# Mekelle University

**Effect of Blended (NPSB) Fertilizer Rates on Growth Performance, Yield and Yield Components of Tomato *(Lycopersicon esculentum* M.) Varieties in Enderta District, Northern Ethiopia.**

**By**

**Birhane Kebede Weldegebriel**

**MSc. Thesis**

**Submitted in Partial Fulfillment of the Requirements For the Master of Science in Horticulture**

**College of Dryland Agriculture and Natural Resources, Department of Dryland Plant and Horticultural Science, Mekelle University, Ethiopia**

**Major Advisor: Yemane G/her (Ph.D)**

**Co-advisor: Rahel Hagos (Ph.D)**

**June, 2025**

**Mekelle University, Ethiopia**

## DECLARATION

I, Birhane Kebede, hereby, present for consideration of my MSc thesis by the Dryland Plant and Horticultural Science Department within the College of Dryland Agriculture and Natural Resources at Mekelle University. My thesis is in partial fulfillment of the requirements for the degree of master's in Horticulture, entitled **''Effect of Blended (NPSB) Fertilizer Rates on Growth Performance, Yield, and Yield Components of Tomato (*Lycopersicon esculentum* M.) Varieties in Mekelle District, North Ethiopia''**. I sincerely declare that this thesis is the product of my own effort. No other person has published a similar study that I might have copied, and at no stage will this be published without my consent and that of the Dryland Plant and Horticultural Science Department.

Name of the student: Birhane Kebede Signature and date [signature] 13/06/2025

**Approval**

1. Name of the main advisor Yemane G-Egziabher, P/ Signature & date [signature] 13/06/2025
2. Name of the co-advisors: ______ Signature & date ______
3. Name of the external examiner ______ Signature & date ______
4. Name of the internal examiner Berhanu Abrha Signature & date [signature] 13/06/2025
5. Name of postgraduate coordinator Lijalem G/wahd Signature & date [signature] 13/06/25
6. Name of department head Wendim Yigzaw Signature & date [signature] 13/06/2025

## BIOGRAPHY OF THE AUTHOR

The author, Birhane Kebede Weldegebriel, was born on June 10, 1997, in Shame, Ethiopia. He then started his academic journey from Shame Primary School in 2004 (to 2012), after which he attended his junior school, and then he attained his secondary and preparatory school at Hakfen Secondary and Preparatory School from 2013 to 2016 academic years.

After successfully completing the Ethiopian Universities Entrance Examination, he joined Mekelle University in the Department of Dryland Crop and Horticultural Science from 2016/17-2018/19 academic years, where he graduated with a Bachelor of Science degree in Horticulture. Then the author joined the Graduate School of Mekelle University to pursue his Master of Science degree majoring in the field of horticulture.

## DEDICATION

I would like to dedicate this M.Sc. thesis work to my entire family, who have experienced many ups and downs in my achievement and life, especially in the terrible war of Tigray.

## ACKNOWLEDGMENT

First and for most, I would like to thank **"Almighty God"** for his protection favor in my entire life, not only for those who made it also to begin and finish this work successfully.

I would like to thank my major advisor, Dr. Yemane G/ezgeabiher, for his guidance, consistent encouragement, pertinent comments while supervising the fieldwork, and creative suggestions during the course of the research and writing of the thesis. My co- advisor, Dr. Rahel Hagos, for her open support, valuable comments, ideas, and advice in the writing of the thesis.

My deepest appreciation also goes to Dr. Berhan Mengesha, Mr. Guesh Arafayne, Mr. Tarekegn Yohanse and Dr. Kelali Haftu for their encouragement, regular advice, and kindness, as well as proper guidance during the analyzing of the collected data.

I wish also to express my deepest gratitude to my beloved Family; my mother Harya Yanshet; sisters (Shewit Kebede, Nigisti Kebede and Teacher Helen Kebede) and brothers (Shambel Kebede, Teacher Hadushalem Kebede, Teacher Filmon Kebede, Yibrah Kebede, Hayelom Kebede and Meresie Kebede) for their continuous encouragement and giving kind advises.

I would like to express my fondness with great thank to all my colleague's Abreha G/tasdkan, Azeb Berihu, Gebremeskel Hagos, and Rahel Habtu for their support and encouragement during this work. And my sincere thanks also go to my friend Goitem Senay, Kibrom Kidane, and other friends who always encouraged me during my study.

My deepest gratitude also goes to Elshadai Relief Development Association Management and all the farm workers of Elshadai Farm for their support from the giving of permission for the experimental site and starting of the field work until finishing. Lastly, I wish to express my honest appreciation to Mekelle University for funding and helping the research activities.

## LIST OF ABBRIVATION AND ACRONYMS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| ATA | Agricultural Transformation Agency |
| CEC | Cat-ion Exchange Capacity |
| CSA | Central Statistical Agency |
| EAIR | Ethiopian Institute of Agricultural Research |
| EC | Electrical Conductivity |
| Ethio-SIS | Ethiopian soil information system |
| FAO | Food and Agricultural Organization |
| FAOSTAT | Food and Agricultural Organization Statics |
| Ha | Hectare |
| Kg | Kilogram |
| LSD | List Significance Difference |
| M.a.s.l | Meter above sea level |
| NPSB | Nitrogen, Phosphorus, Sulfur and Boron |
| RCBD | Randomized Complete Block Design |
| ERDA | Elshadai Relief and Developmental Association |
| INM | Integrated Nutrient Management |
| EJAS | Ethiopian Journal of Agricultural Sciences |

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

## Abstract

*The effects of blended fertilizer rates (NPSB) on growth, production, and yield components of tomato varieties (lycopersicon esculentum M.) were studied using irrigation facilities at Elshadai Relief and Developmental Association (ERDA agricultural farm, Mekelle). 4x3 factorial experiment was set up in a randomized complete block design (RCBD. The treatments included four rates of blended (NPSB) fertilizer (0 kg $ha^{-1}$, 50 kg $ha^{-1}$, 100 kg $ha^{-1}$, and 150 kg $ha^{-1}$) and three tomato varieties (Melka shola, Roma VF, and Gelelma). Data were collected on tomato growth, yield, and yield components. Results indicated that the impacts of blended fertilizers (NPSB) on tomato varieties were significant with p-value of 0.05 in terms of plant height, leaf number per plant, marketable fruit number per plant, and number of total fruit yield per plant, and total fruit yield per hectare. The blended fertilizer rates (NPSB) and tomato varieties had important interaction effects on the Number of fruit cluster per plant, number of leaves per plant and total fruit yield per hectare. Results indicated a positive association between tomato varieties growth, yield, and yield components. Among the different rates of blended fertilizer rates, significantly shorter days to 50% flowering dates (47 days) and maturity date (105), taller plant height (92cm), higher leaf number per plant (93.79), the highest number of total fruit number per plant (43.61), higher marketable fruit number per plant (40.51), and total fruit yield (28.23 t $ha^{-1}$) were gained from the application of 150 kg $ha^{-1}$ and 100 kg $ha^{-1}$. Among the varieties, Gelelma produced the highest overall fruit number per plant (40.62) and marketable fruit yield (24.50 t $ha^{-1}$) over Melka shola and Roma VF. In the study area, Gelelma tomato variety treated with 150 kg $ha^{-1}$ of blended (NPSB) fertilizer produced the highest total yields (32.20 t $ha^{-1}$) under 150 kg $ha^{-1}$ of blended (NPSB) fertilizer. Therefore, it is recommended to conduct further research in tomato varieties in many locations and seasons with different (NPSB) blended fertilizer rates.*

**Keywords:** *Growth; NPSB Blended fertilizer; Tomato variety; Yield; Yield component*

## Table of Contents

# CHAPTER 1: INTRODUCTION

## 1.1. Background Information

Ethiopian economy predominantly depends on agriculture, which contributes about 50 percent to the nation GDP and 90 percent of export items of which horticultural crops are the leading components (Fekadu and Dandena, 2006, and FAO, 2021). Ethiopia has a variety of vegetable crops grown in different agro-ecological zones for commercial as well as small-scale production as source of income and food. The production of vegetables varies from cultivating a few plants in the backyards for home consumption up to a large-scale production for domestic and export markets (Dawit *et al*., 2004). However, the type is limited to few crops and production is concentrated to some pocket areas.

Tomato (*Lycopersicon esculentum* M.) is the most widely produced vegetable crop in the world. It was originated in a tropical region that stretched from Mexico to Peru (Maerere *et al*., 2006; FAO, 2005), and its use as a food was spread throughout the world after the Spanish colonization of the Americas (Medina Saavedra *et al*., 2017). Tomato is one of the most important edible and nutritious vegetable crops in the world. It is an economically advantageous crop which matures in a short growing season and produces high yield. It is widely cultivated in tropical, subtropical, and temperate climates (FAO, 2019 and its area of cultivation is growing every year. The leading tomato producing countries are China, which is the biggest tomato producer in the world with an annual production of 62.87 million metric tons (FAOSTAT, 2019) and it is followed by India, United State of America, Turkey, and Egypt (FAO, 2019). Tomato ranks first among all vegetables as a processing crop, and it is the third largest vegetable crop in terms of overall vegetable production, after sweet potatoes and potatoes (Yebirzaf *et al*, 2016).

In Ethiopia, there is no exact information as to when tomatoes were first introduced (Sirba *et al*., 2022); however, the crop is cultivated in different major growing areas of the country. Today farmers are interested in tomato production more than any other vegetables for their multiple harvests, which result in high profit per unit area. It is an important cash-generating crop to small scale farmers and provides employment in the production and industries. It is also a source of vitamin A & C as well as minerals (Bjarnadottir and Adda. 2023). In Ethiopia, tomatoes are one of the most important and widely grown vegetable crops, both during the rainy and dry seasons for their fruit by smallholder farmers, commercial state and private farmers (Gemechis *et al*., 2012). The fruits are eaten raw or cooked and can be processed into soup, juice, sauce, ketchup, puree, paste and powder. They also serve as an ingredient in stews and vegetable salads. Such diverse uses make the tomatoes an important vegetable in irrigated agriculture in the country.

Ethiopia is the world's 84$^{th}$ largest producer of tomato in the world (CSA, 2012; CSA, 2015). In 2015 cropping calendar, tomato production in Ethiopia was about 22,788 tons which was harvested from 3,677 ha. According to CSA (2016), 41,815 metric tons of tomatoes were produced from a total of 5,342 ha of land. In Ethiopia, the national mean yield of tomato ranges below 10 ton/ha (CSA, 2015, Regassa *et al*., 2016) which is low as compared to the average yield obtained from the neighboring African countries like Kenya (16.4 t/ha). Tesfay (2008) also reported that, the productivity under farmers condition was 9.0 tones/ha whereas a yield of up to 40.0 ton/ha can be recorded on research plots. This indicates that the average national tomato productivity is by far below the world average (= 34.84 ton/ha) which is due to poor management practice in Ethiopia (Lemma, 2002). Although yield increments are obvious over recent years, many diverse and complex biotic and abiotic factors have contributed to the existing low productivity of tomato in Ethiopia. Tomato production is highly constrained by several factors. Among these, poor soil fertility, lack of well adapted improved varieties (Bayo and Rodrigo, 2024), lack of adequate nutrient supply (Kebede et al., 2023) and poor irrigation practices (Senbeta et al., 2023) are the main constraints to agricultural production systems in low-input agriculture in Ethiopia (Dandena *et al*., 2012).

Even though the overall yield of tomato has been increasing significantly in Ethiopia, the productivity is still far below the world average tomato production was 34 ton per year (FAO stat, 2015). This may be the result of the constant use of chemical fertilizers and low soil fertility. Tomatoes require nutrients such as N, P, K, Mg, Ca, Na, B and S for good production. These nutrients are specific in function and must be supplied to the plant at the right time and in the right quantity (Shukla & Naik, 1993). But most researchers who have worked on enhancement of tomato production in our region focused only on Nitrogen and Phosphorus requirements. Hence, limited information is available especially on micronutrient requirement like S, Zn, and B. It is important to enhance the productivity of crops along with desirable qualities through production management practices and application of other sources of nutrients beyond the blanket recommendation of urea and DAP, especially those that contain sulfur, boron and other micronutrients (Ethio SIS, and Solomon, 2014). Therefore, the application of other sources of nutrients beyond urea and DAP, especially those containing S, B, and other micro-nutrients could increase crop productivity (Ethio SIS 2014).

## 1.2. Statement of the Problem and justification

The national average yield of tomato fruit yield in Ethiopia is often low (6.21 t/ha) and the average of tomato fruit yield in Tigray is 4.06 t/ha (CSA, 2015). This is very low when compared with the yield (40.0 t/ha) obtained from a research yield in Ethiopia (EAOR, 2004). Inorganic fertilizer application has been among the important crop management inputs which are used to overcome soil fertility problem. It has been estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers (Stewart *et al*., 2005).

The status of soil fertility and the appropriate fertilizer rates required for application were not known for smallholders. Recently, the Ethiopian soil information system (Ethio-SIS) project gathered and analyzed grid-based soil samples from each of the agricultural fields and developed soil fertility maps as well as fertilizer recommendation for Tigray Region (ATA, 2014). The Bureau of agriculture and rural development of the region has introduced chemical fertilizers particularly blended fertilizers in each district of zone including the study area. According to the soil fertility status and fertilizer recommendations Atlas for Tigray Region through the Ethio-SIS project (ATA, 2014) has developed soil fertility status-based recommendations for the type of fertilizers to be applied, whereas the rate of fertilizer specifically for tomato was not established.

Except for the roles of nitrogen and phosphorus from blanket recommendations of nitrogen and phosphorus found in urea and DAP, studies on the effect of micronutrients added in the blended fertilizers by ATA on growth, yield components, and yield performance of tomato is scanty. Even though the new blended fertilizers introduced by ATA (agricultural transformation agency) based on soil test such as NPSB (19% N, 38% P2 O5, 7% S and 1%B) is currently being used by the farmers in Tigray, the recommendation of this fertilizer has not been validated yet. Furthermore, the rate of optimum NPSB rate needs to be determined based on research. Hence, there is a need to develop a site-specific recommendation on the NPSB fertilizer rates and varieties to increase production and productivity of tomato in the study area.

## 1.3. Objectives

### 1.3.1. General objective

- To investigate the contribution of different rates of NPSB blended fertilizer on growth performance, yield and yield components of tomato varieties in *Enderta* district.

### 1.3.2. Specific objectives

- To determine optimum rate of blended NPSB fertilizer that results in the best growth performance, yield and yield components of tomato.
- To identify the best tomato variety in terms of growth performance, yield, and yield components of tomato.
- To analyze the profitability of the different rates of NPSB blended fertilizer for tomato production under different fertilizer combinations.

## 1.4. Hypothesis

- Different NPSB fertilizer rates, influence the growth performance and production of tomato varieties.

# CHAPTER 2: LITREATURE REVIEW

## 2.1. Origin, Production, Importance, and Challenge of Tomato Production

### 2.1.1 Tomato and its origin

Although tomato (*Solanum lycopersicum* L.) is actually an herbaceous perennial, it is grown as an annual vegetable crop and develops into branched bush or vine with compound leaves and yellow flowers (Rice and Rice, 2000). The plant is commonly used as an annual herb with erect to prostrate stems. Its growth habit ranges between erect and prostrate, and the plant has a strong taproot with a dense system of lateral and adventitious roots. Additionally, the stem is solid, coarsely hairy and glandular. Leaves are spirally arranged, and flowers are bisexual (self-pollinated) and regular. Fruits are fleshy berry, globular to oblate in shape. Seeds are numerous, kidney or pear shaped (Akida *et al*., 2015).

It originally came from tropical area from Mexico to Peru (Maerere *et al*., 2006; FAO, 2005). In Ethiopia, there is no exact information as to when tomato was first introduced; however, the crop is cultivated in different major growing areas of the country.

Tomato plants are described as determinate or indeterminate. The term 'determinate' refers to the plant growth habit, where determinate tomato plants grow like a bush to a certain size (about 0.9 to 1.5 meter), set fruit, and then decline. Most of the early ripening tomato varieties are of the determinate type, whereas the vines of indeterminate plants continue to grow until frost or disease kills them. Many of the standard sized and all summer tomatoes typical of the home garden are of the indeterminate type; they require support of some kind for best results since the fruit would otherwise be in contact with the soil and thus susceptible to rot and other diseases (Babu *et al*., 2000).

### 2.1. 2 Tomato production

It is the second most important vegetable crop next to potato. Present world production is about 100 million tons fresh fruit on 3.7 million hectares. Tomato production has been reported from 144 countries, but the major country being China in both hectares of harvested Production (1,255,100 ha) and total weight of fruit produced (30,102,040 t). The two leading countries in fruit yield per hectare are the Netherlands (546.92 t $ha^{-1}$) and Belgium (459.29 t $ha^{-1}$). The top five leading fruit-producing countries are China, Egypt, India, Turkey and the United States (FAOSTAT, 2012). China is the biggest tomato producer in the world with annual production 34.1

million tons (FAOSTAT. 2010). FAO (2006), reported that as it is widely cultivated in tropical, subtropical and temperate climates and thus ranks third in terms of world vegetable production and as the leading tomato producing countries are China, the United State of America, India, Egypt, Turkey, Iran, Mexico, Brazil and Indonesia.

In Ethiopia, tomato ranks fourth in total production (5.45%) after Ethiopian cabbage, red pepper and green pepper and third in area coverage (4.49%) next to red pepper and Ethiopian cabbage from vegetable crops cultivated. Its national mean yield is 6.2ton/ha (CSA 2015). This is by far below the world average 34.84 ton/ha (FAO 2009). This is due to shortage of varieties and recommended information packages, poor quality seed, poor irrigation systems, lack of information on soil fertility, disease and insect pests, high post-harvest loss, and poor marketing system (Lemma, 2002).

In 2015 cropping calendar, tomato Production in Ethiopia was about 22,788 tons from harvested area of 3,677 ha (CSA 2015). But according to Desalegn *et al*., (2016), the area coverage by tomato in Ethiopia was 4, 953 ha and production in tons was 40,426 with the productivity of 6.2 ton $ha^{-1}$ in 2015. However, the production and productivity in Ethiopia is far below the average of major producers in Africa (FAOSTAT, 2011). FAOSTAT (2010), also reports the average yield of tomato in Ethiopia is low, ranging from 6.5 to 24.0 ton $ha^{-1}$ compared with average yields of 51, 41, 36, and 34 ton $ha^{-1}$ in America, Europe, Asia and the entire world, respectively.

Tomato is produced both during the rainy and dry seasons under supplemental irrigation (Lemma, 2002). Under this circumstance the total area under tomato production in Ethiopia reaches 9767.78 ha and in Meher season production is estimated to be over 913,013.42 ton with the average productivity of 93.47 t ha-1 (CSA, 2016). In 2008, tomato production in Ethiopia reached about 41, 815 tons from a total harvested area of 3542 ha (FAO, 2009). The shortage of varieties and recommended information packages, poor irrigation systems, lack of information on soil fertility, diseases and insect pests, high postharvest loss, lack of awareness of existing improved technology and poor marketing system are the major constraints in Ethiopian tomato production (Lemma, 2002).

According to Central Statistical Agency (2016/2017), the production area, production in quintals and productivity per hectare is highly reduced as compared production calendar of 2015/2016. Numerically the area of production is reduced by 3.87% (9,524.24 ha to 6,298.63ha), production in quintals declined by 52.05% (from 591,563.36Qt to 283,648.27Qt) and the productivity also fluctuated by 27.55 (from 62.11 Qt/ha to 45.03Qt/ha). Under this circumstance the total area under tomato production in Ethiopia reaches 9767.78 ha and in Meher season production is estimated to be over 913,013.42 t with the average productivity of 93.47 t ha-1.

In Tigray region more than 3,361.58 ha were covered with vegetables in the year 2016/2017 with total production of 127,431.73Qt of which tomato around the study area (South Estern Tigray) shares 495.55ha with total yield of 33, 670.25 Qts. Tomato is very important vegetable crop in the study area next to red pepper in area coverage (1021.26ha) (CSA, 2016/2017).

### 2.1.3 Ecological requirements of tomato

Tomatoes can adapt to various climatic conditions. However, the optimum temperatures for their growth and development lie between 21 and 27 $^{0}$C (Hanson, 2001; Shankara *et al*., 2005). In addition, tomatoes are day-length neutral plants (Nuruddin, 2001). Light intensity of 400-500 μ mol/m$^2$/s is optimal for growth and development. High light intensity may cause fruit cracking, sunscald and green shoulders (Jones,1999). Though tomatoes have high water requirement (Peet, 2008) water surplus may cause fruit rot (Jones, 1999) and bacterial wilt (Nuruddin, 2001). According to Jones (1999) tomato is most sensitive to water deficit at the flowering stage. Bud and flower-drops might occur under a prolonged dry period. Various soil types can be used for tomato production, preferably well-drained sandy loam soil (Hanson, 2001; Jones, 1999; Nuruddin, 2001; Peet, 2008). Suitable soil pH is between "6.0-7.0". If the pH is less than 5.5, plant disorders such as blossom-end-rot may occur (Hanson, 2001)

Due to their rapid growth in a long production period, tomatoes have high requirements of nutrients. For instance, to produce 1 ton of fruits the crop requires1.36 - 3.63 kg N; 0.23 - 1.36 kg PO; 2.27 - 5.45 kg $K_2O$ (Peet, 2008).

### 2.1.4 Agricultural importance of tomato

The Global production of tomatoes in 2013 was approximately 164 million tones (FAOSTAT 2013), making it the most important vegetable crop (in terms of weight produced) after potatoes worldwide. Two broad groups of tomato cultivars with differing characteristics exist those primarily intended for consumption in their raw, fresh state, and processing tomatoes, which typically have higher dry matter content, contain less seed gel, and are better suited for canning and use in soups, sauces, and other cooked foods).

It is used as canned vegetable having multiple uses and supplies essential nutrients in human diets (Choudhury, 1979). It is popularly used for both commercial and home use purposes. The fresh produce is sliced and used as salad. It is also cooked for making local saucer ('watt'). The processed products like tomato paste, tomato juice, tomato catch-up and whole peel-tomato are produced in the country for local market and export. It was recognized as quality product for both local and export markets and providing a route out of poverty for small scale producers, who live in developing countries in general and in Ethiopia in particular (Tewodros and Asfaw, 2013). The importance of tomato is increasing and since it is a high value commodity, it has been given top priority in vegetable research too in Ethiopia (Tsedeke, 2007). Small-scale farmers and commercial growers could grow the crop for its fruits in different regions of the country. Tomatoes contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibers.

The crop is grown for its fruits, which are used in salads or cooked as a vegetable, in processed form as tomato paste (puree), tomato sauce, ketchup and juice and the ripe fruits are rich in nutrients, minerals and vitamins A, B and C. Consumption of tomato is important because it contains lycopene, a food component known to reduce incidences of prostate cancer, heart and age-related diseases as well as a source of β-carotene (USDA, 2005).

Processing type varieties are used for the production of purees, juices, canned fruits and sauces. The seeds contain 24% edible oil (Tindall, 1988). In the growing areas, tomato is produced mainly as a source of income and food both under rain fed and irrigated conditions and in-home gardens as well. The majority of fresh market tomato is produced by small scale farmers and commercial growers along river banks and lake areas.

### 2.1. 4 Tomato Production Constraints

Production challenges for tomato crop include insect pests, diseases, weeds, harsh environmental, moisture stress, improper rates of fertilizer application and extreme temperatures. Among these factors' application of NPSB fertilizers depend mainly on soil condition and have a significant effective relationship with tomato vegetative growth and yield. The levels of NPSB fertilizer are very determined to optimum growth of tomato. It is important to enhance the productivity of crops along with desirable qualities through production management practices and application of other sources of nutrients beyond the blanket recommendation of urea and DAP, especially those that contain sulfur, boron and other micronutrients (Ethio SIS, and Solomon, 2014).

#### 2.1.5 The tomato varieties (Roma VF, Gelelma, and Melka shola)

The three tomato varieties Roma VF, Gelelma, and Melka Shola are commonly cultivated in Ethiopia, as well as in Tigray region soil condition. FAO and other agricultural extension services often recommend Roma VF due to its adaptability in various climates and its resistance to common diseases, which is particularly beneficial in regions with challenging growing conditions like Tigray. Roma VF is a popular variety of tomato due to its resistance to Verticillium and Fusarium wilt diseases. Studies on tomato varieties in Ethiopia, including those from the Ethiopian Institute of Agricultural Research (EIAR), often highlight Roma VF as one of the top varieties for processing in commercial agriculture (source: EIAR). Gelelma is one of the most commonly grown varieties in Ethiopia, particularly in the highlands, and has been widely used for local markets and smallholder farming (Ethiopian Agricultural Transformation Agency, (ATA, 2010). According to Kassa *et al*. (2012), Gelelma was found to be a productive and resilient variety in Ethiopian highlands, offering good yields with moderate disease resistance. Melka Shola is widely regarded as an important local variety for smallholder farmers in Ethiopia, especially in the highland areas (Ethiopian Institute of Agricultural Research (EIAR, 2014). Biru *et al*. (2018) highlights that Melka Shola is well-suited for the cooler climates of highland Ethiopia, including Tigray, where it performs well under both rain-fed and irrigated conditions. In addition to this Khat Gach Ger, *et al*., (2024) reported that using mixed (NPS) fertilizer rates with two tomato varieties get best results from treatments of 150 kg $ha^{-1}$ combined with Melka shola tomato Varity under Jimma condition.

## 2.2 Effects of NPSB on Tomato Growth and Production

According to the Atlas for Tigray (ATA, 2014), the study area requires 10 types of blended fertilizers. These are: NPKS, NPKSB, NPKSFeZn, NPKSZn, NPKSZnB, NPSB, NPSFeZn, NPSFeZnB, NPSZn, and NPSZnB.

Generally total nitrogen, available phosphorus, extractable potassium, available sulfur and extractable iron, zinc and boron were found to be deficit in the *Enderta* areas (AtlasForTigray_Jul2014 (4)).

The status of soil fertility and appropriate fertilizer rates were not known for smallholders. Recently, the Ethiopian soil information system (Ethio-SIS) project gathered and analyzed grid-based soil samples from each of the agricultural fields and developed soil fertility maps as well as fertilizer recommendation for Tigray Region (ATA, 2014). The Bureau of agriculture and rural development of the region has introduced chemical fertilizers particularly blended fertilizers in each district of zone including the study area. According to the soil fertility status and fertilizer recommendation Atlas for Tigray Region through the Ethio-SIS project has developed soil fertility status-based fertility recommendations the rate of fertilizer for tomato was not established.

### 2.2.1 Effect of nitrogen on tomato

Nitrogen is one of the most important nutrients affecting the growth, yield and fruit quality of Tomato (Laura, 2012). It is required in large quantity at each growth stage during which N affects markedly the amount of Rubisco content of plant and therefore photosynthesis. Nitrogen fertilizer influence leaf number per plant, plant height, fruit number per plant, fruit mean weight and total yield and growth of tomato crops (Ruiz and Romero, 1998).

Nitrogen is a vital nutrient and a major yield limiting factor; and it is very essential for plant growth and makes up one to four percent of dry matter of the plants. Nitrogen is a component of protein and nucleic acids and when nitrogen is sub optimal growth is reduced (bellow, 2002). Its availability in sufficient quantity throughout the growing season is essential for optimum tomato growth. It is also element of proteins and also an integral component of many other compounds essential for plant growth processes including chlorophyll and the many enzymes. It also mediates the utilization of phosphorus, potassium and other elements in plant (Onasanya a *et al*., 2000).
The optimal amount of the elements in the soil cannot be utilized efficiently if nitrogen is deficient for plants. Increased plant height with respect to increased nitrogen rate indicates maximum vegetative growth of the plant under higher nitrogen availability (kidist, 2013).
Akbar *et al*, (1999) also found that plant height in tomato was increased with increment in nitrogen rate. In contrast to the result of this study, Sedeghi and Bahrani (2002) reported that increase in nitrogen rate had no significant effect on plant height. They reported that the discrepancy in the result obtained might be due to the differences in the plant population density, soil fertility status and crop varieties used. (Sedaghi and bahani, 2002).

### 2.2.2 Effect of phosphorous on tomato

Phosphorus is a component of ATP (adenosine triphosphate), the energy currency of cells, which is vital for metabolic activities (Taiz & Zeiger, 2018). Phosphorus deficiency in tomato can resulted in stunted growth with purple tinge leaves and low fruit yields (John *et al*., 2004). The idea was also supported by Parray and Fazing (2007) as tomato with phosphorus deficient became dwarf and spindled, small and stiff leaves and development of purple tints on the underside of leaves. Developments of brown areas on old leaves that change to yellow and die before maturity due to lack of phosphate translocation are indicators. A short-term experiment was conducted with tomato cultivars Blizzard, Liber to and Calypso was carried out in a controlled temperature room to investigate the effectiveness of phosphorus (P) and iron (Fe) supplemented in nutrient solution on plant growth at high zinc concentration. Application of supplementary P and Fe resulted in marked increases in both dry weight and chlorophyll concentrations achieving values not significantly different to the control (FAO, 2007).

### 2.2.3 Effect of sulfur on tomato

Sulfur is an essential plant nutrient required for the synthesis of the amino acid cysteine and methionine, protein and enzymes. It has been shown to play an important role in yield and quality of crops (Heebn *et al*., 2006, Rhoads and Olson, 2000). Sulfur occurs in the soil both as organic and inorganic forms. In most of the soils, over 90% of S is in the diverse organic form (Tabatabai, 1984). The majority of plant absorb S through the root in the inorganic sulfate ($SO_4^{-2}$) form, although limited amount can be absorbed through the leaf stomata as the gas form ($SO_2$). It has been suggested that to achieve high yield and to minimize S leaching, rate of S fertilizer should be recommended on the basis of available soil S and crop requirement (Scherer, 2001).

### 2.2.4 Effect of boron on tomato

Boron is an essential micro-nutrient required for plants and it plays a crucial role in the growth and development of tomatoes. Boron is essential for proper flower and fruit development in tomatoes. It helps in the pollination process and is involved in the formation of viable pollen grains. Boron deficiency can result in poor fruit set, reduced fruit size, and abnormal fruit shape. Adequate boron levels ensure optimal flowering and fruiting in tomato plants. While the excess amount of boron can lead to toxicity, stunted growth and reduced yield. As stated by Fassil Kebede and Phil Hollington (2010), effective B-fertilization will help better crop production in the irrigated field of northern Ethiopia. Therefore, it is crucial to maintain a balance and provide tomatoes with appropriate amount of boron based on soil tests and specific crop requirements.

## 2.3 Integrated Effect of Nitrogen, Phosphorous Sulfur and Boron on the Growth of Tomato

Nitrogen fertilizer influence leaf number per plant, plant height, fruit number per plant, fruit mean weight and total yield and growth of tomato crops (Ruiz and Romero, 1998). Phosphorus deficiency in tomato can result in stunted growth with purple tinge leaves and low fruit yields (John *et al*., 2004). The idea was also supported by (Parray and Fazing, 2007) as tomato growth became dwarf and spindled, small and stiff leaves and development of purple tints on the underside of leaves in phosphorus deficient soils (Parray and Fazing, 2007). Sulfur has also been shown to play an important role in yield and quality of crops (Heebn *et al*., 2006, Pavlista, 2005, Rhoads and Olson, 2000). Boron is essential for proper flower and fruit development in tomatoes. It helps in the pollination process and is involved in the formation of viable pollen grains. The blended NPSB fertilizer main contain N=18.9, P=37.7, S=6.95, B=0.1 and the remaining amounts are fillers. The combinations of NPS blended fertilizer have a major effect on growth, yield and quality of tomato. And also, adequate boron levels ensure optimal flowering and fruiting in tomato plants. The combined application of nitrogen, phosphorus, sulfur, and boron has been found to enhance growth attributes such as plant height, branch number, leaf number, and fruit yield. Integrated nutrient management (INM) approaches, which include a balanced supply of these nutrients through organic and inorganic sources, are considered beneficial for sustainable tomato production (Sharma et al., 2023). A field study by Patel et al. (2022) established that a well-balanced application of these nutrients significantly increased fruit yield and improved overall plant health compared to individual nutrient applications.

## CHAPTER 3: Materials and Methods

### 3.1 Description of the study area

The experiment was carried out in the Northern Ethiopia, Tigray region, at Elshadai Relief and Developmental Association's farm (Mekelle City), (Figure 1). The geographical location of Elshadai Relief and Developmental Association's farm is 13$^{o}$ 27′ 283″ N and 39$^{o}$ 27.996′ E with an average altitude of 2161 meters above sea level.

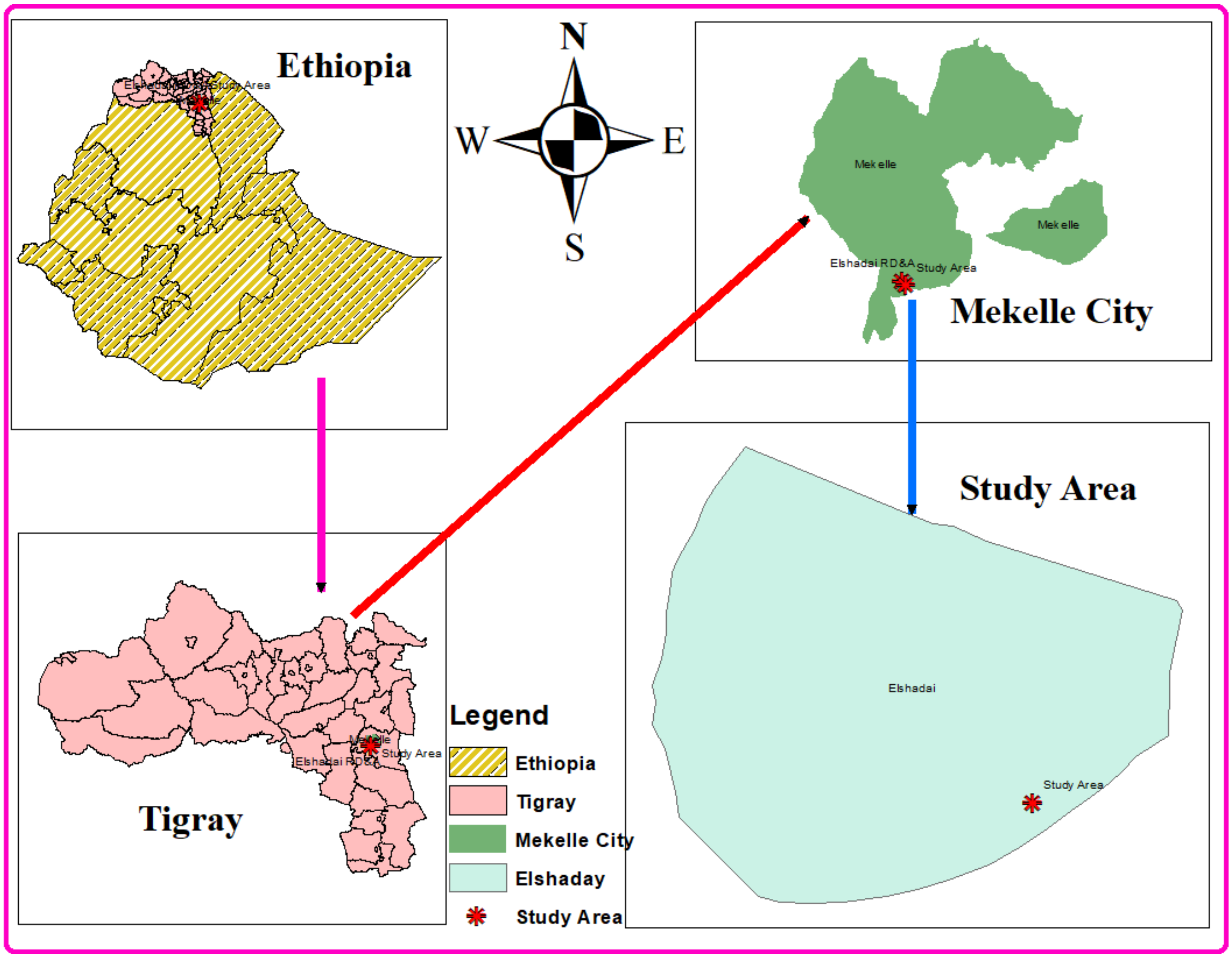


Figure 2. Location map of the study area

The climate of the study area is semiarid with a mean annual rainfall range 400 to 600mm, most of which falls in the main/heavy rainy season (locally known as *Kiremt*) and lasts from June to mid-September (Gebrehiwot and van der Veen 2013). Furthermore, the study site receives a small rain shower (locally known as *Belg*) from February to May (Kelali, 2023). The daily mean air temperature at the Elshadai Relief and Developmental Association site ranges from 11.0°C in December to 28°C in May (National Meteorology Agency Mekelle Branch). The soil type of

Elshadai Relief and Developmental Association's farm is classified as Vertisols. The soil pH was about 7.5 and the soil texture was sand clay loam.

The farming system of the farming communities in study area includes both crop and livestock production. Crop rotation in the study area includes cereals and vegetables. The major cultivated cereal crops are wheat (*Triticum aestivum*), teff (*Eragrostis tef*), hanfets (*Hordeum vulgare* + *Triticum aestivum*), and barley (*Hordeum vulgare*). Furthermore, major vegetable crops are onion (*Allium cepa*), tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum* L.) garlic (*Allium sativum*), cabbage (*Brassica oleracea*), lettuce (*Lactuca sativa*), and carrot (*Daucus carota*).

## 3.2 Experimental materials

### 3.3.1 Planting material

Three tomato varieties (Roma VF as V1, Gelalma as V2 and Melka shola as V3) were used as planting material. The varieties were selected based on their adaptation, better performance and disease resistance. For instance: Roma VF is a popular variety of Roma tomatoes resistant to Verticillium and Fusarium wilt diseases (Getahun, 2019).

**Table 1: 2.1.5.1 Description of the three tomato varieties from different sources**

| Variety | Type | Shape | Yield (tons/ha) | Maturity (days) | Verticillium and Fusarium wilt | Main Use | References |
|---|---|---|---|---|---|---|---|
| Roma VF | Hybrid (paste) | Oval, meaty | 20 | 70-80 | Resistance | Processing | FAO, EIAR |
| Gelelma | Local (fresh, processing) | Round/slightly flattened | 17 | 70-90 | Moderate resistance | Fresh, Processing | ATA, Kassa *et al*. (2012), EJAS |
| Melka Shola | Local (fresh, processin | Round to elongated | 22 | 80-100 | Good Resistance | Fresh, Processing | Biru *et al*. (2018), EIAR |

### 3.3.2 Types of Fertilizers

NPSB (18.9N + 37.7$P_2O_5$ + 6.95%S + 0.1B) were used as the source of fertilizer **(**Khat Gach Ger, *et al*., 2024).

## 3.4 Experimental design and Treatments

The study was conducted under irrigation condition during the dry season of 2024. The experimental treatments were composed of three tomato varieties (V1=Roma VF, V2=Gelalma s and V3=Melka shola) and four levels of blended NPSB (18.9%N, 37.7%$P_2O_5$, and 6.95% S, and 0.1% B which are F0=0, F1=50, F2=100, and F3=150 kg). It was applied using band placement (application of fertilizers into the soil close to the seed). The treatments were laid out in factorial Randomized complete block design (RCBD) with three replications.

The spacing between rows within a plot, plants, plots and blocks was 75, 30, 100 and 150 cm, respectively. The area of the plot was 3mx3m=9 $m^2$. The total experimental area of the research site was 12m x 47m = 564 $m^2$ **(**Khat Gach Ger, *et al*., 2024). The treatment combination was listed below.

Table 2: 3.4.1 Treatment combination

| Treatment name | Treatment combination | Rates of NPSB Fertilizer (kg/ha) |
|---|---|---|
| Trt1 | NPSB0V1 | 0 |
| Trt2 | NPSB1V1 | 50 |
| Trt3 | NPSB2V1 | 100 |
| Trt4 | NPSB3V1 | 150 |
| Trt5 | NPSB0V2 | 0 |
| Trt6 | NPSB1V2 | 50 |
| Trt7 | NPSB2V2 | 100 |
| Trt8 | NPSB3V2 | 150 |
| Trt9 | NPSB0V3 | 0 |
| Trt10 | NPSB1V3 | 50 |
| Trt11 | NPSB2V3 | 100 |
| Trt12 | NPSB3V3 | 150 |

Trt= treatment, NPSB= Nitrogen, Phosphorus, Sulfur and Boron, V1=variety one (Roma vf) V2=variety two (Gelilama), V3= variety three (Melkashola).

The layout of the experimental field and placement of treatments within replication (blocks) is indicated as follows:

T9, T2, T3, T12, T1, T7, T6, T4, T8, T11, T10, T5, block 1

T7, T6, T4, T11, T5, T9, T3, T12, T1, T8, T2, T10 block 2

T11, T8, T4, T7, T1, T12, T3, T2, T9, T5, T6, T10, block 3

## 3.5. Field Managements

The land was ploughed with a plough pulled by a tractor based on the modern practice of tillage in Ethiopia. The land was prepared to break clods, and the field was levelled properly to avoid cobbles. Furrows were made manually in such a way that it allows proper furrow irrigation. Seedlings of tomato variety (Roma VF, Gelelma, and Melka shola) were raised in a well-prepared in a nursery which was located in Mekelle Biotechnology Center close to the experimental field. Hence, seedlings were transplanted to the experimental plots when they were 40 days old (Liu *et al*., 2024). Irrigation was applied every three days to bring the soil moisture content to field capacity uniformly for all treatments during the whole growing season. Seedlings were planted at a spacing of 75 cm between rows and 30 cm between plants (Kahsay *et al*., 2016). Each experimental plot had 3m length x 3m width, with 40 plants accommodated per plot. The seedlings were transplanted on March 14, 2024.

In selecting the different rates of the blended fertilizer (NPSB), the farmers practice of fertilizer application was taken as a baseline. Farmers around the study area commonly apply 100 kg of urea and 150 kg of DAP per ha. The total amount of blended fertilizers (NPSB) required for each treatment was applied in two splits where half of the rate was applied.  one week after transplanting, and the second half was applied when the plants began to flower (Smith *et al*. 2018). This was done to avoid withering and overgrowth of the vegetative tissues, which could be the biggest factor reducing the yield of tomato fruits. The tomato plant was physically fortified during the growing season with a two-meter-tall stick, made to stand erect with thin metal wire and rope when it began to flower (Torre *et al*., 2024). Utilizing a hand tool and hand weeding was the most efficient method of controlling weeds. It was carried out every fifteen days, and corrective action was taken as soon as the plants displayed symptoms of disease or insect pests such as late blight, early blight and powder mildew and aphides. All agronomic practices were carried out in the experimental field in agreement with the guidelines provided for the crop in each plot.

When the tomato fruits reached the green mature stage (physiological mature) and some turned light yellow, they were hand-picked to prevent the fruits' metabolism from changing and leading to weight loss. To demonstrate their determinateness, three tomato varieties were harvested once. The two middle rows from which the data originated were marked with different colored ropes prior to data collection.

## 3.6 Data Collection Methods

Meteorological data (precipitation, minimum temperature, maximum temperature, during the experiment and soil data was collected before planting.

### 3.6.1 Analysis of Soil sample

Soil samples from a depth of 0–30 cm was collected from 36 plots using an auger that were used to drill through the experimental units in a zigzag pattern. These samples were bulked into one sample. The bulked soil samples collected were air dried, thoroughly mixed and ground to pass through 2-mm sieve size before laboratory analysis. Then the sample was reduced to a working sample size of one kg by quartering method and properly labeled, packed and transported to the laboratory. After that, several soil chemical (soil pH, cation exchange capacity, organic carbon, total nitrogen, available phosphorus, sulfur and boron) and physical parameters (soil texture) were analysed.Soil tests were performed by the Mekelle University Research Center Soil laboratory.

Soil texture (particle size distribution or the relative proportion of sand, silt and clay) was measured by hydrometer method. Soil pH was measured by pH meter. Organic matter content of the soil was estimated from the organic carbon content determining by using Walkley and Black (1934) method as described in Jackson (1967). The cation exchange capacity (CEC) was measured by using ammonium acetate method at natural state (Jackson, 1967). Total soil N was determined by colorimeter using the Kjeldhal procedure (Jackson, 1967). Available P was measured by Olsen method (for slightly acidic to alkaline soils) and Bray II for acidic soils (having pH $\leq$5.5). Available sulfur was analyzed by Turbidity method. Available Boron was analyzed by turbid metric method.

### 3.6.2 Phenological Stages

Plant phenology refers to specific characteristics or events that are observed and measured to track and understand the timing and progression of tomato plant development and growth. These parameters help in monitoring and managing tomato crops effectively. Some common phenological collected were:

**Days to 50% flowering (Day)**: days to 50% flowering were recorded, as the number of days from transplanting to the time when 50% of plants in each plot set flowers.

**Days to maturity (DM) (Day):** this was taken on plot basis when 90% of the plant population in a plot reached physiological maturity (i.e., attained their first crop harvest).

### 3.6.3 Growth parameter

**Plant height:** The plant height was measured from the base of the plants to the terminal growing point of the main stem. The data were taken to measure the height of six randomly taken samples from the central rows per plot. The average plant height was expressed in centimeter. The plant height data were collected from the main stem at 50% flowering stage and at 50% fruiting stage.

**Number of branches per plant:** the number of primary and secondary branches of each tagged plant from all plots was recorded and the average was considered for statistical analysis.

**Number of leaves per plant:** fully opened and matured leaves of tagged plants were counted and recorded at 60 days after transplanting.

### 3.6.4 Yield and yield related parameters

**Number of fruit cluster per plant:** Two days before the final harvesting, six plants were selected at random from two center rows, and each plant's total number of fruit clusters were counted.

**Number of fruits per cluster**: This was determined by counting the fruits from the flower cluster that had been tagged, and their mean was also determined.

**Marketable fruit number per plant:** those fruits from the six tagged plants, which were free from visible damage, insect pest and with appropriate size (>20 g), were considered as marketable. The fruits were counted at each harvest time, and the average expressed in number was considered.

**Unmarketable fruit number per plant:** Fruits with cracks, rotting, damaged by insect, diseases, birds and sunburn as well as extra small sized fruits which were collected from the six tagged plants were considered as unmarketable. The fruits were counted at each harvest time and expressed in number.

**Total number of fruits per plant:** the matured fruits from the two central rows of each net plot (pre-tagged plants) at each harvest was counted and summed up and divided by the number of plants to obtain the mean number of fruits per plant.

**Marketable and unmarketable fruit yields (t/ha):** During each harvest time, the marketable fruit from the net plot area of each plot was assessed based on marketability rating by women and experienced labors. The colored fruit, absence of defects from insects, disease or physiological disorder and size of the fruit was used to determine marketable yield. The total marketable yield was the sum of successive harvested marketable fruits. Diseased, discolored, shrunken shape, small sized and unwanted fruits by consumers in the study area were sorted out as unmarketable yield for each plot, weighted and converted to t/ha. The remaining fresh colored fruit were weighted in each plot as marketable yield and converted to t/ha.

**Total fruit yield per hectare (t/ha):** This refers to the cumulative fruit yields obtained from successive harvests of the net plot. This was calculated by summing marketable and unmarketable fruit yields. The total fruit yields of all harvests were weighted for each net plot (kg/m$^2$) and converted to t/ha.

## 3.7 Economic analysis (Partial budget analysis)

Economic analysis was performed to investigate the economic feasibility of the treatments by using partial and marginal analysis. Tomato yield harvested from each treatment was reduced by 10 % in order to adjust the yield obtained from the research field (smaller field size and better crop management) to the yield that can be obtainable from the farmers' field. Under the research field relatively better crop management is performed than the farmers' field. Marginal rate of return (MRR) was calculated by the change in net benefit (NB) divided to the change in total variable cost (TVC) of the successive treatments that were sorted in the order of increasing the variable costs and after the dominated treatments were excluded from the list (CIMMYT, 1988). In this study, the different rates of blended fertilizer (NPSB) were considered as the variable cost, and the price of this fertilizer in 2024 was xxx Birr/quintal. Labor costs to apply fertilizer were calculated by considering 300 ETB per person per day. The average open market price for tomato during harvest in the field was (25 Birr kg$^{-1}$). The dominance analysis procedure as detailed in CIMMYT (1998) was also used to select profitable treatments from the range that were tested. The marginal rate of return (MRR) was calculated by considering a pair of non-dominated treatments listed in the order of increasing net benefit.

Marginal rate of return (MRR) = change in net benefit / change in total variable cost

## 3.8 Statistical Analysis

The collected data on agronomic traits like tomato phonological, morphological, and yield and yield components were subjected to statistical analysis. The analysis of variance (ANOVA) was carried out using Gene Stat software version 14 (Payne et al, 2011). All significant pairs of treatment means were compared using the Least Significant Difference (LSD) test at 5% level of significance.

# CHAPTER4: RESULTS AND DISCUSSION

## 4.1 Soil physical and chemical properties of the experimental site

The analysis result for the soil sample collected before cultivation indicated that the experimental field had soil texture of sand clay loam (Table 4.1). The pH of the soil was 7.3, which is neutral in reaction. According to Tekalign (1991), soils having a pH value of 6.73-7.3 are considered as neutral soils. As indicated in Srinivasan (2010), the optimal soil pH for tomato plant production is 6-7.5, hence the soil had conducive pH for tomato cultivation. The organic matter content of the experimental field was 1.595% which is rated as low (Tekalign, 1991), who reported that soils having OM value in the range of 0.86-2.59% are considered as low. The reason for the low amount of OM levels observed in the soils of the study area could be the intensive cultivation of the land that enhanced oxidation reactions (Lal, 2005) and the total removal of crop residues for animal feed and sources of energy. Moreover, there is no practice of applying organic fertilizer such as animal manure and green manure, which might be contributing to the low level of OM and total nitrogen (Teklu & Haile, 2007). The cation exchange capacity (38.5 meg/100gm) of the soil falls in the medium category. Total nitrogen (0.13%) was low, and available P (18.3 ppm) was categorized as medium. The other plant nutrients of the experimental field were also found to be low (Sulfur = 11.92 ppm; Boron = 1.90 ppm) (Table 4.1).

The CEC of the experimental area could be categorized under a very high level (38.5 meq/100 gm) as per the range established by Hazelton and Murphy (2007). This indicates that the soil of the experimental field had excellent nutrient-holding capacity and potential for sustained fertility, provided that nutrient inputs are well-balanced and matched to crop demand. These authors categorized the soil with CEC ranges from 6 and 12meq/100 gm, 12 and 25meq/100 gm, and 25 and 40meq/100 gm as low, moderate, and high levels, respectively.

**Table 3: 4.1 major soil properties of the experimental site**

| s/no | Soil physical and chemical parameters | measured values | Unit | Rating | Standard values | References |
|---|---|---|---|---|---|---|
| 1 | Soil texture | | | | | Kamara *et al*.,1992 |
| | Sand | 49 | % | | | |
| | Clay | 17 | % | | | |
| | Silt | 34 | % | | | |
| | Textural class | Sand clay loam | | | | Mulugeta *et al*., 2016 |
| 2 | pH | 7.3 | | Neutral | 6.73-7.3 | Tekalign (1991) |
| 3 | CEC | 35.5 | (meq/100g) | Very high | 25-40 | Hazelton and Murphy, 2007 |
| 4 | TN | 0.13 | % | Low | 0.1-0.2 low | Dewan and Amasu,1987 |
| 5 | Av.P | 18.3 | Ppm | Medium | 15-30 | FAO (2006) |
| 6 | Av. Sulfur | 11.92 | Ppm | Low | 10-20 | FAO (2006) |
| 7 | Boron | 1.90 | Ppm | Low | 1.29-2.5 | Fassil Kebede and Phil Hollington, 2010. |

## 4.2 Treatment Effect on Phenological Parameters of Tomato

### 4.2.1 Days to 50% flowering (DF)

The result of ANOVA indicated that both the tomato variety and fertilizer rates showed highly significant difference ($p < 0.001$), in days of 50% flowering; while their interaction effect was found to be significant ($p \leq 0.05$). This was due to the variety difference and rate of blended fertilizers on days of 50% flowering (appendix table 1). The interaction effect of NPSB blended fertilizer rates and tomato varieties indicated Gelelma tomato variety treated with 150 kg per ha delayed flowering time by 7 days compared to the Roma VF tomato variety treated with no fertilizer (Table 4.2).

The longest (49.33 days) flowering date was recorded from the application of 150 kg NPSB $ha^{-1}$ and Gelelma tomato variety. while the shortest (42.33 days) was recorded from the unfertilized treatment and Roma VF tomato variety (Table 4.2). This delay may be attributed to the higher N content supplied from the 150 kg of blended fertilizer per ha, which leads to enhanced vegetative growth and probably delays reproductive growth by decreasing the sink strength of flowers relative to vegetative tissues. This result is similar to the findings of Khan *et al*., (2009) who reported that high N levels in the soil promoted excessive vegetative growth, which delayed flowering, fruit setting, and maturity in tomato. In tomato, earliness or lateness in flowering and maturity significantly influences productivity. While early flowering can be advantageous for escaping end-of-season stress and targeting early markets, they may limit yield potential due to reduced vegetative growth. Conversely, late flowering often supports higher yields due to extended growth periods, provided environmental conditions remain favorable (Ahmad et al., 2014). Hozhbryan (2013) reported similar findings in tomato. This result is also consistent with the findings of Maji and Taber (2001), who observed that tomato flowering is significantly influenced by the rate of fertilizer application. Consequently, due to varietal differences, the rates of blended fertilizers, and their interaction effects, the number of days to 50% flowering and the yield of tomato were significantly affected ($p < 0.05$).

### 4.2.1 Days to 90% Maturity (DM)

The result of ANOVA indicated there was a highly significant ($p \leq 0.001$) effect of variety and NPSB-blended fertilization on days to physiological maturity. However, the interaction effect of the variety and the fertilizer rate did not show significant different ($p \leq 0.001$) effect on days to physiological maturity but it shows significantly different at ($p < 0.05$) (Appendix table 1).

The earliest day to 90% physiological maturity was (91 days) which was recorded from the Roma VF tomato variety with no fertilized, and the maturity days were extended up to 105 days with the application of 150 kg NPSB with Gelelma per ha (Table 4.2). In this study maturity was delayed under higher levels of NPSB blended fertilization. This could be due to the increment of N levels in the soil which in turn extended the vegetative growth of the plant. Similar observation was also observed in delaying the date of flowering. This finding is in line with Wakene *et al*., (2014) who reported that high dose of NP fertilizers delayed tomato maturity time compared to the lower dose of application. Moreover, Maji (2013) noticed that increase of K dose could also delayed fruit setting and ripening time in tomato.

**Table 4:** 4.2 The main effects of variety, and fertilizer rates, and their interaction on days to flowering and maturity.

| **Treatments** | DF **(days)** | MD (days) |
|---|---|---|
| | Varietal effects | |
| **V1** | 44.5 | 95.50 |
| **V2** | 46.67 | 100.67 |
| **V3** | 45.17 | 97.92 |
| **Probability** | $p \leq 0.001$ | $p \leq 0.001$ |
| **LSD (5%)** | 0.569 | 1.634 |
| **CV (%)** | 1.5 | 2.0 |
| | Fertilizer effects | |
| **F0** | 43.22 | 93.00 |
| **F1** | 44.56 | 95.56 |
| **F2** | 46.33 | 98.56 |
| **F3** | 47.67 | 105.00 |
| **Probability** | $p < 0.001$ | $p < 0.001$ |
| **LSD** | 0.657 | 1.887 |
| **CV (%)** | 1.5 | 2.0 |
| | Interaction effect | |
| **V1F0** | $42.33^{a}$ | $91.00^{a}$ |
| **V1F1** | $44.00^{b}$ | $94.00^{abc}$ |
| **V1F2** | $45.33^{cd}$ | $96.00^{bcd}$ |
| **V1F3** | $46.33^{de}$ | $101.00^{ef}$ |
| **V2F0** | $44.00^{b}$ | $95.00^{bcd}$ |
| **V2F1** | $45.33^{cd}$ | $97.00^{cd}$ |
| **V2F2** | $48.00^{f}$ | $101.67^{f}$ |
| **V2F3** | $49.33^{g}$ | $109.00^{h}$ |
| **V3F0** | $43.33^{ab}$ | $93.00^{ab}$ |
| **V3F1** | $44.33^{bc}$ | $95.67^{bcd}$ |
| **V3F2** | $45.67^{d}$ | $98.00^{de}$ |

| | | |
|---|---|---|
| **V3F3** | 47.33 ef | 105.00 g |
| **Probability** | $p \leq 0.05$ | $p \leq 0.05$ |
| **L.S.D** | 1.138 | 3.268 |
| **CV%** | 1.5 | 2.0 |

Where, means with the same letter with in the column are not significantly different at p<0.05. DM= days to maturity, DF= days to flowering (50%), CV= coefficient of variation in percent, LSD= least significance difference.

## 4.3 Treatment Effect on Growth Parameters of Tomato

### 4.3.1 Plant height

The difference in plant height was highly significant at (p< 0.001) in response to the application of blended NPSB fertilizer rates and tomato varieties. The interaction effect of application of NPSB fertilizer rates and the tomato varieties were also significant (p=0.016). This indicates that the response to fertilizer depends on the tomato variety. Compared to Roma vf and Melka shola, Gelelma had higher plant height per plant (70.25 cm) (Table 4.3). This could be attributed to the difference in varietal and genetic makeup of Gelelma, which produced much higher plant height than Melka Shola and Roma VF.

With regard to interaction of variety and fertilizer application, the tallest (92 cm) plant height was recorded from Gelelma which was treated with 150kg NPSB $ha^{-1}$, while, the shortest height (43.53 cm) was recorded from the unfertilized Roma VF tomato variety. Plants grown under higher blended fertilizer rate (150kg/ha) were all taller (88.83 cm) than the remaining and plant height showed a decreasing tend as the rate of fertilizer decreases (table 4.3). The taller height observed in plots applied with more rates of fertilization could be due to adequate supply of required nutrients that enhanced cell division and enlargement. Because nitrogen is an essential component of protein, fundamental building material of the cells, a constituent of all enzymes, which are specialized protein, which involves in metabolic processes of the plant (Sainju, 2003). Similar results from application of NPK fertilizer were also reported by Kiset and Heri (2014). In addition, Yeboah *et al*., (2014) reported that a significant variation in plant height of tomato occurred due to the effect of blended fertilizer rates.

### 4.3.2 Number of Leaves per plant:

In terms of the number of leaves per plant, the main effects of blended fertilizer (NPSB) and tomato variety and their interaction were significant ($p = 0.001$) (Appendix Table2). The application of a blended fertilizer at a rate of 150 kg $ha^{-1}$ with the Gelelma tomato variety produced the highest number of leaves per plant (95.93), which was followed by 150 kg $ha^{-1}$ with melka shola variety (94.77). The lowest number of leaves per plant was observed in the control treatment (Roma Vf unfertilized treatment). The largest number of leaves per plant was produced when a greater blended fertilizer (NPSB) rate was applied. This increased plant elongation, plant height, and the number of primary branches per plant were all much enhanced.

Compared to Roma vf and Melka shola, Gelelma had the highest number of leaves per plant (75.47) (Table 4.3). This could be attributed to the differences in varietal and genetic makeup of Gelelma, which produced much more leaves than Roma VF and Melka shola.

The results of this study were found to be consistent with those of Ogundare, *et al*., (2015) who reported the highest number of leaves per plant with the application of 125 kg $ha^{-1}$ NPK and 3 t ha-$^{1}$ poultry manure. This experiment's significance showed that fertilizer treatment had an impact on the increase in the number of leaves per plant. In addition to this, Khat Gach Ger *et al*., (2024) reported that the largest amount of leaves per plant leaves (82) was produced when 150 NPS kg/ha blended fertilizer was applied.

### 4.3.3 Number of branches per plant

The differences between tomato varieties and different rates of NPSB blended fertilizers in number of branches per plant of tomato were highly significance at ($p<0.001$). in addition to this, there was significant interaction effect at ($p<0.05$) of tomato varieties and fertilizer rates (Table 4.3).

More numbers of branches per plant (23.67) was obtained from the Gelelma tomato variety treated with 150 kg $ha^{-1}$ NPSB rate of blended fertilizer; whereas the lowest number of branches per plant (7.27) was recorded from the Roma Vf unfertilized treatment (control). Number of branches per plant found to be increased as the rate of fertilizer increased from 0 to 150 kg NPSB $ha^{-1}$ (Table 4.3). This might be attributed due to the possible supplies of nutrients which lead to increase in numbers of branches through the increased photosynthetic area that enhanced assimilate production and partitioning to the plant parts.

This result is in line with the previous finding of Maji (2013) and Rahaman *et al*., (2011) who obtained the highest number of primary branches per plant in response to the combination applications of 160 kg and 80 kg N/ha, while the lowest number of branches per plant were for the control treatment. Khan, *et al*., (2010) also reported that the maximum number of primary branches per plant ranged from 14.21 to 17.98, and the number of primary branches per plant increased with an increase in nitrogen fertilizer application rate from 0 kg ha-$^{1}$ to 150 kg ha$^{-1}$ N, which are consistent with the findings of this study.

With regard to the main effects of varieties, the highest number of branches per plant was observed in V1 and this was followed by V3 and V2.

**Table 5: 4.3** The main effects of variety, and fertilizer rates, and their interaction **on tomato growth parameters**

| Treatments | Growth parameters | | |
|---|---|---|---|
| | PH (cm) | NLPP | NBPP |
| | **Variety effect** | | |
| V1 | 59.85 | 66.66 | 13.98 |
| V2 | 70.25 | 75.47 | 16.68 |
| V3 | 66.45 | 70.74 | 14.78 |
| LSD (5%) | 2.919 | 2.513 | 0.885 |
| CV (%) | 5.3 | 4.2 | 6.9 |
| | Fertilizer effect | | |
| F0 | 45.78 | 45.86 | 7.51 |
| F1 | 55.86 | 63.26 | 12.42 |
| F2 | 71.60 | 80.93 | 18.24 |
| F3 | 88.83 | 93.79 | 22.41 |
| LSD (5%) | 3.370 | 2.902 | 1.02 |
| CV (%) | 5.3 | 4.2 | 6.9 |
| | Interaction effect | | |
| V1F0 | 43.53 f | 45.77 $^{a}$ | 7.27 $^{a}$ |
| V1F1 | 49.83 $^{f}$ | 58.47 $^{b}$ | 11.57 $^{b}$ |
| V1F2 | 60.80 e | 71.73 $^{c}$ | 16.10 $^{c}$ |
| V1F3 | 85.23 bc | 90.67 $^{ef}$ | 21.00 $^{d}$ |

| | | | |
|---|---|---|---|
| V2F0 | 47.17 f | 46.20 a | 8.23 a |
| V2F1 | 60.60 e | 70.63 c | 13.40 b |
| V2F2 | 81.23 c | 89.13 e | 21.40 d |
| V2F3 | 92.00 a | 95.93 f | 23.67 e |
| V3F0 | 46.63 f | 45.60 a | 7.03 a |
| V3F1 | 57.13 e | 60.67 b | 12.30 b |
| V3F2 | 72.77 d | 81.93 d | 17.23 c |
| V3F3 | 89.27 ab | 94.77 f | 22.57 de |
| L.S.D | 5.838 | 5.026 | 1.770 |
| CV% | 5.3 | 4.2 | 6.9 |

Where, means with the same letter with in the column is not significantly different at $p<0.05$. PH= plant height, NLPP= Number of leaves per plant, NBPP= Number of branches per plant, CV= coefficient of variation in percent, LSD= least significance difference.

## 4.4 Treatment Effect on Yield and Yield Components of Tomato

### 4.4.1 Number of fruit cluster per plant

As shown in Appendix Table 3, the main effects of the blended fertilizer and tomato varieties on the number of fruit clusters per plant were very highly significant ($p < 0.001$). Similarly, their interaction effect was highly significant ($p = 0.008$). The application of 150 kg NPSB $ha^{-1}$ with Gelalma variety resulted in the highest number of fruit cluster per plant (21.13) and this was followed by 150 kg NPSB $ha^{-1}$ and the Roma VF tomato variety (18.61); whereas the lowest number of fruit clusters per plant (6.80) was observed in the control treatment (Gelalma no fertilized treatment). Increased number of fruit cluster observed per plant in plots treated with high amount of NPSB could be because there are nutrients available to nourish the fruit while the plant grows and develops.

With regard to the main effects of verities (Table 4.4), Melka Shola showed the highest number of fruit clusters per plant (13.30), whereas Roma VF had the lowest number of fruit clusters per plant (10.87). The result of this study is agreement with Tadele, (2016) who concluded that Melka shola produced the greatest amount of fruit clusters per plant. This study also supports the findings of Gebisa, *et al*., (2017) who tested nine different tomato cultivars and reported greatest amount of fruit clusters per plant for Melka shola variety. The result of this study was also consistent with Khat Gach Ger, *et al*., (2024) who observed that the highest nitrogen level was associated with the greatest number of fruit clusters per plant, while the lowest number was associated with the control treatment (no fertilizer).

### 4.4.2 Number of Fruits per Cluster

The number of fruits per cluster was significantly ($p < 0.001$) impacted by the blended fertilizer and tomato varieties, whereas their interaction effect was significant at ($p < 0.05$) (Appendix Table 3). The application of a blended (NPSB) fertilizer at a rate of 150 kg ha$^{-1}$ with Melka shola tomato variety produced the maximum number of fruits per cluster (5.867), whereas the least number of fruits per cluster was observed at unfertilized Roma Vf treatment (4.133).

The number of flowers per cluster increased gradually as blended fertilizer (NPSB) fertilizer application increased from 0 kg ha$^{-1}$ to 150 kg ha$^{-1}$ (Table 4.4), indicating that fertilizer application had a significant impact on producing the highest number of fruits per cluster because the tomato plant was able to absorb the ideal amount of nutrients from the soil. With regard to the main effects of varieties, Melka shola showed the highest number of fruits per cluster (5.22) while Roma VF showed the lowest amount (4.775). This could be because of a natural difference between the three tomato varieties, Melka shola, Gelelma, and Roma VF, which causes difference in fruits per cluster to yield Melka shola more fruits per cluster.

Result of this study is agreement with the findings of Gebisa, B, *et al*., (2017) who reported a significant difference in the number of fruits per cluster when comparing nine different tomato varieties, as well as Tesfaye, B. (2008) who reported that the maximum number of fruits per cluster was achieved by applying a higher nitrogen fertilizer rate.

### 4.4.3 Total number of fruits per plant

Appendix Table 3 shows that the total number of fruits per plant was significantly affected by both tomato variety and the application of NPSB blended fertilizer ($p < 0.001$ and $p = 0.004$, respectively). The interaction effect was statistically significant ($p = 0.023$), though not strongly so. This indicates that the response of tomato varieties to different fertilizer rates varies to a certain extent and may have practical implications despite not being highly significant statistically.

Table 4.4 shows that the application of blended fertilizer (NPSB) at a rate of 150 kg ha$^{-1}$ with Gelalma tomato variety produced the highest number of total fruit yields per plant (49.9). This was followed by the application of 150 kg ha$^{-}$1 with the Melka shola tomato variety, while the unfertilized Melka shola tomato variety treatment produced the lowest number of total fruit yields per plant (21.93).

With respect to the main effects of varieties, Gelelma had the greatest number of total fruit yields per plant (40.62), whereas Roma vf produced the fewest total fruit yields per plant (33.12).

The results of this study are consistent with those of Aminifard, *et al*., (2010) who observed that egg plants with the application of 100 kg ha$^{-1}$ N level in loam soil with 0.05% nitrogen had the highest fruit output per plant. This is also consistent with the results of Lidia (2014) who found that applying nitrogen fertilizer at a rate of 138 kg ha$^{-1}$ or 0 kg ha$^{-1}$ would result in the maximum and minimum total fruit output per plant, respectively.

This study aligns with the findings of Salem et al. (2013), who compared 30 tomato genotypes with different fertilizer rates in Pakistan. Their research showed that certain genotypes produced the highest number of fruit yields per plant.

### 4.4.4 Marketable fruit number per plant

The response of marketable fruit number per plant to NPSB fertilizer application rates and main effect of tomato varieties was highly significant ($p < 0.001$). In the other hand, the interaction effect of tomato varieties and fertilizer rates were significant ($p < 0.05$) (Appendix Table 4). Application of blended fertilizer at a rate of 150 kg ha$^{-1}$ resulted in highest marketable fruit number per plant (40.51) and the lowest marketable fruit number per plant (19.53) was obtained from the control treatment. Therefore, the application of blended fertilizer at a rate of 150 kg ha$^{-1}$ increased marketable fruit number per plant by more than 107.4% as compared to the control. Similar trends were observed with the interaction of fertilizer and tomato varieties, where the highest marketable fruit number per plant of tomato varieties (46.73) was obtained from the the application of NPSB at the rate of 150 kg ha$^{-1}$ in plots planted with Gelalma tomato variety.

This showed that the yield of marketable fruits per plant had increased with an increase in the application rate of blended fertilizers (NPSB) from 0 kg ha$^{-1}$ to 150 kg ha$^{-1}$, and that the tomato plant had absorbed all available nutrients from the soil to support fruit production, growth, and development.

This result of this study was consistent with results reported by Lidia (2014), which revealed that the application of nitrogen fertilizer rates at 138 kg $ha^{-1}$ resulted in the largest number of marketable fruits per plot and the lowest number at control. It also agrees with the results of Amin (2018) who observed that 100 kg $ha^{-1}$ NPS + 30 t $ha^{-1}$ composted manure produced the greatest quantity of potato tubers that could be sold.

### 4.4.5 Unmarketable fruit number per plant

Appendix Table 4 shows that the main effect of blended fertilizer rates and variety affected unmarketable fruit number per plant significantly ($p<0.001$ for fertilizer, and $p<0.05$ for variety), however, the interaction effect was not significant.

The highest unmarketable fruit per plant (5.33) was recorded from the plots treated with unfertilized (control treatment), while the lowest unmarketable fruit per plant (3.10) was obtained from 150 kg/ha NPSB of blended fertilizer rates. High unmarketable fruit production observed in the control treatment might be because the plants could not uptake enough nutrients, which are important in determining fruit size, increase fruit crack and disease severity comparing with the other fertilizer treated plots. In plots which were treated with fertilizer, the extent of disease affected fruits was minimized.

With regard to the main effects of variety, Melka Shola had the highest number of unmarketable fruit numbers per plant (4.34), whereas Gelelma and Roma VF showed the lowest number of unmarketable fruit numbers per plant (3.87 & 4.04, respectively) (Table 4.4). The highest number of unmarketable fruit number observed in Melka shola could be the result of physiological disorders and undersized fruits. The result of this study is consistent with those of Amin (2018) who conducted an experiment on the effects of blended (NPS) fertilizer rate combined with cattle manure on potatoes and reported a non-significant influence on unmarketable tuber potatoes. According to Khat Gach Ger, *et al*. (2024), the application of blended fertilizers (NPS) to two tomato varieties Melka shola and Gelelma in Jimma (South-West Ethiopia) showed similar results, where Melka Shola recorded the highest number of unmarketable fruit numbers per plant from Gelelma. However, Kirimi, *et al*. (2011), observed a marked rise in the quantity of unsaleable fruits in each plot with the greatest nitrogen content.

### 4.4.6 Weight of Marketable fruit by size group (g)

On the weight of marketable fruit by size group, the impacts of tomato varieties and interaction effect was not determined to be significant ($p = 0.322$ and $p= 0.427$) respectively, but the effect of blended (NPSB) fertilizer showed a high significance ($p < 0.001$) (Appendix Table 4). The blended fertilizer rate at 150 kg ha$^{-1}$ produced the greatest number of marketable fruit weights by size group (78.5 g), which was followed by 100 kg ha$^{-1}$ and 50 kg ha$^{-1}$, respectively. The control rate (0 kg ha$^{-1}$) produced the fewest marketable fruit weights by size group (61.88 g). This showed that there was a considerable rise in blended fertilizer rate (NPSB) at a greater level, marketable fruit weight by size group as a result of the tomato plant absorbing the right quantity of nutrients from the soil throughout growth and development to achieve its typical fruit weight and size. Due to Gelelma's inherent characteristics, it displayed the greatest number of marketable fruit weights by size group (73.43 g) compared to Roma VF and Melka shola, which displayed 71.92 and 70.61 g (Table 4.4). The results of this study were found to be consistent with those of (Girmachew, 2007), who discovered that at a greater amount of nitrogen fertilizer (150 kg ha$^{-1}$), the maximum marketable fruit weight per size group was reached. It also found to be consistent with the results of (Lidia, B. 2014), who reported that the lowest marketable fruit weight by size group at control and the maximum marketable fruit weight by size group at a higher level of nitrogen fertilizer rate (138 kg ha$^{-1}$). This outcome was also associated with (EARO, 2004), which categorized the standard fruit weight into three size groups: large fruit weight (>71 g), 60–70g medium, and small fruit weight (59–31 g).

#### 4.4.7 Marketable fruit yield per hectare (t/ha)

The blended fertilizer rates and tomato varieties had a highly significant at ($p < 0.001$) effect on marketable fruit production per hectare. However, their interaction was non-significant (Appendix Table 4). The highest marketable fruit yield per hectare (24.91 t ha$^{-1}$) was produced by applying a blended (NPSB) fertilizer at a rate of 150 kg ha$^{-1}$ whereas the lowest marketable fruit yield per hectare (13.92 t ha$^{-1}$) was produced at the control treatment. This indicates that increasing the application rate of blended fertilizers (NPSB) from 0 kg ha$^{-1}$ to 150 kg ha$^{-1}$ gradually increased marketable fruit yield per hectare due to the continuous supply of available nutrients from the soil to support tomato fruit growth and development. The result of main effects of tomato varieties indicated Gelelma tomato variety produced higher marketable fruit yield per hectare (21.18 t ha$^{-1}$), while Roma VF tomato variety produced the lowest marketable fruit yield per hectare (17.04 t ha$^{-1}$).

This study aligns with the results of Lidia (2014) who reported that the highest marketable fruit yield per hectare (49.30 t ha$^{-1}$) was achieved with the application of the highest nitrogen fertilizer rate (138 kg $ha^{-1}$ N), while the control treatment showed the lowest yield. Similarly, results of this study agree with the findings of Ahmed *et al*. (2012) who observed that higher nitrogen fertilizer levels improved tomato marketable fruit production per hectare.

### 4.4.8 Unmarketable fruit yield per hectare (t/ha)

The effects of rate of blended fertilizer (NPSB) and tomato varieties, and the interaction effect of both factors on the unmarketable fruit yield per hectare were non-significant ($p>0.05$) (Appendix Table 4).

The finding of this study aligns with Khat Gach Ger, et al. (2024) who mentioned that the application of blended fertilizers (NPS) to two tomato varieties (Melka shola and Gelelma) at Jimma (South-West Ethiopia) showed non-significant effect on the unmarketable fruit output per hectare. However, Kirimi *et al.* (2011), Samaila *et al*. (2011) and Lidia (2014), reported a notable rise in unmarketable fruit yield per hectare at the highest nitrogen level (135-138 kg N $ha^{-1}$).

### 4.4.9 Total fruit Yield per Hectare (t $ha^{-1}$)

Appendix Table 4 indicates that the overall tomato fruit production per hectare was significantly different ($p <0.001$) which was affected by tomato varietals and blended fertilizer rates (NPSB). The interaction effects of fertilizer application and variety on total fruit production was significant ($p <0.05$). A blended (NPSB) fertilizer at a rate of 150 kg $ha^{-1}$ with Gelelma tomato variety produced the highest total fruit yield per hectare (32.20 t $ha^{-1}$), and this was followed by the application of 150 kg $ha^{-1}$ of Melka shola and Roma Vf similarly (25.13 t $ha^{-1}$) indicated (Table 4.4). On the other hand, the control treatment showed the lowest total fruit yield per hectare (19.70 t $ha^{-1}$), Increasing the blended fertilizer rate from 0 kg $ha^{-1}$ to 150 kg $ha^{-1}$ increased the number of fruit clusters per plant and the number of total fruit yields per plant, which led to the highest production of total fruit yield per hectare.

With regard to the main effects of variety, Gelelma had the highest total fruit output per hectare (24.5 t $ha^{-1}$) whereas Melka Shola produced the lowest total fruit yield per hectare (21 t $ha^{-1}$) (Table 4.4). The three tomato varieties naturally differed from one another in fruit yields where the highest yield was recorded from Gelelma and this was followed by Roma VF and Melka shola.

The result of this study is consistent with the findings of Girmachew (2007) who reported the highest and lowest total fruit yield per hectare from application of nitrogen fertilizer rate at 150 kg $ha^{-1}$ and the control treatment, respectively. The results of Falak *et al*. (2011) and Meseret and

Kassahun (2012) also showed total fruit production per hectare ranging between 6.46 and 82.50 t ha$^{-1}$ In agreement with the findings of this study, Chernet et al. (2013), who reported the highest fruit yield per hectare (50.07 t ha$^{-1}$) after comparing 36 tomato genotypes, and Ketema*et al*. (2015) who found the highest total fruit yield per hectare (47.55 t ha$^{-1}$) for Miya variety produced when comparison was made between nine different tomato varieties. However, Gibisa *et al*. (2017) showed the highest number of total fruit output per hectare from Melka shola after evaluating nine distinct tomato varieties, the results of which is consistent with this study.

**Table 6: 4.4:** The main effects of variety, and fertilizer rates, and their interaction on Tomato yield and yield components

| | Yield and Yield related parameters of tomato varieties and NPSB fertilizer | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NFCPP | NFPC | TNFPP | MFNPP | UMFNPP | WMSG | MFYPH | UMFYPH | TFYPH |
| Variety effect | | | | | | | | | |
| V1 | 10.87 | 44.78 | 33.12 | 29.25 | 3.87 | 70.61 | 18.86 | 3.80 | 23.49 |
| V2 | 12.18 | 5.025 | 40.62 | 36.59 | 4.04 | 73.43 | 21.18 | 3.32 | 24.50 |
| V3 | 13.30 | 5.22 | 35.44 | 31.48 | 4.34 | 71.92 | 17.04 | 3.96 | 21.00 |
| LSD | 1.060 | 0.131 | 3.731 | 3.724 | 0.559 | 3.792 | 1.432 | 1.172 | 1.076 |
| CV% | 10.3 | 3.1 | 12.1 | 13.6 | 16.2 | 6.2 | 8.9 | 40.7 | 5.5 |
| | Fertilizer effect (main effect) | | | | | | | | |
| F0 | 7.26 | 4.544 | 24.66 | 19.53 | 5.33 | 61.88 | 13.92 | 4.67 | 19.70 |
| F1 | 9.68 | 4.889 | 36.03 | 32.29 | 4.09 | 73.06 | 17.80 | 3.18 | 20.98 |
| F2 | 12.09 | 5.122 | 41.27 | 37.43 | 3.81 | 74.52 | 19.48 | 3.60 | 23.08 |
| F3 | 19.44 | 5.467 | 43.61 | 40.51 | 3.10 | 78.50 | 24.91 | 3.32 | 28.23 |
| LSD | 1.224 | 0.152 | 4.308 | 4.300 | 0.646 | 4.379 | 1.654 | 1.468 | 1.242 |
| CV% | 10.3 | 3.1 | 12.1 | 13.6 | 16.2 | 6.2 | 8.9 | 40.7 | 5.5 |
| | | The Interaction effect | | | | | | | |
| V1F0 | 7.84$^{abc}$ | 4.133 e | 28.57 a | 23.20 d | 5.400$^{a}$ | 57.37$^{a}$ | 14.07$^{ab}$ | 5.533$^{a}$ | 22.94 def |
| V1F1 | 7.78$^{abc}$ | 4.700 d | 28.77 a | 25.10 d | 3.667 bc | 70.50$^{bc}$ | 17.80 cde | 3.300$^{a}$ | 21.10 cd |
| V1F2 | 9.23$^{bc}$ | 5.033 bc | 36.50 b | 32.93 c | 3.533 bc | 76.43$^{cd}$ | 19.90$^{ef}$ | 2.667$^{a}$ | 22.57 de |
| V1F3 | 18.61$^{f}$ | 5.233 b | 38.63 b | 35.77 bc | 2.867 c | 78.13 cd | 23.67$^{g}$ | 3.700$^{a}$ | 25.13$^{f}$ |
| V2F0 | 6.80 a | 4.833 cd | 23.47 a | 18.33 d | 5.100 a | 64.50$^{ab}$ | 15.50$^{bc}$ | 3.300$^{a}$ | 18.80 ab |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| V2F1 | 11.53$^{de}$ | 4.867$^{cd}$ | 41.83$^{bcd}$ | 37.63$^{bc}$ | 4.267$^{ab}$ | 74.43$^{cd}$ | 19.27$^{def}$ | 2.933$^{a}$ | 22.20$^{d}$ |
| V2F2 | 13.73$^{e}$ | 5.100$^{bc}$ | 47.27$^{cd}$ | 43.67$^{ab}$ | 3.633$^{bc}$ | 73.73$^{cd}$ | 21.10$^{fg}$ | 3.700$^{a}$ | 24.80$^{ef}$ |
| V2F3 | 21.13$^{g}$ | 5.300$^{b}$ | 49.90$^{d}$ | 46.73$^{a}$ | 4.267$^{ab}$ | 81.07$^{d}$ | 28.87$^{h}$ | 3.333$^{a}$ | 32.20$^{h}$ |
| V3F0 | 7.13$^{ab}$ | 4.667$^{d}$ | 21.93$^{a}$ | 17.07$^{d}$ | 5.500$^{a}$ | 63.77$^{ab}$ | 12.20$^{a}$ | 5.167$^{a}$ | 17.37$^{a}$ |
| V3F1 | 9.72$^{cd}$ | 5.100$^{bc}$ | 37.50$^{b}$ | 34.13$^{c}$ | 4.333$^{ab}$ | 74.23$^{cd}$ | 16.33$^{bcd}$ | 3.300$^{a}$ | 19.63$^{bc}$ |
| V3F2 | 13.30$^{e}$ | 5.233$^{b}$ | 40.03$^{bc}$ | 35.70$^{bc}$ | 4.267$^{ab}$ | 73.40$^{cd}$ | 17.43$^{cde}$ | 4.433$^{a}$ | 21.87$^{cd}$ |
| V3F3 | 18.57$^{f}$ | 5.867$^{a}$ | 42.30$^{bcd}$ | 35.77$^{bc}$ | 3.267$^{bc}$ | 76.30$^{cd}$ | 22.20$^{fg}$ | 2.933$^{a}$ | 25.13$^{f}$ |
| LSD | 2.121 | 0.263 | 7.462 | 7.448 | 1.118 | 7.584 | 2.864 | 2.443 | 2.152 |
| CV% | 10.3 | 3.1 | 12.1 | 13.6 | 16.2 | 6.2 | 8.9 | 40.7 | 5.5 |

Where, means with the same letter with in the column is not significantly different at p<0.05. NFCPP = Number of fruit cluster per plant, NFPC=Number of fruits per cluster, TNFPP= Total Number of fruits per plant, MFNPP= marketable fruit number per plant, UMFNPP= un marketable fruit number per plant, WMSG= weight of marketable size by group, MFYPH= marketable fruit yield per hectare, UMFPH= unmarketable fruit yield per hectare, TFYPH= total fruit yield per hectare CV= coefficient of variation in percent, LSD= least significance difference.

## 4.5 Correlation among Growth, Yield and Yield Components of Tomato Parameters

The correlation analysis results presented in our data indicated various relationships between different parameters related to the fertilizer application and tomato production.

**Positive Correlations**: Several parameters display strong positive correlations, suggesting that as one parameter increases, the other tends to increase as well. For instance, the correlation between 50%_DM and MFPP (0.8909) indicates a strong relationship, which suggests that higher dry matter content is associated with better fruit production parameters. The vegetative growth often results in higher fruit yield due to improved resource allocation and biomass accumulation. Kumar et al. (2015) found a significant positive correlation between days to maturity and yield attributes in tomato, emphasizing that genotypes with longer growth periods tend to have a higher number of fruits per plant. The correlation between NLPP and PH (0.9649) is particularly noteworthy, indicating that leaf parameters are closely linked to plant height, which is crucial for overall plant vigor and yield.

**Negative Correlations**: Some parameters show negative correlations, such as UMFPP and UMFPplot, which have values of -0.6382 and -0.5708, respectively. This suggests that as the values of these parameters increase, the associated yield or quality metrics may decrease. This could indicate that excessive stress or unfavorable conditions reflected in these parameters negatively impact tomato production. Saad et al. (2017) reported that increased fruit defects, such as blossom-end rot and cracking, were negatively correlated with marketable yield in tomatoes, often due to water stress or calcium deficiency.

**Moderate Correlations**: Parameters like TFNPP and TFW t/ha shows moderate correlation with other metrics, indicating that while there is some relationship, it may not be as strong as those mentioned above. For example, TFNPP has a correlation of 0.6001 with NLPP, suggesting a moderate positive relationship. A moderate positive correlation, such as the one observed between TFNPP (Total Fruit Number per Plant) and NLPP (Number of Leaves per Plant) with a coefficient of 0.6001**,** suggests that as the number of leaves per plant increases, there is a tendency for the total fruit number per plant to also increase. This relationship indicates that foliage density may play a role in supporting fruit production, possibly due to enhanced photosynthetic capacity.

This result in lines with findings from previous studies, Kumar et al. (2015) reported a significant positive correlation between the number of leaves and fruit yield in tomato plants, suggesting that increased leaf area contributes to higher photosynthetic production, number of leaves per plant exhibited increased fruit numbers, attributing this to improved carbohydrate assimilation, and nutrient translocation supporting for greater fruit set.

Table 4.5 Correlation among Growth, Yield and Yield Components of Tomato Parameters

| Variables | 50%_DF | 50%_MD | MFPP | MFPpl | NBPP | NFCPP | NFPC | NLPP | PH | TFNPP | TF/ha | UMFPp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50%_DF | 1 | | | | | | | | | | | |
| 50%_MD | 0.891 | 1 | | | | | | | | | | |
| MFPP | 0.736 | 0.736 | 1 | | | | | | | | | |
| MFPpl | 0.786 | 0.807 | 0.583 | 1 | | | | | | | | |
| NBPP | 0.892 | 0.873 | 0.824 | 0.826 | 1 | | | | | | | |
| NFCPP | 0.811 | 0.862 | 0.769 | 0.741 | 0.888 | 1 | | | | | | |
| NFPC | 0.724 | 0.719 | 0.622 | 0.622 | 0.7565 | 0.691 | 1 | | | | | |
| NLPP | 0.892 | 0.86 | 0.817 | 0.818 | 0.9759 | 0.898 | 0.764 | 1 | | | | |
| PH | 0.893 | 0.901 | 0.797 | 0.807 | 0.9647 | 0.936 | 0.759 | 0.965 | 1 | | | |
| TFNPP | 0.717 | 0.72 | 0.997 | 0.562 | 0.8024 | 0.75 | 0.6 | 0.797 | 0.776 | 1 | | |
| TF/ha | 0.738 | 0.77 | 0.506 | 0.983 | 0.7452 | 0.684 | 0.543 | 0.734 | 0.737 | 0.488 | 1 | |
| UMFPp | -0.64 | -0.59 | -0.51 | -0.7 | -0.701 | -0.62 | -0.5 | -0.71 | -0.665 | -0.454 | -0.651 | 1 |
| UMFPpl | -0.57 | -0.53 | -0.61 | -0.52 | -0.741 | -0.59 | -0.64 | -0.75 | -0.685 | -0.595 | -0.356 | 0.542 |
| WMF | 0.729 | 0.683 | 0.685 | 0.637 | 0.7392 | 0.659 | 0.679 | 0.735 | 0.689 | 0.646 | 0.572 | -0.73 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

## 4.6 Treatment Effect on the Profitability of Different Rates of Blended Fertilizer

The objective of producer to apply fertilizer is not only targeted at the yield, but also to get good profit. The level to which the use of fertilizer contributes to this objective depends not only up on the kind and amount of the fertilizer applied and crop productivity, but also up on the cost of fertilizer and price of crop harvest (Black, 1992). In the study area, the demand and market price of tomato is very important. Due to this fact, increasing marketable yield can increase farmer's income. The result of this study indicated that there was high benefit that can be obtained due to the effect of both rate of fertilizer and tomato varieties.

The dominance analysis showed that T10 and T11 were dominated because of their non-profitability to the farmers. Hence, they were excluded from further analysis. The remaining treatment combinations were evaluated for their profitability by comparing the adjacent treatments which were sorted in the order of ascending the variable cost. In comparison with Galelma which was not treated with fertilizer (T5), Roma VF treated with 50 kg NPSB per ha offered MRR of 1567.8%. Again, when comparisons were made with T5, Galelma treated with 50 kg fertilizer (T6) offered MRR of 2634 %. This shows that fertilizer application gives more profit. Increased application of fertilizer i.e., 100 kg of NPSB per ha in plots planted with Roma VF (T7) gave MRR of 357 % over Galelema variety which was treated with 50 kg of NPSB per ha (T5). Within the Galelma variety, increasing the rate of fertilizer from 50 to 100 kg per ha gave an MRR of 1227 % which means it offers a return of 12.27 Birr for each 1 Birr investment in the fertilizer application between 50 kg and 100 kg per ha in Galelema tomato production. In comparison with Gelelema tomato variety treated with 100 kg NPSB per ha (T7), Melka treated with 150 kg per ha (T12) still showed a better return (MRR=698%). This highest rate of fertilizer application generally offered the maximum return. In comparison with Gelelema tomato variety treated with 100 kg NPSB per ha (T7), Roma VF (T4) and Gelelema (T8) treated with 150 kg per ha offered a marginal rate of return of 1764 and 5334 %, respectively. Based on the ranking, Galelema followed by Roma VF and Melka treated with 150 kg NPSB per ha were the most profitable treatments to the farmers of the study area.

Table 7: 4.5: Adjusted yield, total and variable cost, net benefit and dominance analysis result of the variety and fertilizer treatment combinations

| Treatment combination | Marketable yield (t/ha) | Adjusted fruit yield (t/ha) | Gross benefit (ETB/ha) | Total cost (Birr) | TVC (Birr) | Net benefit (ETB/ha) | Dominance |
|---|---|---|---|---|---|---|---|
| $Trt_9$ | 12.20 | 10.98 | 274,500 | 47,000 | 0 | 274,500 | |
| $Trt_1$ | 14.07 | 12.663 | 316,575 | 47,075 | 0 | 316,575 | |
| $Trt_5$ | 15.50 | 13.95 | 348,750 | 47,915 | 0 | 348,750 | |
| $Trt_2$ | 17.80 | 16.02 | 400,500 | 49,118 | 3103 | 397,397 | |
| $Trt_{10}$ | 16.33 | 14.697 | 367,425 | 49,518 | 3103 | 364,322 | D |
| $Trt_6$ | 19.27 | 17.343 | 433,575 | 50,118 | 3103 | 430,472 | |
| $Trt_3$ | 19.90 | 17.91 | 447,750 | 52,221 | 6206 | 441,544 | |
| $Trt_7$ | 21.10 | 18.99 | 474,750 | 52,221 | 6206 | 468,544 | |
| $Trt_{11}$ | 17.43 | 15.687 | 392,175 | 53,221 | 6206 | 385,969 | D |
| $Trt_{12}$ | 22.20 | 19.98 | 499,500 | 56,924 | 9309 | 490,191 | |
| $Trt_4$ | 23.67 | 21.303 | 532,575 | 56,324 | 9309 | 523,266 | |
| $Trt_8$ | 28.87 | 25.983 | 649,575 | 57,324 | 9309 | 640,266 | |

Table 7.4.5; Variable cost and the marginal rate of return (MRR) analysis result for the non-dominated treatments

| Treatment combination | Gross benefit | Variable (TVC) | Net benefit (ETB/ha) | MRR (%) |
|---|---|---|---|---|
| $Trt_9$ | 274,500 | 0 | 274,500 | - |
| $Trt_1$ | 316,575 | 0 | 316,575 | - |
| $Trt_5$ | 348,750 | 0 | 348,750 | - |
| $Trt_2$ | 400,500 | 3103 | 397,397 | 1567.7 |
| $Trt_6$ | 433,575 | 3103 | 430,472 | 2633.8 |
| $Trt_3$ | 447,750 | 6206 | 441,544 | 356.8 |
| $Trt_7$ | 474,750 | 6206 | 468,544 | 1226.9 |
| $Trt_{12}$ | 499,500 | 9309 | 490,191 | 697.6 |
| $Trt_4$ | 532,575 | 9309 | 523,266 | 1763.5 |
| $Trt_8$ | 649,575 | 9309 | 640,266 | 5534.1 |

# CHAPTER 5:

# CONCLUSION and RECOMMENDATIONS

## 5.1 Conclusion

The result of this experiment showed that the fertilizer rates highly significantly affect the phonological, growth and development, and yield and yield component parameters of tomato crops. Days to 50% flowering and physiological maturity of tomato were significantly influenced by the application of NPSB fertilizer rates. Among the different rates of NPSB fertilizer, the application of 150 kg $ha^{-1}$ delayed the days to maturity of tomato varieties by four days.

The largest plant height (92 cm) was measured at the 150 kg $ha^{-1}$ NPSB blended fertilizer with the Gelelama tomato variety, while the lowest plant height (43.53 cm) was recorded from the unfertilized (control) treatment of Roma VF. Increasing the rate of fertilizer to 150 kg $ha^{-1}$ also increased plant height by more than 110% over the control. The maximum leaf number per plant (93.78) was recorded at 150 kg $ha^{-1}$ of NPSB blended fertilizer and a lower number of leaves per plant (45.86) was recorded from the control. Increasing fertilizer rates also increased a number of leaves per plant by 104.5% from the control. Yield and components of the tomato varieties were affected by applications of blended fertilizer rates.

The highest mean marketable fruit number (40.51) per plant was obtained at 150 kg $ha^{-1}$, while the lowest marketable fruit number per plant (19.53) was recorded at no fertilizer treatment. Increasing blended fertilizer rate application from 0kg $ha^{-1}$ to 150 kg $ha^{-1}$ highly significantly increased marketable fruit yield per plant. Moreover, the highest total fruit yield of tomato (28.23 t $ha^{-1}$) was also recorded at 150 kg $ha^{-1}$ blended fertilizer rate level; whereas, the lowest marketable fruit yield of tomato (19.70 t $ha^{-1}$) was obtained from the control treatment. The result showed that the total fruit yield of tomato plants increased with the increase of fertilizer rates from 0 kg $ha^{-1}$ to 150 kg $ha^{-1}$ of NPSB blended fertilizer rate.

The result of this study showed that unmarketable fruit yield per hectare was not significantly affected by the rate of blended fertilizer (NPSB). Similarly, the marketable fruit weights by size group, unmarketable fruit number, and unmarketable fruit yield per hectare were not significantly affected by the effect of the tomato varieties.

According to this study, the number of marketable fruit weights by size group, total fruit number per plant, and marketable fruit number per plant, marketable fruit yield per hectare, and total fruit yield per hectare showed increment as the rates of the blended fertilizer increased from the control (no fertilizer applied) to 150 kg per ha. Except number of fruit clusters per plant and the number of fruits per cluster were higher in Melka Shola than in Gelelma and Roma VF. However, Gelelma was higher than in terms of the total number of fruits per plant, marketable number of fruits per plant, marketable fruit yield per plot, and total fruit output per hectare. Regarding tomato variety growth, yield, and yield components, the correlation study showed a strong positive correlation.

The tomato varieties and blended fertilizer (NPSB) had a substantial impact on the economic return. Among the treatment combinations, the variety Gelelma followed by Roma VF and Melka Shola treated with 150 Kg NPSB per ha offered the highest economic return.

## 5.2 Recommendations

The application of 150 kg $ha^{-1}$ NPSB blended fertilizer enhanced most of the yield and yield components of tomato. Moreover, the highest fruit yield of 28.23 t $ha^{-1}$ was recorded from the application of 150 kg $ha^{-1}$ NPSB blended fertilizer. Among the treatment combinations, Gelalma variety followed by Roma and Melka treated with 150 kg of NPSB kg/ha (F3V2) are recommended for the study area because of they offered the highest net benefit and MRR (Table xx).

However, further research experiments by other researchers on different blended fertilizer types and rates beyond 150kg $ha^{-1}$ to validate the results in multiple locations and seasons should be given full consideration to identify the best-blended fertilizer rate under tomato varieties for sustainable tomato production.

## References


Yebirzaf Yeshiwas, Derbew Belew and Kassaye Tolessa, 2016. Debre Markos University, Department of Horticulture, Jimma University College of Agriculture and Veterinary Medicine, Department of Horticulture and Plant Sciences, Ethiopia, Pp 404.

Aminifard, M., Aroiee, H., Fatemi, H., Ameri and Karimpour. S. 2010. Response of eggplant (*Solanum melongena* L.) to different rates of nitrogen under field conditions. *Journal of Central Europe Agric.11 (4):* 453-458.

CSA, (Central Statistical Agency). 2016. Agricultural Sample Survey Report on; Area and Production of Major Crops, Statistical Bulletin No 578, Central Statistical Agency, Addis Ababa, Ethiopia.

CSA, 2012. Report of Federal Democratic Republic of Ethiopia, Statistical Report on Socio-Economic Characteristics of the Population in Agricultural Households, Land Use, Area and Production of Crops. Addis Ababa, Ethiopia.

CSA, 2015. The Federal Democratic Republic of Ethiopia, Central Statistical Agency, Agricultural Sample Survey, Volume I, Report on Area and Production of Crops, (Private Peasant Holdings, Meher Season), Addis Ababa, Ethiopia.

Dandena, G., Abebie, B. and Desalegn. L., 2012.Regulation of tomato (*Lycopersicon esculentum* Mill.) fruit setting and earliness by gibberelin acid and 2, 4 –dichlorophenoxy acetic acid application. Africa journal of biotechnology.

Dawit, A., Abera D., Lemma D., and Chamdo A., 2004. Domestic vegetable seed production and marketing. Research Report No 5. EARO, Ethiopi. 17 p.

EAROS, 2004. Director of released crop varieties and their recommended cultural practices, Addis Ababa, Ethiopia.

Ethio-SIS (Ethiopian Soil Information System) 2014, Soil Fertility and fertilizer recommendation Atlas of Tigray Region. Minister of Agriculture (MoA) and Agricultural Transformation Agency (ATA).

FAO stat, Food and Agricultural Commodities Production 2015, Food and Agricultural Organization Statistics, Rome, Italy.

FAO, 2005. FAOSTAT, Available at http://faostat.fao.org.

FAO, 2019. Food and Agriculture Organization of the United Nations.

FAO, 2006. Soil fertility for sustainable vegetable production; green and animal manure in the human forest belt, Ghana.

Fayera, Asefa Bebayehu**,** Alemayehu Wagari Irge, Abdela Tufa Woticha, and Adugna Hunduma Dabalo, Influences of NPSB and Vermicompost Application Rates on Yields of Tomato (*Lycopersicon esculentum* Mill) at Jimma Ganati Research Site of Wallaga University, Western Ethiopia.

Fekadu M., and Dandena G., 2006. Review of the status of vegetable crop production and marketing in Ethiopia.

Gemechis, A.O., Struik, P.C., and ‘Emana, B., 2012. Tomato production in Ethiopia constraints and opportunities. Tropentage 2012, international research on food security, natural resource management and rural de’velopment. Resilience of Agricultural systems against Crises:

Girmachew, T. 2007. Effects of planting method and nitrogen rate on yield and quality of tomato (*Lycopersicon esculentum* Mill). 2007 M.Sc. Thesis submitted to School of Graduate Studies of Haramaya University.

Hanson, P., Chen, J.T., Kuo, C.G., Morris, R., and Opena, R.T. (2001). Tomato Production.http://www.avrdc.org/ /tomato/production/0LC 4climate.html [24 August 2009].

Jones, J.B. (1999). “Tomato Plant Culture: in the Field, Greenhouse and Home Garden”. 216 p.CRC Press, New York, Kahsay, Y., Embaye, A. and Tekle, G., 2016. Determination of Optimum Rates of N and P Fertilizers for Tomato at Mereb-lekhe District, Northern Ethiopia. Journal of Agriculture and Crops, 2(3), pp.23-30.

Kelali Haftu, Mekelle University (Doctoral Dissertation "Effect of Compost, blended (NPSZn), and Potassium Chloride Fertilizers on Soil Bulk Density and Moisture Content in Two Soil Textural Groups of Tigray, Northern Ethiopia") published research Article 2023.

Khat Gach Ger, Derbew Belew , Amsalu Nebiyu and John Barnaba., 2024. Growth, yield, and yield components of tomato varieties (***Solanum lycopersicum*** L.) influenced by the application of blended fertilizers (NPS) at Jimma, South-West Ethiopia, published in 2024.

Lemma D., Z. Yayeh, and E. Herath, "Varietals development on vegetable," in Proceeding of the Second Workshop of Horticultural Development in Ethiopia, E. Herath and D. Lemma, Eds., IAR, Addis Ababa, Ethiopia, 1992.

Lemma, D .2002. Research experience and production prospects. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia, pp. 20-28.

Lidia, B. 2014. Response of nitrogen and phosphorous fertilizer rate on growth, yields, and quality of Tomato (*Lycopersicon esculentum*), M.Sc. Thesis Submitted to College of Agriculture and Veterinary Medicine, Jimma University.

Maerere, A.P., Sibuga, K.P., Mwajombe, K.K., Kovach, J. and Erbaugh, M., 2006. Baseline survey report of tomato production in Mvomero district-Morogoro region, Tanzania. Sokoine University of Agriculture Faculty of Agriculture, Morogoro, pp.1-31.

Nuez, F. (2001), El Cultivo del Tomate, Ediciones Mundi-Prensa.

Nuruddin, M.M. (2001). "Effects of Water Stress on Tomato at Different Growth Stages". Master Thesis. 113 p. Department of Agricultural and Bio-systems Engineering. McGili University,Montreal.

Ogundare SK, Babalola TS, Hinmikaiye AS, Oloniruha JA. Growth and fruit yield of tomato as influenced by combined use of organic and inorganic fertilizer in Kabba, Nigeria. European Journal of Agriculture and Forestry Research 2015; 3(3): 48-56.

Peet, M. (2008). Sustainable Practices for Vegetable Production in the South: Tomato productionpractices. [31 August 2009].

Regassa, D., Tigre, W. and Shiferaw, A., 2016. Tomato (Lycopersicon esculentum Mill.) varieties evaluation in Borana zone, Yabello district, southern Ethiopia. Journal of Plant Breeding and Crop Science[i], Vol. 8(10):206-210.

Regina R, Melton L, Dufault RJ. Nitrogen, phosphorus, and potassium fertility regimes affect tomato transplant growth. Journal of Hort Science; 26(2): 141-142.

Shukla V. and Naik LB, 1993. Agro-Technique for Solanaceous Vegetables, In: Advance in horticulture, vol. 5. Malhotra publishing house, New Delhi, India, Pp 364-399.

SoilFertilityStatusAndFertilizerRecommendationAtlasForTigray_Jul2014 (4)

Solomon T. Addis Ababa Un (Doctoral dissertation, Addis Ababa University). Encyclopedia.com. (2020). *Miller, Phillip*.

T. Gebrehiwot and A. van der Veen, 2013 "Assessing the evidence of climate variability in the northern part of Ethiopia," *Journal of Development and Agricultural Economics*, vol. 5, no. 3, pp. 104–119.

Tesfay Balemi., 2008. Response of tomato cultivars differing in growth habit to nitrogen and phosphorus fertilizers and spacing on vertisol in Ethiopia. Acta agriculture slovenica,91(1), p.103.

Thompson HC,1949. Vegetable crops. McGram Hill Book company, Inc. New York, Toronto, 611 p. London, 1919-1949.

Medina Saavedra, T., Arroyo Figueroa, G., & Gutiérrez-Díez Cauih, J. (2017). Origin and evolution of tomato production *Lycopersicon esculentum* in México. *Ciência Rural*, 47(3).

Black, C.A 1995. Method of soil analysis (part one). American society of agronomy. Black C.A. 1992. Soil fertility evaluation and control. Lewispublishers, US.

Mulugeta S, Sentayehu A and Kassahun B. 2016. Stability analysis of grain yield in rice genotypes across environments of Jimma Zone, South Western Ethiopia, academic Journal of Cereals and Oil seed, 2016 Vol. 7, ISSN 2141-6591.

Kamara, C.S., I. Haque and A.R. Soka. 1992. Soil Physics Manual. Plant Science Division Working Document No. B.12 (Revised) ILCA, Addis Ababa, Ethiopia, 106p.

Dewan, H and Amasu, N. Physical and Chemical Methods for Soil. Water and Fertilizers DP/ETH/82/011. Field document 1. NSSP. Addis Ababa, Ethiopia.

Hozhbryan, M., 2013. Effect of different levels of urea fertilizer on growth and yields of tomato. JNYSjournal, 2, pp.1031-1035.

Khan, A.,Jan, M.T.,Marwat,K.B.,Arif, M., 2009. Organic and inorganic nitrogen treatments effects on plant and yield attributes of maize in a different tillage system.

Maji, S., 2013. Effect of nitrogen, phosphorus and potassium fertilizers on growth, yield and quality of tomato varities. The Asian journal of horticulture.

Wakene Tigre., Worku, W., and Haile, W., 2014. Effects of nitrogen and phosphorus fertilizer levels on growth and developments of barley (Hordeum vulgare L.) a bore district, southern Oromia, Ethiopia. American journal of life science.

Khan, S., Rehman, S., Khan, A.Z., Khan, M.A and Shan, M.T. 2010. Soil and Vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan. Ecotoxicology and Environmental Safety 2010:*73*, 1820-1827.

Gebisa, B., Gezu. D., Alemayehu. B and Fikadu, T. 2017. Performance evaluation of tomato (*Lycopersicon esculentum*) varieties under supplemental irrigation at Erer Valley, Babile District, Ethiopia. *Journal of Plant Sciences. Vol. 5(1*), pp. 1-5.

Tadele, S. 2016. Evaluation of Improved Tomato Varieties *(Lycopersicon esculentum* ) performance against major Insect Pests under open field and glasshouse conditions. *International Journal of Research Studies in Agricultural Sciences (2),* pp 1-7

Khat Gach Ger, Derbew Belew, Amsalu Nebiyu, and Jhon Barnabas. 2024. Growth, Yield and Yield Components of tomato varieties (*Solanum Lycopersicun L.)* Influenced by the Application of Blended (NPS) Fertilizers at Jimma, South West Ethiopia.

Ahmed, T., Munsur, A., Khantum, A., Majumdar and A. Sarker. 2012. Increase tomato yield through maximization of nitrogen fertilization. *Bangladesh research publications J.7 (4*): 336-344.

Lidia, B. 2014. Response of nitrogen and phosphorous fertilizer rate on growth, yields and quality of Tomato (*Lycopersicon esculentum*), M.Sc. Thesis Submitted to College of Agriculture and Veterinary Medicine, Jimma University.

Girmachew, T. 2007. Effects of planting method and nitrogen rate on yield and quality of tomato (*Lycopersicon esculentum* Mill). 2007 M.Sc. Thesis submitted to School of Graduate Studies of Haramaya University.

Meseret, D., Ali, M. and Kassahun, B. 2012. Evaluation of tomato (*Lycopersicon esculentum*) genotypes for yield and yield components. *The African Journal of Plant Science and Biotechnology*, pp 45-49.

Falak, N., Ihsan, U., Syed, A., Abdus, S and Abdur. R. 2011. Studies on growth, yield and nutritional composition of different tomato cultivars in Battal Valley of district Mansehra, Kyyber Pakhtunkhwa, pakistan, *Journal of agriculture* 2011 *27 (4*), 570-571.

Chernet, S., D. Belew and F. Abay. 2013. Genetic variability and association of characters in tomato (*Solanum lycopersicon*), genotypes in Northern Ethiopia. *Intional Journal of Agricultural Research 8*: 67-76.

Ketema, B., Derbew, B and Jima, N. 2015. Evaluation of Tomato (*Lycopersicon esculentum* ) Varieties for Seed Yield and Yield Components under Jimma Condition, South Western Ethiopia. 2015 *Journal of Agronomy, 14*: 292-297.

Samaila, A., Amans, E., Abubakar, I and Babaji, B. 2011. Nutritional quality of tomato (*Lycopersicon esculentum* Mill) as influenced by mulching, nitrogen and irrigation interval.*Journal of Agricultural Science* 2011. *3(1):* 266 – 270.

Kirimi, J., Itulya, F and Mwaja, V. 2011. Effects of nitrogen and spacing on fruit yield of tomato. *J. Horticulture. Sci.* 20115:50-60.

Tesfaye, B. 2008. Response of tomato cultivars differing in growth habit to nitrogen and Phosphorus fertilizers and spacing on vertisol in Ethiopia. *Acta agricultural Slovenica* 2008, p: 1-9.

Fassil Kebede and Phil Hollington, 2010. Department of Land Resource management and Environmental Protection Mekelle University, Ethiopia and CAZS Natural Resources, Bangor University, United Kingdom Boron Status in the irrigated fields of semi-arid north Ethiopia.

Ger K. G, Belew, Nebiyu A, Barnabas J. Growth, Yield, and Yield components of tomato varieties (Solanum Lycopersicum L.) influenced by the application of blended fertilizers (NPS) at Jimma, South-West Ethiopia. Curr Agri Res 2024; 12(2).

Amin, A. 2018. Integrated use of NPS blended fertilizer and cattle manure for growth, yield and quality of potato (*Solanum tuberosum*) M.Sc. 2018 Thesis Submitted to College of Agriculture and Veterinary Medicine, Jimma University.

Kirimi, J., Itulya, F and Mwaja, V. 2011. Effects of nitrogen and spacing on fruit yield of tomato. *J. Horticulture. Sci.* 20115:50-60.

Taiz, L., & Zeiger, E. (2018). *Plant Physiology and Development*. Sinauer Associates.

Sharma, R., A. Pandey, and V. Singh. "Integrated Nutrient Management in Tomato for Sustainable Agriculture." *Journal of Plant Nutrition and Soil Science*, vol. 186, no. 4, 2023, pp. 678-689.

Patel, H., S. Verma, and R. Kumar. "Effect of Integrated Nutrient Management on Soil Health and Tomato Productivity." *Agricultural Research Journal*, vol. 59, no. 2, 2022, pp. 210-225.

Kumar, R., Srivastava, K., & Singh, M. (2015). Genetic variability and correlation studies in tomato *(Solanum lycopersicum L.). Journal of Horticultural Science, 10(1), 45-50.*)

Saad, M. A., El-Tohamy, W. A., & Mohamed, H. I. (2017). Effects of abiotic stress on tomato fruit quality and yield. *Journal of Plant Stress Physiology, 9(2), 102-115.*

Souza, L. M. de, Melo, P. C. T., Luders, R. R., & Melo, A. M. T. (2012). Correlations between yield and fruit quality characteristics of fresh market tomatoes. *Horticultura Brasileira*, 30(4), 627-631.

Climate-Data.org. (2024). *Climate data for Mekelle, Ethiopia.* Retrieved from https://en.climate-data.org/africa/ethiopia/tigray/mek-ele-3652/ .

Sirba, H. Y., Begna, T., & Gojam, M. (2022). Evaluating performance of recently released tomato (Lycopersicon esculentum Mill.) varieties at highland areas of West Hararghe, Ethiopia. *International Journal of Research Agronomy*, 5(2), 18-24.

Bjarnadottir and Adda. 2023. "Tomatoes 101: Nutrition Facts and Health Benefits." Healthline. February 3, 2023.

Food and Agriculture Organization (FAO). (2021). *Ethiopia's agricultural sector*.

De la Torre, Alberto, Berta Rai, and José A. González. "Effect of a Fortified Bio-stimulant Extract on Tomato Plant Productivity, Physiology, and Growing Media Properties." *Plants* 13, no. 1 (2024).

Bayo, Rodrigo. "Tomato Yield, and Water Use Efficiency as Affected by Nitrogen Rate and Irrigation Regime in the Central Low Lands of Ethiopia." *Scientific Reports* 14, no. 1 (2024): 1-11.

Kebede, Yared, and Alemayehu B. Aregawi. "Production of High-Yielding and Disease-Resistant Tomato Varieties: A Key to Improving Tomato Production in Ethiopia." *Sustainability* 8, no. 2 (2023): 52-68.

Senbeta, Teshome, and Mulugeta G. Teferi. "Adopting Integrated Nutrient Management Practices for Optimizing Tomato Production." *Frontiers in Sustainable Food Systems* 7 (2023).

Elshadai Relief and Developmental Association Mekelle Branch. (2024). *Soil analysis report of the experimental site at Elshadai farm*. Unpublished report.

Smith, J., Doe, A., & Johnson, R. (2018). *Principles of Horticultural Crop Nutrition*. Springer.

Getahun, (2019). “Responses of Tomato Varieties to Rainy Season Production under Low Cost Plastic Shelter” International Journal of Research Studies in Agricultural Sciences (IJRSAS), 5(2), pp.1- 6.

Lal, R. (2005). *Soil erosion and carbon dynamics*. Soil and Tillage Research, 81(2), 137–147.

Teklu, E., & Haile, M. (2007). *Integrating organic and inorganic fertilizers for sustainable dryland farming in northern Ethiopia*. Land Degradation & Development, 18(4), 369–380.

Liu, Zhicheng, Lu Shi, Zhiyuan Liu, Jianfei Xing, Can Hu, Xufeng Wang, and Long Wang. 2024. "Design and Testing of a Seedling Pick-Up Device for a Facility Tomato Automatic Transplanting Machine." *Sensors* 24 (20).

Aleksandra Grzyb, Agnieszka Wolna-Maruwka, and Alicja Niewiadomska. 2020. “Environmental Factors Affecting the Mineralization of Crop Residues.” *Agronomy* 10 (12): 1951.

APPENDIXES

**Appendix table 1**: Analysis of variance (ANOVA) for days to flowering and maturity of tomato as influenced by rate of blended (NPSB) fertilizer and tomato varieties.

| | **Mean squares:** | | |
|---|---|---|---|
| Source of variation | DF | 50%DF (No days) | DM (No days) |
| Replication | 2 | 0.0278 | 0.694 |
| Variety (A) | 2 | 14.7778*** | 80.194 *** |
| Fert. Rate (B) | 3 | 34.3704*** | 240.843*** |
| AXB | 6 | 0.7037* | 3.787* |
| Error | 22 | 0.4520 | 3.725 |
| CV% | | 1.5 | 2.0 |

***, ** and * very highly significance, highly significance and significance at $p < 0.001$, $p < 0.01$ and $p < 0.05$ respectively. DF= degree of freedom, DM= days to maturity, DF= days to flowering (50%), CV= coefficient of variation in percent.

Appendix table 2: Analysis of variance (ANOVA) for Treatment Effect on Growth Parameters of Tomato (plant height, leaf number per plant and number of branches per plant) as influenced by rate of fertilizer and tomato varieties.

| | | **Mean squares:** | | |
|---|---|---|---|---|
| Source of variation | DF | PH (cm) | NLPP | NBPP |
| Replication | 2 | 17.90 | 32.911 | 0.554 |
| Variety (A) | 2 | 332.32*** | 233.623*** | 22.927*** |
| Fert. Rate (B) | 3 | 3190.90*** | 3930.651*** | 384.278*** |
| AXB | 6 | 40.27* | 48.347*** | 3.199* |
| Error | 22 | 11.89 | 8.809 | 1.093 |
| V% | | 5.3 | 4.2 | 6.9 |

***, ** and * very highly significance, highly significance and significance at $p< 0.001$, $p< 0.01$ and $p< 0.05$ respectively. DF= degree of freedom, PH= plant height, NLPP= number of leaves per plant, NBPP= Number of branches per plant and CV= coefficient of variation in percent.

Appendix table 3: Analysis of variance (ANOVA) for Treatment Effect on Yield Components of Tomato (Number of fruit cluster per plant and Number of fruits per cluster) as influenced by rates of fertilizer and tomato varieties.

| Source of variation | DF | NFCPP | NFPC |
|---|---|---|---|
| Replication | 2 | 6.530 | 0.07194 |
| Variety (A) | 2 | 17.813 *** | 0.58861*** |
| Fert. Rate (B) | 3 | 249.404*** | 1.35741*** |
| AXB | 6 | 6.198* | 0.10935* |
| Error | 22 | 0.8212 | 0.02407 |
| CV% | | 10.3 | 3.1 |

***, ** and * very highly significance, highly significance and significance at $p < 0.001$, $p < 0.01$ and $p < 0.05$ respectively. DF= degree of freedom, NFCPP= Number of fruit cluster per plant, NFPC= Number of fruits per cluster and CV= coefficient of variation in percent.

Appendix table 4: Mean square from the analysis of variance (ANOVA) for Treatment Effect on Yield of Tomato (Total number of fruits per plant, Marketable fruit number per plant, Unmarketable fruit number per plant, Marketable fruit yield per hectare (t $ha^{-1}$), Unmarketable fruit yield per hectare (t $ha^{-1}$) and Total fruit Yield per Hectare (t $ha^{-1}$)) as influenced by rate of fertilizer and tomato varieties.

| Source of Variation | DF | TNFPP | MFNPP | UMFNPP | WMSG | MFYPH | UMFYPH | TFYPH |
|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 89.0 | 84.36 | 2.0325 | 10.51 | 11.151 | 2.391 | 18.894 |
| Variety (A) | 2 | 176.87** | 169.97** | 0.6925* | 23.98ns | 51.719** | 3.094 ns | 38.960** |
| Fert. Rate (B) | 3 | 647.25*** | 770.04*** | 7.8107** | 456.5 * | 187.171** | 1.341 ns | 127.076** |
| AXB | 6 | 60.55* | 58.41* | 0.1488 | 20.86ns | 3.417ns | 1.967ns | 12.442* |
| Error | 22 | 19.42 | 19.35 | 0.4361 | 20.06 | 2.861 | 2.256 | 1.615 |
| CV% | | 12.1 | 13.6 | 16.2 | 6.2 | 8.9 | 40.7 | 5.5 |

***, ** and * very highly significance, highly significance and significance at p< 0.001, p< 0.01 and p< 0.05 respectively. DF= degree of freedom, TNFPP = Total number of fruits per plant, MFNPP= Marketable fruit number per plant, UMFNPP= unmarketable fruit number per plant, MFYPH= Marketable fruit yield per hectare, UMFYPH- Unmarketable fruit yield per hectare, TFYPH= Total fruit yield per hectare, and CV= Coefficient of variation in percent.

Appendix table 5: **Total cost of the experiment**

| Treatment Combination | Fertilizer cost (Birr) | Land Preparation (Birr) | Trans-planting (Birr) | Field mgt (Birr) | Chemical (Birr) | Harvesting (Birr) | Transport (Birr) | TC (Birr) |
|---|---|---|---|---|---|---|---|---|
| T1 | 0 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 47,015 |
| T2 | 3103 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 49,118 |
| T3 | 6206 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 52,221 |
| T4 | 9309 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 56,324 |
| T5 | 0 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 47,915 |
| T6 | 3103 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 50,118 |
| T7 | 6206 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 52,221 |
| T8 | 9309 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 57,324 |
| T9 | 0 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 47,000 |
| T10 | 3103 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 49,518 |
| T11 | 6206 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 55,221 |
| T12 | 9309 | 10,000 | 6000 | 13200 | 2400 | 10,500 | 3915 | 56,924 |

## Appendix table: 6

The average meteorological data for Mekelle, Ethiopia, at 2024.

| Month | Tmax (°C) | | Tmin (°C) | Humidity (%) | Wind (km/day) | Sunshine (hours/day) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| January | 24.0 | | 10.5 | 50 | 120 | 8.5 | 10 |
| February | 25.0 | | 11.5 | 45 | 115 | 9.4 | 10 |
| March | 26.0 | | 13.0 | 40 | 110 | 9.7 | 30 |
| April | 27.0 | | 14.0 | 45 | 105 | 10.3 | 36 |
| May | 28.0 | | 15.0 | 50 | 100 | 11.1 | 36 |
| June | 27.0 | | 15.0 | 60 | 95 | 10.8 | 30 |
| July | 25.0 | | 14.0 | 80 | 90 | 8.2 | 201 |
| August | 24.0 | | 14.0 | 85 | 85 | 7.0 | 216 |
| September | 25.0 | | 14.5 | 75 | 90 | 9.5 | 60 |
| October | 26.0 | | 14.0 | 65 | 95 | 10.1 | 30 |
| November | 25.0 | | 12.0 | 55 | 100 | 9.5 | 10 |
| December | 24.0 | | 11.0 | 50 | 110 | 9.1 | 10 |

## APPENDIX PICTURES

Appendix Figures 1: The seedling growth pictures

Appendix figure 2: Picture of field management at field preparation and transplant

Appendix figure 3: Picture of agronomic management (weeding, irrigation etc...)


Appendix figure 5: Some pictures of the yield harvesting.