers can maintain high fruit growth by potentially improving soil health. Garlic and onion peel powder as organic amendments may enhance microbial activity and physical property of the soil. However, the relatively lower performance of sole organic treatments and eco-green fertilizer combinations may be due to the slower nutrient release patterns, which might not meet the immediate nutrient demand during critical growth stages.

Related to this finding, Qasim *et al*. (2023) reported increased fruit diameter of tomato from the combined application of chemical fertilizer with organic fertilizer. (Islam *et al.*, 2017) also reported that integrated nutrient management improves crop yield and quality by combining the rapid nutrient supply of inorganic fertilizers with the soil-enhancing properties of organic inputs. Table 6. Effect of Fertilizer Types on tomato fruit diameter

| Treatment | Parameters | | |
|---|---|---|---|
| | Major fruit diameter (mm) | Intermediate fruit diameter (mm) | Minor fruit diameter (mm) |
| Control | 34.47[c] | 31.60 [c] | 30.43[d] |
| Rec Fertilizer (RF) | 56.67 [a] | 55.10 [a] | 54.10 [a] |
| 50% RF + 381kg Peel $ha^{-1}$ | 53.23 [a] | 52.77 [a] | 51.77[a] |
| 25% EcoG + 572 kg Peel $ha^{-1}$ | 53.95 [a] | 49.80 [a] | 48.77 [ab] |
| 50% EcoG + 381kg Peel $ha^{-1}$ | 46.17[b] | 43.40 [b] | 42.20 [c] |
| 75% EcoG + 191kg Peel $ha^{-1}$ | 45.37[b] | 43.73[b] | 43.73[bc] |
| 762kg Peel $ha^{-1}$ | 46.37[b] | 43.17[b] | 41.67[c] |
| Rec EcoG | 44.90 [b] | 40.90 [b] | 39.73 [c] |
| Mean | 47.64 | 45.06 | 44.05 |
| LSD (0.05) | 4.64 | 5.68 | 5.95 |
| CV (%) | 5.57 | 7.2 | 7.71 |
| SE (Mean) | 1.53 | 1.87 | 1.96 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

### 4.4.2. Total Fruit Number per Plant

The result of the study revealed that total fruit number per plant was significantly ($p<0.001$) affected by fertilizer types. The highest fruit number per plant (60.13 and 54.83) were obtained from the plots treated with recommended RF rate and 50% RF + 381kg peel $ha^{-1}$, respectively while the lowest number of fruit per plant (12.97) was recorded on control treatment (Table 6). Plots fertilized with recommended RF rate and 50% RF + 381kg peel $ha^{-1}$ improved fruit number per plant by 363.61 and 322.75% from the control treatment, respectively. The increased fruit number per plant could be attributed to the readily availability of nutrients including

phosphorous form inorganic and organic sources. Besides, role of onion and garlic peel in hormonal regulation might contribute through diverting nutrient towards the reproductive organs than the vegetative parts. Related findings are reported by Islam *et al*. (2017) where increased tomato fruit numbers are observed from the combined application of inorganic and organic fertilizer. (Li *et al.*, 2025) also reported a significant increase in the number of fruits per plant with the foliar application of inorganic fertilizer and hormone alone or in combination.

Table 7. Effect of Fertilizer Types on tomato fruit volume and total fruit number per plant

| | **Parameters** | |
|---|---|---|
| **Treatments** | Total fruit number per plant | Fruit Volume ($cm^3$) |
| Control | $8.53^{e}$ | $0.1700^{d}$ |
| Rec Fertilizer (RF) | $54.73^{a}$ | $0.5167^{a}$ |
| 50% RF + 381kg Peel $ha^{-1}$ | $49.67^{a}$ | $0.4967^{a}$ |
| 25% EcoG + 572 kg Peel $ha^{-1}$ | $33.43^{b}$ | $0.3633^{b}$ |
| 50% EcoG + 381kg Peel $ha^{-1}$ | $19.90^{c}$ | $0.1897^{d}$ |
| 75% EcoG + 191kg Peel $ha^{-1}$ | $11.10^{de}$ | $0.1883^{d}$ |
| 762kg Peel $ha^{-1}$ | $14.73^{cd}$ | $0.2958^{bc}$ |
| Rec. EcoG | $12.57^{de}$ | $0.2323^{cd}$ |
| Mean | 25.58 | 0.3066 |
| LSD (0.05) | 5.97 | 0.094 |
| CV (%) | 13.32 | 17.51 |
| SE (Mean) | 1.97 | 0.031 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

### 4.4.3. Fruit Volume

The analysis of variance showed that fruit volume of Tomato was highly significantly ($p<0.001$) influenced by type of fertilizer (Appendix Table 4). The highest (0.5167) fruit volume was recorded from Rec Fertilizer which is statistically at par with 50% RF + 381kg Peel treatments (0.497cm$^3$), while the lowest (0.1700 cm$^3$) fruit volume was recorded from the control (Table 6). The largest values for both diameters were observed in fruits harvested from plots treated with the recommended fertilizer, 50% RF + 381 kg Peel ha$^{-1}$, and 25% EcoG + 572 kg Peel ha$^{-1}$. In contrast, the smallest values were recorded in fruits obtained from the control plots. Integrated management using Eco-Green and peels encourages beneficial microbes and improves soil water retention, allowing fruits to pack more biomass inside (Nan *et al.*, 2025).

## 4.5. Yield Parameters

### 4.5.1. Marketable Fruit Yield

Analysis of variance indicated that fertilizer type highly significantly ($p<0.001$) affected marketable yield of tomato (Appendix Table 4). The use recommended NP fertilizer rate (RF) and 50% RF + 381kg peel ha$^{-1}$ enhanced the marketable yield of tomato compared to the rest of the treatments (Figure 2).

The maximum fruit yield (65.33 and 65.29 t/ha) were recorded on treatments that received recommended rate of NP fertilizer and 50% RF + 381kg peel ha$^{-1}$ respectively, while the lowest marketable yield (3.98 t/ha) was recorded on the control treatment. Application of RF rate and 50% RF + 381kg peel ha$^{-1}$ improved the marketable yield by 1541 and 1540 over the control treatment, respectively. These implies that the yield of marketable fruits per plot had significantly increased with the use optimal rate of inorganic fertilizer and combined application of partial recommended NP rate mixed with organic fertilizer like (garlic and onion peels). In line with this study Yohannes and Gebretsadikan (2019) reported that tomato plant received optimum amount of NP fertilizers produced high marketable fruit yields. Applying onion wastes is reported to increase soil fertility and improve the soil microbiome in soil-based culture (greenhouses or in open fields) (Keerthana *et al.*, 2024). Higher yield of tomato was also reported from integrated application of organic and chemical fertilizer (Islam *et al*., 2017).

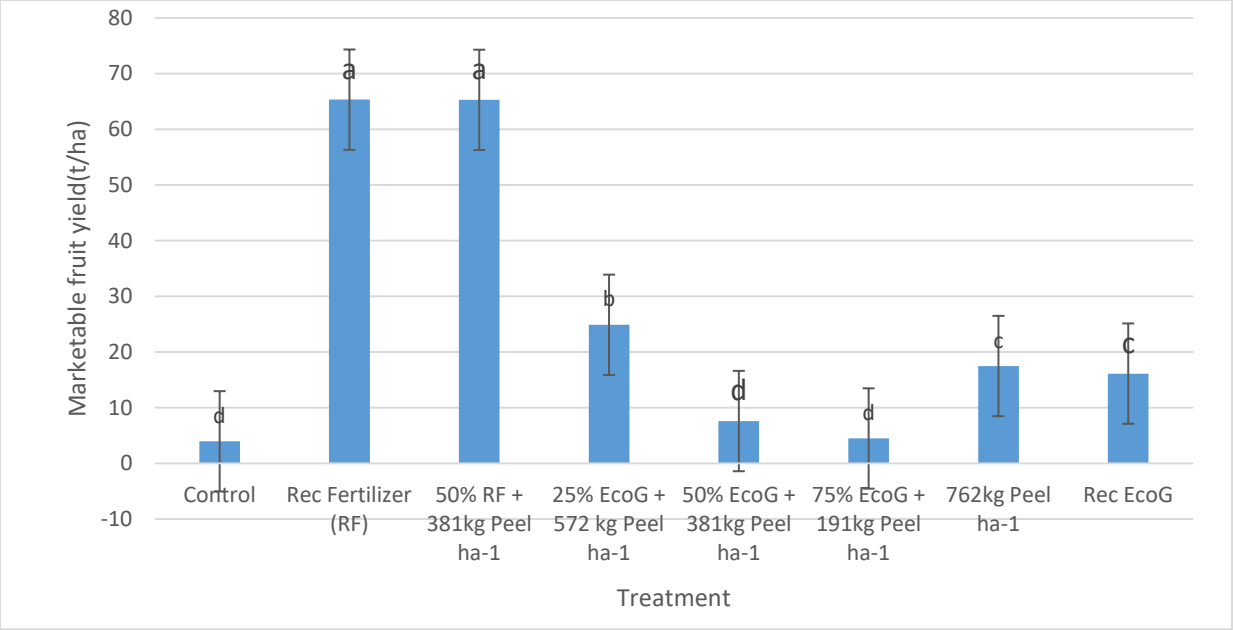



Figure 2. Effect of fertilizer types on tomato marketable fruit yield

### 4.5.2. Unmarketable Fruit Yield

The analysis of variance revealed that the unmarketable fruit yield was highly significantly ($p<0.001$) influenced by fertilizer types (Appendix Table 3). The highest unmarketable yield (3.97 t/ha) was recorded in the Recommended Fertilizer (RF) treatment, which was significantly higher than all other treatments and the lowest (0.19 t/ha) unmarketable yield was recorded from the control unit. Interestingly, the integration of 50% EcoG + 381kg Peel $ha^{-1}$ dramatically reduced the unmarketable yield to just 1.46 t/ha (Figure 3). The significantly higher rate of unmarketable yields in the plots treated with RF can be explained by the overconsumption of nitrogen leading to succulent fruit development that makes them more prone to physical disorders such as fruit cracking and sun scalding (Sigaye, 2025). At the same time, the combined use of the peel powder from onions and the liquid organic fertilizer guarantees a steady and consistent release of nutrients. Consistent nutrient supply ensures the preservation of fruit skin elasticity and thus prevents fruit cracking (Temesgen et al., 2025). In addition, it is possible to suggest that the bioactive substances present in garlic and onion peels were responsible for fruit protection against the damage due to damping off, blight, and pests (Korane *et al*., 2025).

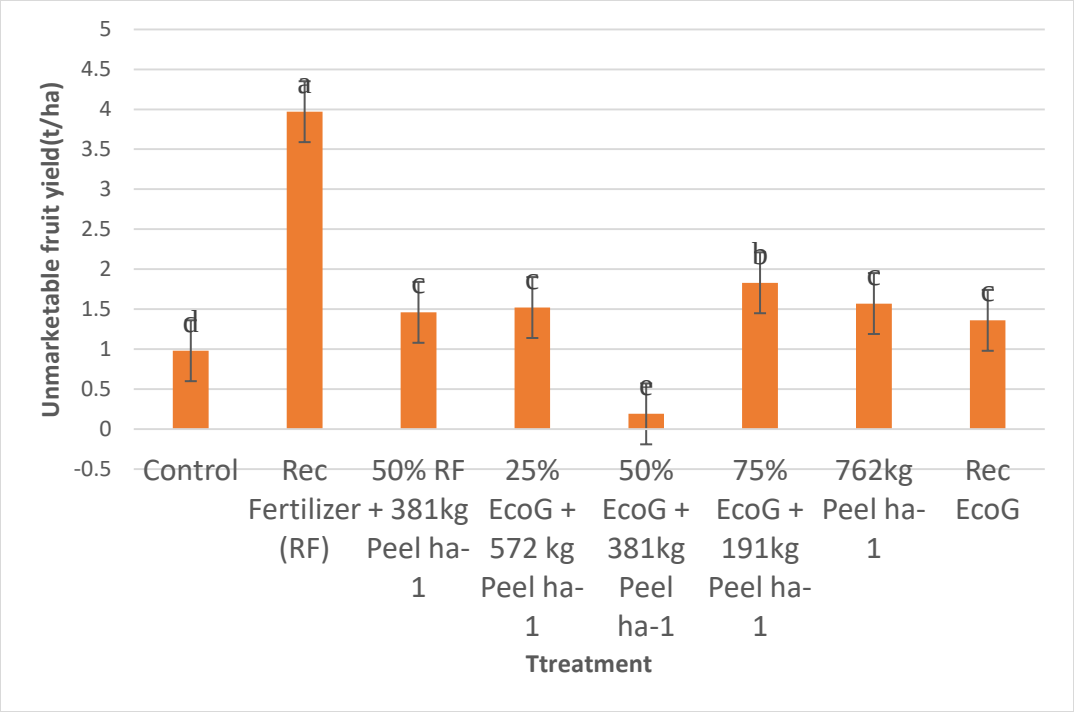



Figure 3. Effect of fertilizer types on tomato unmarketable fruit yield

### 4.5.3. Total Fruit Yield

The analysis of variance (ANOVA) indicated that the total fruit yield of tomato was highly significantly ($p<0.001$) influenced by the fertilizer treatments (Appendix Table 3). The highest total fruit yield (69.30 t/ha) was achieved under the Recommended Fertilizer treatment. The lowest marketable yield (4.96 t/ha) also gained from control group which is statistically at par with 75% EcoG + 191kg Peel $ha^{-1}$ (6.32 t/ha) and 50% EcoG + 381kg Peel $ha^{-1}$ (7.81t t/ha) (Figure 4).

The superior performance of the RF and integrated RF+Peel treatments highlights the critical role of nitrogen and phosphorus interaction in driving fruit weight and cluster production. As noted by Temesgen *et al*. (2025), the total yield of tomato varieties is significantly enhanced when nitrogen (from Urea) and phosphorus (from DAP) work together to increase the number of fruits per plant.

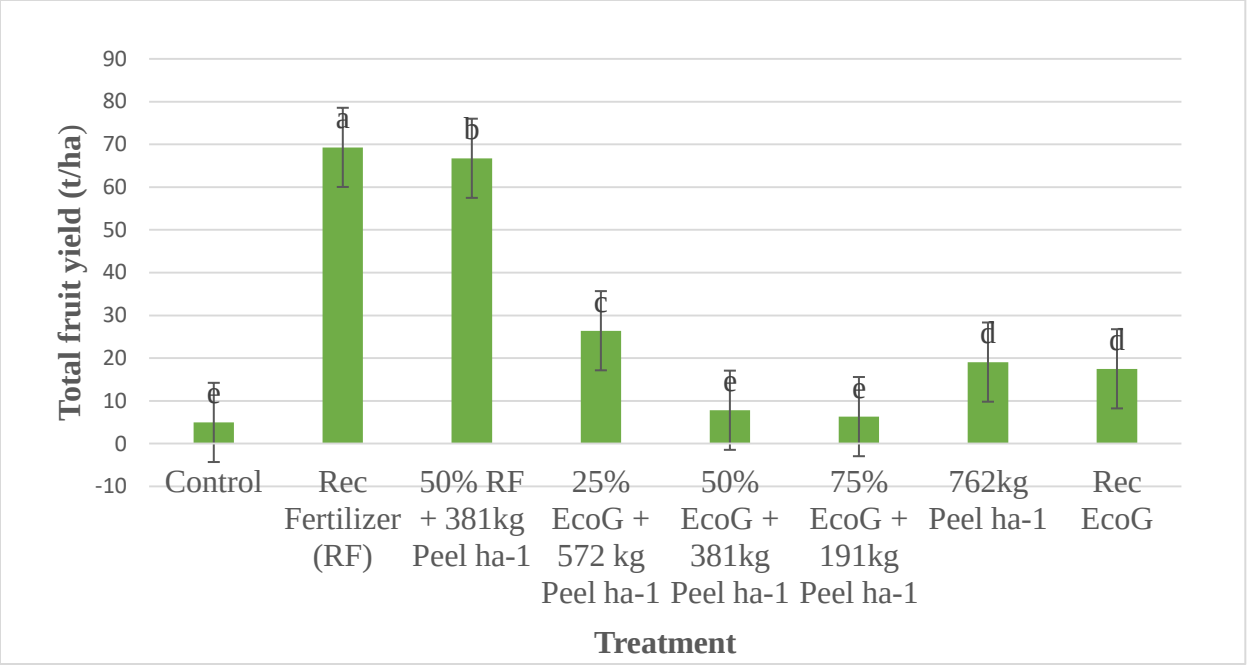



Figure 4. Effect of Fertilizer Types on tomato total fruit yield

These results align with the findings of Korane *et al.* (2025), who reported that balanced applications of DAP and Urea could increase total yields by over 200% compared to unfertilized plots. Furthermore, the success of the integrated approach supports the meta-analysis by Gao *et al.* (2023), who concluded that organic fertilizers effectively enhance tomato yield by improving nutrient uptake efficiency and soil microbial activity.

### 4.5.4 Fruit weight

The Analysis of Variance (ANOVA) indicated that the weight of Tomato fruit was highly significantly ($p < 0.001$) affected by different fertilizer types (Appendix Table 3). The highest fruit weight performance (137.28 g) was gained from the 50% RF + 381kg Peel $ha^{-1}$ treatment, which was statistically equivalent to the Rec Fertilizer (133.17 g) (Table 7). The lowest fruit weight (56.71 g) is recorded from the control group which is statistically at par with 762 kg Peel $ha^{-1}$ (65.02 g) and Rec EcoG (59.9 kg/ha).

The addition of both inorganic and organic fertilizer enhances the amount and market value of the tomato fruit weight (Sabit, 2020).. It is important to note that 50% decrease in the usage of the chemical fertilizer with peel powder gives results similar to the usage of 100% chemical

fertilizer, which supports the synergistic effect theory of Roshini et *al*. (2023)in which the botanical powders enhance nutrient absorption and yield. The absence of significant difference between the control and organic fertilizer group could be explained by the insufficient speed of nutrients' discharge. As stated by Roshini *et al*. (2023), while bio-fertilizers like Eco-Green speed up the final weight depends heavily on the concentration and the presence of macronutrients.

### 4.5.5 Fruit Density

The Analysis of Variance (ANOVA) indicated that the density of Tomato fruit was highly significantly ($p < 0.001$) affected by different fertilizer types (Appendix Table 4). These results indicate that the internal compactness and structural integrity of the fruit are heavily influenced by the specific combination of synthetic and organic nutrient sources applied. The highest fruit density (1067.33 $kg/m^3$) was gained from the Recommended Fertilizer which is statistically at par with 50% RF + 381kg Peel $ha^{-1}$ (1066 $kg/m^3$) (Table 7). The lowest fruit density (980 $kg/m^3$) is recorded from the control group which is statistically at par with 762 kg Peel $ha^{-1}$ (149 $kg/m^3$) and Rec EcoG (1008 $kg/m^3$)

The highest fruit density suggests that while full synthetic fertilization provides the necessary nutrients for fruit expansion, a 50% reduction in chemical fertilizer can be successfully compensated for by the addition of garlic and onion peel powder without losing fruit density. This finding is supported by the literature, which indicates that phosphorus (P), a major component of Recommended Fertilizers like DAP, is essential for the development of thick pericarp walls and dense locular gel, which creates fruit with increased structural quality (Ger *et al.*, 2024).Moreover, the effectiveness of the integrated application (50% RF + 381kg Peel ha-1) corresponds well to the results of. Khan *et al*. (2017),who emphasized the effectiveness of combined use of inorganic nutrients and organic additives in maximizing physiological volume and density of the fruit by providing a balanced supply of nutrients.

The significant difference between control plots and those treated with nutrients confirms that inadequate nutrient conditions affect negative biomass distribution and poor structural

organization. As emphasized by Zhang *et al*. (2024), fruit density is rarely assessed directly but is an important indirect indicator of compactness of the fruit.

The low density in the control group likely results from a lack of the supportive functionality of phosphorus in energizing the movement of nutrients, which is required to prevent succulent or weak structures (Keerthana *et al*., 2024).

Table 8. Effect of Fertilizer Types on tomato fruit density and Fruit weight

| Treatments | Parameter | |
|---|---|---|
| | Fruit Density ($kg/m^3$) | Fruit weight (g) |
| Control | $980^{d}$ | $56.71^{d}$ |
| Rec Fertilizer (RF) | $1067.3^{a}$ | $133.17^{a}$ |
| 50% RF + 381kg Peel $ha^{-1}$ | $1066^{a}$ | $137.28^{a}$ |
| 25% EcoG + 572 kg Peel $ha^{-1}$ | $1055^{ab}$ | $109.13^{b}$ |
| 50% EcoG + 381kg Peel $ha^{-1}$ | $1034^{bc}$ | $95.31^{c}$ |
| 75% EcoG + 191kg Peel $ha^{-1}$ | $1022^{c}$ | $60.53^{d}$ |
| 762kg Peel $ha^{-1}$ | $1015^{c}$ | $65.02^{d}$ |
| Rec EcoG | $1008^{cd}$ | $59.9^{d}$ |
| Mean | 1031 | 89.63 |
| LSD (0.05) | 29.2 | 10.8 |
| CV (%) | 0.98 | 4.18 |
| SE (Mean) | 5.85 | 2.17 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

## 4.6. Quality Parameters

### 4.6.1. Fruit pH

The analysis of variance (ANOVA) indicated that the pH value of tomato fruit was highly significantly ($p<0.001$) influenced by different fertilizer types (Appendix Table 4). The highest fruit pH values (4.30) were recorded in the Recommended Fertilizer (RF) treatment which is statistically at par with 50% RF + 381kg Peel $ha^{-1}$ treatment (4.20) (Table 8). In contrast, the lowest pH value (3.49) was recorded from unfertilized control. The rest of the integrated methods using Eco-Green and peel powder had pH values ranging between 3.59 and 3.79.

The pH value indicates the quality of tomatoes since the flavor of the fruit depends on its pH value. This indicates that the use of a balanced amount of inorganic nutrients (N and P) in addition to the use of peels has kept the pH value in the right range required for processing the tomatoes. Balanced levels of nitrogen and phosphorus applications will ensure the pH value remains at 4.32 for optimal taste reduction and acidity as explained by Temesgen *et al*. (2025).

The decrease in the pH (increased acidity) in the control group implies that the nutrients-deficient tomato plants do not undergo the biochemical changes required during the process of ripening. Teka *Teka* (2013) explains that the pH usually ranges between 4.23 and 4.63 when the fruit moves from the mature green stage to the ripe stage. Moreover, the fact that the integration of 50% RF + Peel can maintain a high pH (4.20) proves that the organic material present in Allium peels regulates fruit acidity (Roshini *et al*., 2023)..

### 4.6.2. Total Soluble Solids (TSS°) °Brix

The ANOVA test revealed that the content of Total Soluble Solids (TSS) of tomatoes was significantly ($p<0.001$) influenced by the fertilizer treatments (Appendix Table 4). The highest TSS was measured for the Recommended Fertilizer (RF) treatment (5.50 °Brix), statistically equal to the combination of 50% RF + 381 kg Peel $ha^{-1}$ treatment (5.43 °Brix) (Table 8). On the contrary, the unfertilized control group demonstrated low values of TSS with a level of 3.63 °Brix, which implies low sugar accumulation without fertilizer use.

TSS is an indicator that reflects the level of sweetness and flavor in tomatoes. Its level depends on the concentration of sugars and organic acids in the fruits. The high TSS in the RF and

integrated fertilization is a proof of the importance of nitrogen and phosphorus for carbohydrate synthesis and translocation. According to Keerthana *et al*. (2024), phosphorus provides energy for nutrient transportation, whereas nitrogen is responsible for biomass accumulation. In addition, bioactive compounds from onion peel have improved nutrient uptake by plants leading to a high TSS concentration equal to the chemical fertilization (Sabit, 2020).

Table 9. Effect of Fertilizer Types on tomato fruit quality

| | Parameters | |
|---|---|---|
| Treatments | pH | Total soluble solid (°Brix) |
| Control | 3.49 $^{c}$ | 3.63 $^{d}$ |
| Rec Fertilizer (RF) | 4.30 $^{a}$ | 5.50 $^{a}$ |
| 50% RF + 381kg Peel $ha^{-1}$ | 4.20 $^{a}$ | 5.43 $^{a}$ |
| 25% EcoG + 572 kg Peel $ha^{-1}$ | 3.75 $^{b}$ | 4.77 $^{b}$ |
| 50% EcoG + 381kg Peel $ha^{-1}$ | 3.59$^{bc}$ | 4.37$^{bc}$ |
| 75% EcoG + 191kg Peel $ha^{-1}$ | 3.60$^{bc}$ | 4.03 $^{cd}$ |
| 762kg Peel $ha^{-1}$ | 3.79 $^{b}$ | 4.30$^{bc}$ |
| Rec EcoG | 3.71 $^{b}$ | 4.33$^{bc}$ |
| Grand Mean | 3.8 | 4.55 |
| LSD (0.05) | 0.197 | 0.501 |
| CV (%) | 2.96 | 6.29 |
| SE (Mean) | 0.065 | 0.165 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

### 4.6.3. Fruit color

Tomato color is the primary external attribute influencing consumer purchase decisions. Its complexity in color arises from a diverse carotenoid pigment system, with appearance determined by pigment type and concentration, and regulated by both genetic and environmental factors (Radzevičius et *al*., 2014).

The effect of fertilizer types on tomato color is presented in Table 9. The a/b ratio, a key indicator of color quality widely employed in both commercial practice and scientific studies of concentrated tomato products (Porretta *et al*., 1989). The a/b value of tomato fruit was significantly affected by fertilizer treatments. The highest a/b values were recorded in fruits harvested from applications of 50% RF + 381 kg Peel ha$^{-1}$, 50% EcoG + 381 kg Peel ha$^{-1}$, 75% EcoG + 191 kg Peel ha$^{-1}$, and Rec EcoG. Conversely, the lowest a/b ratio was recorded in fruits treated with 25% EcoG + 572 kg Peel ha$^{-1}$. This means fertilizer treatments -50% RF + 381 kg Peel ha$^{-1}$, 50% EcoG + 381 kg Peel ha$^{-1}$, 75% EcoG + 191 kg Peel ha$^{-1}$, and Rec EcoG resulted in the highest lycopene content. Gao *et al*. (2023) conducted a meta-analysis on the impact of organic fertilizer use on tomato yield and quality, finding that organic fertilizers boosted lycopene content by 23.95%.

Table 10. Effect of Fertilizer Types on Tomato fruit color

| | Parameters | |
|---|---|---|
| Treatments | a/b | Hue angle |
| Control | 1.03$^{bc}$ | 0.77$^{bc}$ |
| Rec Fertilizer (RF) | 1.01$^{cd}$ | 0.78$^{ab}$ |
| 50% RF + 381kg Peel ha$^{-1}$ | 1.15$_{a}$ | 0.72$^{d}$ |
| 25% EcoG + 572 kg Peel ha$^{-1}$ | 0.95$^{d}$ | 0.81$^{a}$ |
| 50% EcoG + 381kg Peel ha$^{-1}$ | 1.10$^{ab}$ | 0.74$^{bcd}$ |
| 75% EcoG + 191kg Peel ha$^{-1}$ | 1.06$^{abc}$ | 0.76$^{bcd}$ |
| 762kg Peel ha$^{-1}$ | 1.05$^{bc}$ | 0.76$^{bc}$ |

| | | |
|---|---|---|
| Rec EcoG | 1.08[abc] | 0.75[bcd] |
| Grand Mean | 1.0574 | 0.7581 |
| P value (0.05) | 0.0148 | 0.0150 |
| CV (%) | 4.34 | 2.88 |

LSD (0.05) =Least Significant Difference at 5%; CV=Coefficient of Variation. Means with in columns followed by the same letter(s) are not significant at 5% level of significance.

Pandurangaiah *et al*. (2020) examined carotenoid content in cherry tomatoes and reported a strong correlation between color space values (L, *a, b*) and carotene concentration, highlighting particularly close associations of carotenoid content *and hue angle.* The highest hue angle (0.81 radian) was observed in tomato fruits harvested from plots treated with 25% EcoG + 572 kg Peel ha⁻¹. While the lowest hue angle (0.72 radian) was recorded in fruits from plots receiving 50% RF + 381 kg Peel ha⁻¹. This pattern indicates that carotene content was greatest in fruits from the 50% RF + 381 kg Peel ha⁻¹ treatment, whereas the lowest carotene levels were found under the same application. This may be attributed to the bioactive compounds present in onion and garlic peels.

## 4.7. Partial Budget Analysis

To identify treatments with the optimum return to the tomato producers a partial budget analysis was done as described by CIMMYT (1988). Treatment to be considered as worthwhile to the producer, between 50% and 100% marginal rate of return (MRR) was the minimum acceptable rate (CIMMYT, 1988). The partial budget analysis showed that fertilizer type 50% RF + 381kg peel $ha^{-1}$ gave the maximum net benefit (1,705,731 Birr $ha^{-1}$) with marginal rate of return 3064.2%. Whereas the lowest net benefit (107,541 Birr $ha^{-1}$) was obtained in the control treatment (Table 10).

Table 11. Partial Budget Analysis

| Treatments | Total yield/kg | Adj. Yield (10%) | Gross benefit | Total Variable cost | NB | MRR (%) |
|---|---|---|---|---|---|---|
| Control | 3983 | 3584.7 | 107541 | 0 | 107541 | _ |
| Rec EcoG | 17496 | 15746.4 | 472392 | 13525.5 | 458866.5 | 25.97505 |
| 25% EcoG + 572 kg Peel $ha^{-1}$ | 24895 | 22405.5 | 672165 | 22708.5 | 649456.5 | 20.75466 |
| 50% EcoG + 381kg Peel $ha^{-1}$ | 7624 | 6861.6 | 205848 | 23319 | 182529 | D |
| 75% EcoG + 191kg Peel $ha^{-1}$ | 4487 | 4038.3 | 121149 | 23929.5 | 97219.5 | D |
| 762kg Peel $ha^{-1}$ 8 | 16139 | 14525.1 | 435753 | 24540 | 411213 | D |
| 50% RF + 381kg Peel $ha^{-1}$ | 65293 | 58763.7 | 1762911 | 57180 | 1705731 | 30.64197 |
| Rec Fertilizer (RF) | 65334 | 58800.6 | 1764018 | 92262 | 1671756 | D |

Note: Total Variable Costs (TVC), Recommended rate of DAP (75kg/ha) and Urea (381kg/ha) fertilizer (RF) was 83904 ETB, eco-green fertilizer 24000 ETB/hectare and 3.75 ETB/kg peel powder, Gross Benefit (GB) based on local market prices of 30 ETB/kg.

# 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Conclusions

The study indicated that the use of organic and inorganic fertilizers in integrated approach affect the phenological, growth, yield component, yield and quality parameters of tomato. The use of 50% recommended fertilizer + 381kg/ha peel hasten days to first flowering, 50% flowering and 1st fruit setting and 1st fruit harvest of tomato by 46.5, 40.4, 41.68 and 13.58 % over the control treatments, respectively. Growth parameters of tomato like plant height, stem diameter, and number of primary and secondary branches enhanced with use of in recommended inorganic fertilizer rate (RF) and 50% RF + 381kg/ha peel, which implies the use of peels serves as a partial substitute of inorganic fertilizer for tomato production.

Major and intermediate diameter, total fruit number per plant, and fruit weight per plant as yield component of tomato increased with the use of recommended fertilizer rate, 25% eco-green +572 kg/ha peels, and 50% RF + 381kg/ha peel. This suggests the use of the organic and inorganic

fertilizers alone or in combination contributes to boost yield components of tomato, which ultimately enhance the yield of tomato. The use of recommended inorganic fertilizer (RF) and 50% RF + 381 kg/ha peel gave maximum tomato marketable yield (65.33 and 65.29 t/ha) respectively. More over the partial budget analysis indicated that 50% RF + 381kg peel $ha^{-1}$ gave the maximum net benefit (1,705,731 Birr ha-1) with marginal rate of return 3064.2%.

Quality parameters of tomato including pH, total soluble solid, fruit density, shape, and size were influenced by the use of organic and inorganic fertilizers. The use of integrated fertilizer (50% inorganic fertilizer combined with 381 kg) increased pH, TSS, fruit density, and fruit diameters.

In general, the synergetic effect organic and inorganic fertilizers enhance yield component, yield and quality of tomato. In their combined application, inorganic component ensured immediate nutrient availability for rapid early-season growth and branching, while the organic fertilizer improved the soil's physical and biological properties and enhanced moisture retention, increased microbial activity, and improved cation exchange capacity collectively created a more favorable rhizosphere environment, which reduced nutrient leaching and promoted efficient uptake by the tomato plants. Their overall synergetic effect enhances yield and quality of tomato.

## 5.2. Recommendations

Based on the results of this study, integrated used of organic and inorganic allow producers to achieve higher yields and quality of tomato while safeguarding the environment. The study revealed the use of the use 50% RF + 381kg peel ha-1 gave the maximum yield (65.29 t/ha) with a net benefit of 1,705,731 Birr $ha^{-1}$ with marginal rate of return 3064.2% and improved fruit quality. Therefore, urban, semi-urban and rural farmers can use 50% RF + 381kg peel $ha^{-1}$ for optimized tomato production. However, further research suggested to be undertaken under field condition with inclusion of different organic and inorganic treatments.

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# 7. APPEDNIXXS

Appendix 1: ANOVA Summary for Phenological parameters

| Source of Variation | DF | Metric | **FFD** | **D50** | DFFS | DFH |
|---|---|---|---|---|---|---|
| REP (Replication) | 2 | SS | 424.66 | 430.33 | 79.21 | 12.4 |
| | | MS | 212.332 | 215.167 | 39.607 | 6.202 |
| Treatment | 7 | SS | 3,935.79 | 3,609.33 | 6,041.39 | 822.06 |
| | | MS | 562.256 | 515.619 | 863.056 | 117.437 |
| | | F-Value | **11.17*** ** | **14.56*** ** | 32.03*** | 4.11* |
| | | P-Value | 0.0001 | 0 | 0 | 0.0117 |
| Error | 14 | SS | 704.49 | 495.67 | 377.19 | 399.78 |
| | | MS | 50.321 | 35.405 | 26.942 | 28.555 |
| Total | 23 | SS | 5,064.95 | 4,535.33 | 6,497.79 | 1234.24 |
| Grand Mean | | | **65.035** | **74.833** | 81.484 | 132.34 |
| CV (%) | | | **10.91** | **7.95** | 6.37 | 4.04 |

Appendix 2: ANOVA Summary for Growth parameters

| Source of Variation | DF | Metric | SD | PHT | PBN | SBN |
|---|---|---|---|---|---|---|
| Replication (REP) | 2 | SS | 20.017 | 1,053.52 | 3.7308 | 1.203 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | MS | 10.0085 | 526.762 | 1.86542 | 0.6017 |
| Treatment | 7 | SS | 193.655 | 5,696.89 | 52.96 | 104.486 |
| | | MS | 27.6651 | 813.842 | 7.56571 | 14.9266 |
| | | F-Value | 18.62*** | 19.00*** | 14.87*** | 72.31*** |
| | | P-Value | 0 | 0 | 0 | 0 |
| Error | 14 | SS | 20.798 | 599.7 | 7.1225 | 2.89 |
| | | MS | 1.4856 | 42.835 | 0.50875 | 0.2064 |
| Total | 23 | SS | 234.47 | 7,350.11 | 63.8133 | 108.58 |
| Grand Mean | | | 6.4242 | 64.183 | 3.9333 | 3.2458 |
| CV (%) | | | 18.97 | 10.2 | 18.13 | 14 |

Appendix 3: ANOVA Summary for Yield and Fruit Count

| Source of Variation | DF | Metric | MFYt | UFYt | TFYt | TFN | FW |
|---|---|---|---|---|---|---|---|
| Replication | 2 | SS | 23 | 0.0543 | 23.6 | 35.13 | 6.4 |
| | | MS | 11.49 | 0.02717 | 11.82 | 17.563 | 3.2 |
| Treatment | 7 | SS | 14,719.60 | 24.4011 | 15,555.70 | 6,933.83 | 23994.2 |
| | | MS | 2,102.79 | 3.48587 | 2,222.24 | 990.548 | 3427.8 |
| | | F-Value | 202.17*** | 207.42*** | 201.64*** | 85.28*** | 243.8*** |
| | | P-Value | 0 | 0 | 0 | 0 | 0 |
| Error | 14 | SS | 145.6 | 0.2353 | 154.3 | 162.61 | 196.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | MS | 10.4 | 0.01681 | 11.02 | 11.615 | 14.1 |
| Total | 23 | SS | 14,888.20 | 24.6907 | 15,733.60 | 7,131.57 | 24197.6 |
| Grand Mean | | | 26.198 | 1.6087 | 27.807 | 25.583 | 89.63 |
| CV (%) | | | | 12.31 | 8.06 | 11.94 | 4.18 |

Appendix 4: ANOVA for Fruit Quality and Physical Parameters

| Source of Variation | DF | Metric | MFD | IFD | MFD-01 |
|---|---|---|---|---|---|
| Replication | 2 | SS | 100.5 | 84.36 | 100.33 |
| | | MS | 50.25 | 42.178 | 50.165 |
| Treatment | 7 | SS | 1,027.76 | 1,167.72 | 1,188.14 |
| | | MS | 146.823 | 166.817 | 169.734 |
| | | F-Value | 20.88*** | 15.83*** | 14.70*** |
| | | P-Value | 0 | 0 | 0 |
| Error | 14 | SS | 98.43 | 147.5 | 161.61 |
| | | MS | 7.031 | 10.536 | 11.544 |
| Total | 23 | SS | 1,226.69 | 1,399.58 | 1,450.08 |
| Grand Mean | | | 47.64 | 45.058 | 44.05 |
| CV (%) | | | 5.57 | 7.2 | 7.71 |

| | **DF** | **Metric** | **FVcm$^3$** | Ph | TSS | FD |
|---|---|---|---|---|---|---|
| **REP (Replication)** | 2 | SS | 0.00147 | 0.03563 | 0.6758 | 614.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | MS | 0.00074 | 0.01781 | 0.33792 | 307.13 |
| **Treatment** | 7 | SS | 0.40627 | 1.8023 | 8.9396 | 19774.5 |
| | | MS | 0.05804 | 0.25747 | 1.27708 | 2824.93 |
| | | **F-Value** | **20.15*** ** | 20.34*** | 15.63*** | 2.99*** |
| | | P-Value | 0 | 0 | 0 | 0 |
| **Error** | 14 | SS | 0.04033 | 0.17724 | 1.1442 | 1435.8 |
| | | MS | 0.00288 | 0.01266 | 0.08173 | 102.55 |
| **Total** | 23 | SS | 0.44807 | 2.01516 | 10.7596 | 21,824.6 |
| **Grand Mean** | | | — | 3.8038 | 4.5458 | 1,031.25 |
| **CV (%)** | | | — | 2.96 | 6.29 | 1 |

Appendix figure 1: all over view of management activity of tomato production











