SCHOOL OF GRADUATE STUDIES

EFFECTS OF BLENDED FERTILIZER TYPES ON GROWTH, YIELD AND QUALITY OF TOMATO (*Lycopersicon esculetum Mill.*) VARIETIES AT CHEHA DISTRICT, GURAGHE ZONE, CENTRAL ETHIOPIA

MSc THESIS

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Effects of Blended Fertilizer Types on Growth, Yield and Quality of Tomato (*Lycopersicon esculetum Mill*) Varieties at Cheha District, Guraghe Zone Central Ethiopia

A Thesis Submitted to School of Graduate Studies, in Partial Fulfillment of the Requirements for the Degree of Master of Agriculture in Horticulture

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APPROVAL SHEET

As the thesis research advisors, we hereby certify that we have read and evaluated the thesis entitled **"Effects of Blended Fertilizer Types on Growth, Yields and Quality of Tomato (***Lycopersicon esculetum Mill.***) Varieties at Cheha Districts, Central Ethiopia''** prepared under our guidance by **Hayatu Abdella Bedru**. We recommend that is to be submitted as fulfilling the thesis requirement and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read and evaluated the thesis prepared by **Hayatu Abdella Bedru** and examined the candidate. We recommend that the thesis be accepted as fulfilling the requirements for the Degree of Master of Science in Horticulture.

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BIOGRAPHICAL SKETCH

The author was born on 01 September 1990G.c. in Cheha district, Guraghe Zone, Central Ethiopia. He attended Emtebarye Elementary School (grade 1-6) from 1997-2002. He joined Gubrye Senior Secondary School from 7-10 in years 2003-2007 and completed preparatory program at Emdibir in 2008-2009. The author joined Arba Minch University, College of Agriculture in 2010 to pursue a study leading to the Degree of Bachelor of Science. He graduated with a BSc Degree in Horticulture, June 2012. Soon after graduation, he was recruited by Cheha Woreda Agricultural Office for eight years. He then joined the School of Graduate Studies of Wolkite University in 2022 to pursue a study leading to the Degree of Master of Science in Agriculture (Horticulture).

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CSA	Central Statistical Agency
CWADO	Cheha Woreda Agricultural Department Office
CSSE	Crop Science Society of Ethiopia
CV	Coefficient of Variation
DAP	Di-Ammonium Phosphate
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
Ethio-SIS	Ethiopian Soil Information System
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization Statistics
LSD	Least Significant Difference
MoARD	Ministry of Agriculture and Rural Development
NPS	Nitrogen Phosphorus Sulfur
NPSB	Nitrogen Phosphorus Sulfur and Boron
NPSZN	Nitrogen Phosphorus Sulfur and Zink
NPSBZN	Nitrogen Phosphorus Sulfur Boron and Zink
RCBD	Randomized Complete Block Design
RDA	Recommended Daily Allowance
SAS	Statistical Analysis Software

Abstract

Tomato (Lycopersicon esculetum Mill.), which is farmers used for income generation and home conception. In Ethiopia is facing challenges in low productivity for the major reasons including inaccessibility of improved varieties and specific fertilizer recommendations. Therefore, this experiment had initiated to evaluate the roles of blended fertilizers on yield and yield components of tomato varieties in Cheha district of Central Ethiopia during this cropping season. Sixteen treatments (four blended fertilizer types with four tomato varieties) were assigned and triplicated in RCBD design. Data on phonology; vegetative and yield related attributes were recorded and analyzed using SAS software. From the experiment, 50% flowering and plant height were significant (P<0.001) response for melkashola varieties and NPSBZn blended fertilizer. Numbers of clusters per plant and fruits per cluster, fruit diameter, total fruit yield as well as individual fruit size were highly significant(P<0.001) for Gelilema variety and NPS fertilizer. Marketable yield was highly significant for Gelilema variety with NPSB blended fertilizer. 50% fruiting, dry weight, days to maturity and total soluble solid were highly significant (P<0.001) Melkashola and NPS fertilizers. However, unmarketable fruit yield and pH significantly affected by the varieties. The highest (76.6 ton/ha) total fruit yield was obtained when NPSB fertilizers applied to Gelilema variety. Observing the partial budget analysis, the application of NPSB fertilizers with Gelilema variety gave the maximum net return of 1278200ETB with an acceptable marginal rate of return (5219.6 %). Therefore, the combination of NPSB fertilizer with Gelilema variety is economically feasible for growing tomatoes in Cheha areas. However, this study cannot provide a solid recommendation because the research only one season of work was done in one place. .

Keywords: Blended fertilizer, tomato varieties, growth parameters, yield, quality

1. INTRODUCTION

The tomato (*Lycopersicon esculentum Mill.*) is a member of the *Solanaceae* family and originated in South America's western coastal plain. It is the second most important vegetable food produced worldwide, after potatoes (Melkamu *et al*., 2016). Tomatoes are a good source of vitamins, minerals, and antioxidants, all of which are vital for a balanced human diet (Falak *et al*., 2011). After rice, wheat, and soybeans, the crop, which was the top vegetable, is the fourth most financially significant in the world (FAO, 2015). It is uncertain when tomatoes were introduced to Ethiopia. Its cultivation in Ethiopian agriculture, however, goes back to the time between 1935 and 1940 (Gemechis *et al*., 2012), and it is currently one of the most well-liked and extensively cultivated vegetables. According to Wilcox *et al*. (2003), it is a fantastic source of nutrients and secondary metabolites that are crucial for human health, such as potassium, vitamins C and E, chlorophyll, β-carotene, and lycopene.

According to FAOSTAT (2018), there were 5 million hectares of tomatoes grown globally, producing an average of 171 million tons. The average tomato production in Ethiopia was 34,947 tons, while in Africa it was 21,664,774 tons, in Europe it was 22,805,866 tons, and in Asia it was 112,104,020 tons (FAO, 2019).

According to CSA (2016), Ethiopia has a total tomato production area of 9,767.8 hectares, with a total output and productivity of 913,013.4 tons and 93.47 tons per hectare, respectively. Central Ethiopia region has a total tomato production area of 19029 hectares with productivity of 30tones per hectares. Tomatoes are one of the most important vegetable crops grown in the Gurage Zone for both income production and family use. It is primarily cultivated during the dry season under conditions of supplemental irrigation. The Gurage Zone's tomato growing area is expanding over time, primarily because of its productive capacity and strong market demand. In the 2024/2025 production season, tomatoes were grown on 3,450 hectares of land the productivity is 30.5 tones per hectares. Abeshiege, Enor, and Cheha are some of the zone's top producing districts (DGZA, 2025).

Cheha district is one of the promising places for tomato cultivation. With four permanent rivers and plenty of command areas, In the 2024/25 production year, 550 hectares were planted with tomatoes, and 1150 farmers took part. However, tomato productivity in the district is low 25t ha^{-1} as compared to the national average 93.47t ha^{-1}, regional 30t ha^{-1}, and zonal 30.5t ha-1. Because of shortage of seeds of improved varieties, poor agronomic

practices including use of inadequate rate of fertilizer and disease and insect pest problems (CWAO, 2025).

The low average productivity of tomatoes in Ethiopia is likely caused by a variety of factors, including a lack of advised packages and improved varieties, low-quality seeds, inadequate irrigation systems, insufficient knowledge of soil fertility, diseases, and insect pests, significant post-harvest losses, and a subpar marketing system (Lemma, 2002).

In Ethiopia, numerous tomato varieties have been nationally released and endorsed for both commercial and small-scale farming systems, according to Seifudin *et al.* (2016). However, the areas with the greatest potential for tomato production do not extensively utilize these improved varieties along with their agronomic packages. This could be caused by a lack of awareness and/or access. Therefore, introducing and assessing enhanced types for their suitability in potential production regions would help raise awareness and improve grower access.

There are currently advances being made toward increasing tomato output worldwide. Nonetheless, about half of the majorities of nations like Ethiopia that is developing lack availability of sufficient tomato resources. Among numerous distinct Poor quality tomato seeds and a lack of enhanced varieties are contributory factors to the low yield (Yeshiwas *et al. 2*016). Tomato production success is mainly dependent to location based variety selection and planting as per recommendation for the varieties by the breeder or variety releasing organization appropriate variety for a particular location. In the last few decades, several high yielding varieties and hybrids have been developed and recommended by agricultural research centers in Ethiopia.

In Ethiopian agriculture, chemical fertilizer sources have been limited to Urea and Diammonium Phosphate (DAP) over the past five decades. These types of fertilizers deliver only nitrogen and phosphorus that may not satisfy the nutrient requirements of the crops including tomato in the agricultural soils. The growth and yield of vegetable crops mainly depend on the quality and quantity of fertilizers used (Chang *et al*., 2010).In most parts of Ethiopia, there is no recommendation of fertilizer types for tomato production specific to cultivars and locations or agro ecologies. It is common to apply the national recommendation of 92 and 46 kg ha^{-1} P2O5 and Nitrogen containing fertilizers, respectively (Lemma, 2002) at all locations and to all tomato varieties. However, tomatoes vary in their growth and

production season (Naika *et al.,* 2005) and the types and amount of fertilizers need to be recommended for the specific growing area(s) and cultivars. Large differences have been shown to exist among species or cultivars of the same species in absorption, translocation, and use of mineral nutrients (Baligar *et al.,* 2001). According to Hailu (2014), Ethiopian soil lacks most of the macro (N, P, and S) and micro (Cu, Zn, and B) nutrients that are required to sustain the optimal growth and development of crops. Consequently, the yield and productivity of crops in Ethiopia are much lower than in other countries (USAID, 2013). To solve these problems, the Ministry of Agriculture (MoA) currently popularized the implementation of soil test based fertilizer application system, using soil fertility information 7.3% S, 0.67% B, and 2.23% Zn) was used in the country's farming system. (MoA, 2013) and thus introduced a new fertilizer (NPS) which contains 19% N, 38% P2O5, and 7% S, NPSB (18.9% N, 37.7% P_2O_5, 6.9% S, 0.1% B), and NPSZn fertilizer with the ratio of 17.7% N, 35.3% P O, 6.5% S and 2.5% Zn and NPSBZn (16.9% N, 33.8% P2O5, 7.3% S, 0.67% B, and 2.23% Zn).

Though several studies have explored in fertilizer requirement for tomato, the problems related with poor quality and low productivity not solved yet (Ambecha *et al*., 2012). As far as the study area is concerned, there is no study carried out in regard to Effects of blended fertilizer types to tomato varieties on yields and quality on application types of the newly introduced blended fertilizer. Research-based recommendations of tomato varieties and the types of blended fertilizer can increase tomato crop production and increase the benefits of farmers. Therefore, it is imperative to identify the best tomato verities and blended fertilizer types (NPS, NPSB, NPSZn and NPSBZn) have been introduced to substitute DAP fertilizer aiming to include micronutrients (MoANR, 2013). These fertilizer types have not yet been recommended for specific vegetables for optimum tomato production in the area. Considering the existing gap for tomato production, this study was designed to address the following objectives.

- **General objectives**
  - The general objective of the study was to evaluate the response of tomato varieties to different blended fertilizer types for a better yield and quality.
- **Specific objectives**

✓ To evaluate high yielding and quality tomato variety and blended fertilizer type in study area

✓ To determine best variety and blended fertilizer type combination for optimum tomato yield and quality

✓ To determine economically feasible fertilizer type and varieties for optimum yield and quality.

2. LITERATURE REVIEW

2.1. Origin, Distribution and Taxonomy of Tomato

Tomatoes are group of the *Solanaceae* family and the *Solanum* genus that contains a small number of annual and herbaceous perennial plants (Naika *et al*. 2005). It originated in the Andes of South America. The tomato was first domesticated and cultivated in Mexico (Tigchelaar *et al*., 1986). Tomatoes were brought to Europe from Mexico or Peru in the early sixteenth century, but they have only been cultivated for commercial purposes since the 1800s. The early explorers then brought it to other areas of the world, where it was cultivated as decorative curiosities (Gould 1983). Improvements in technologies that enabled mechanized processing contributed to a rise in worldwide tomato output during the 1920s (Tan *et al*., 2010). Tomatoes are self-pollinating plants that mature 80 to 90 days after transplanting (Giovannoni, 2001).

2.2. Significance of Tomatoes

Tomatoes are among the most economically significant crops, placing first among all vegetables worldwide and fourth overall behind rice, wheat, and soybeans (FAO, 2015). According to Bauchet and Causse (2012), it is a valuable source of micronutrients for the human diet. Additionally, it provides a wealth of nutrients and secondary metabolites beneficial to human health, such as potassium, vitamins C and E, chlorophyll, β-carotene, and lycopene (Willcox *et al*., 2003). Tomatoes are a significant source of lycopene, a potent antioxidant carotenoid, according to Lemma (2002). In Ethiopia, tomatoes are among the most commonly grown vegetables by both small-scale farmers and commercial producers for use in both the processing and fresh fruit sectors.

2.3. Soil and Climate Conditions for Tomato Production

Well-drained sandy loam soil is preferred, but a variety of soil types can be utilized for tomato cultivation (Hanson, 2001; Nuruddin, 2001; Peet, 2008). The ideal soil pH ranges from 6.0 to 7.0. Plant disorders like blossom-end-rot can develop if the pH is below 5.5. According to Nuruddin (2001), tomatoes can thrive in a range of climates, but their ideal growth and development temperature is between 21 and 27 degrees Celsius (Hanson, 2001; Shankara *et al*., 2005). Tomatoes are also plants that are neutral to day length. The ideal light intensity for growth and development is 400–500 $\mu mol.m^{-2}. S^{-1}$. High light intensity can lead

to fruit cracking, sunscald, and green shoulders (Jones, 1999). However, tomatoes have a significant demand for water (Peet, 2008).

2.4. Status and challenges of tomato production in Ethiopia

The introduction of cultivated tomato to Ethiopian agriculture date back to1940. Since 1969 adaptation trial had been carried out but challenged by diseases (Tesfa Binalfew *et al*., 2016). According to Lemma Desalegn, 2002, the first record of commercial tomato cultivation is from 1980 with a production area of 80 hectares in the upper Awash by Merti Agro industry for both domestic as well as export markets. The total area increased to 833 hectares by the year 1993 and later on the cultivation spread towards other parts of the country. In 2014/15 Ethiopian rain fed cropping season, only tomato production was estimated to be 7,237 hectares and production is estimated to be over 55,514 tones with the average productivity of 8 tones per heater (CSA, 2016).

According's to Tesfa Binalfew *et al*.,2016, in Ethiopia, the crop is produced in the range of 700 up to 2200 meter above sea level, with about 700 mm to over 1400 mm annual rainfall, in different areas and seasons, in different soils under different weather conditions but also at different levels of technology(furrow , drip or spate irrigation).

Large scale production of tomato takes place in the upper Awash valley, under irrigated and rain fed conditions whereas small scale production for fresh market is a common practice around Koka, Ziway, Wondo Genet, Guder and many other areas of the country (Lemma Desalegn, 2002).Commercial production is carried out mainly in the central rift valley and eastern part of the country. Most of the vegetables including tomato produced in the eastern region are exported to Djibouti and small amounts of fruit and vegetables are also exported to Europe, Pakistan, Saudi Arabia and Yemen (FAO, 2014).

The shortage of varieties that are adaptable to different agro ecologies, poor quality seeds, disease and insect pests, improper fertilizer application and chemicals pest management method, increase in soil acidity, high postharvest loss, lack of awareness of existing improved technology and poor marketing systems are some of the major constraints associated with tomato production in Ethiopia (Lemma Desalegn, 2002).

2.5. The Significance of Blended Fertilizers for Crop Production

According to Beaton (1997), fertilizer blending is the mechanical mixing of two or more granular fertilizer materials to create mixtures that include nitrogen (N), phosphorus (P),

sulfur (S), and other vital plant nutrients. The foundation for increasing crop production from currently cultivated land is the appropriate use of balanced fertilizers (Caruso *et al*., 2019).

Understanding the nutrient needs of plants in a specific region is crucial for sustainably improving crop yield and productivity. However, enhancing crop yields solely through the application of nitrogen (N) and phosphorus (P) can exhaust other nutrients (FAO, 2000). Fertilizers are an effective external source of plant nutrients (Akram *et al*., 2007), as a sufficient and balanced supply of nutrients is necessary for maximizing productivity by optimizing plant nutrient uptake. Numerous studies have found that chemical fertilizers are the primary nutrient source for enhancing crop yield (Akram *et al*., 2007).

Generally speaking, blended fertilizers contribute to balanced fertilization, which enhances the environment and provides added Profit for Farmers by allowing small batches of high-analysis, soil- and crop-specific fertilizers to be mixed and transported economically (Mekashaw *et al*., 2020).

2.6. Effects of NPS on yield, yield attributes and qualities of tomato

2.6.1. Effects of nitrogen on the growth, yield and qualities of tomato

According to Dufault *et al*., (2000) reported that, Nitrogen fertilization increased fruit number, fresh and dry yields and N uptake, stem, leaf, and root dry weights and N uptake, root length, and total dry weight and N uptake. The residue was as effective in increasing fresh fruit yield, total dry weight, and N uptake was 4.4 to 7.9 g/plant of N fertilizer. Tomato yield and N uptake per unit amount of N supplied were greater for the residue than N fertilization.

Xin *et al*., (1997) reported that Nitrogen is essential for the building up of protoplasm and protein which induced cell division and initial meristematic activity when applies in optimum quantity. Nitrogen had the largest effect on the yield and quality of tomatoes.

The distribution and retention of soil nitrates in the soil profile as affected by N fertilization and cover cropping. Total marketable tomato yield increased as fertilizer N increased to 60 kg/ha in two out of four years and with 120 kg/ha in one out of four years. In all cover crop or fallow plots, as fertilizer N application levels increased, the soil nitrates also increased (Dufault *et al*., 2000)

2.6.2. Effects of Phosphorus on Tomato Growth, Yield, and Quality

Field experiments conducted in Haryana, India, by Nanadal *et al*. (1998) demonstrated that increasing amounts of phosphorus up to 50 kg P2O5 and potash up to 80 kg K2O/ha enhanced tomato plant height, flower count, fruit weight, early and total yield, ascorbic acid content, total soluble solids (TSS), and reducing and non-reducing sugars in the fruit. While the greater rates of 75 kg P2O5/ha and 120 kg K2O/ha improved the fresh and dry weight of the plants and promoted flowering and fruiting, they also negatively affected the quality of the fruit (Nanadal *et al*., 1998).

According to Topeuoglu and Yalcin (1994), potted tomato plants received varying amounts of lime (calcium hydroxide) and phosphorus. Higher rates of lime application boosted individual fruit weight but reduced fruit yield per plant. Higher rates of phosphorus lead to more plant growth and higher fruit production. Candilo *et al*. (1993) conducted an experiment to investigate the effects of sulfur and phosphorus application on cloth marketable yield and TSS content, and they found that these factors caused noteworthy, linear increases. Phosphorus shortage in tomatoes can cause stunted growth, purple-tinged leaves, and poor fruit output, according to John *et al*. (2004). Rodge and Yadlod (2009) produced a similar report, in which they observed the greatest height in tomato plants with the both organic and inorganic fertilizers. Reddy's *et al*. (2002) also discovered that utilizing a combination of factors resulted in the greatest plant height. The highest plant, as stated by Patil *et al*. (2004), height through the use of inorganic fertilizers in combination with organic manure.

2.6.3. The Effects of Sulfur on Tomato Growth, Yield, and Quality

Scherer (2001) stated that the rate of sulfur fertilizer should be recommended based on available soil sulfur and crop needs in order to maximize yield and reduce sulfur leaching. Sulfur is a crucial nutrient for plants, necessary for the production of proteins, enzymes, and the amino acids cysteine and methionine. It has been demonstrated that it is crucial in the quality of crops (Heebn *et al*., 2006; Pavlista, 2005; Rhoads & Olson, 2000).

Sulfur is present in the soil in both organic and inorganic forms. More than 90% of sulfur in typical soils is in the varied organic form. The majority of plants take up sulfur (S) in the inorganic sulfate (SO4) form through their roots, although a small quantity can also be absorbed through their leaf stomata as sulfur dioxide (SO2) gas (Tabatabai, 1984).

2.7. Tomato Response to NPSBZn Mixed Fertilizer

2.7.1. Tomato Reaction to Nitrogen

Nitrogen fertilizers are crucial for enhancing crop productivity, but their low use efficiency poses a risk to sustainable plant production, according to Souri (2010). According to Marschner (2011), there are several nitrogen sources available for use in field and hydroponic settings. The primary nitrogen fertilizers used for soil application are ammonium sulfate, urea, and ammonium nitrate, whereas the primary nitrogen sources typically used in hydroponic systems are calcium nitrate and potassium nitrate. According to Souri and Roemheld (2009), the form of nitrogen (ammonium vs. nitrate) can greatly affect a plant's morphology and physiology, especially in hydroponic environments.

Farmers in Yemane *et al*. (2016) choose to use a lot of fertilizer in the hopes of producing hearty, vigorous plants and a plentiful supply of fruits that are marketable. Because fertilizer application is crucial for producing high-quality fruit, reasonable amounts of nitrogen and phosphorus should be utilized at various points in conjunction with extension experts until research recommendations are available for various soils. No such research was conducted on tomatoes for various hybrid types, and all of these earlier agronomic investigations were limited to the sandy loam soils of the country's rift valley areas.

According to Sainju *et al*. (2001), nitrogen fertilization boosted the number of fruits, the fresh and dry yields, the nitrogen uptake, and the dry weights of the stem, leaf, and root, the length of the root, the total dry weight, and the nitrogen uptake. The residue was more effective than nitrogen fertilization in increasing tomato yield and nitrogen uptake per unit of nitrogen applied. The optimal amount of nitrogen fertilizer for maximizing fresh fruit yield, total dry weight, and nitrogen uptake was between 4.4 and 7.9 grams per plant. In soils with low nitrogen availability, like sandy soils, nitrogen has a significant impact on the growth and development of tomatoes. According to Hokam *et al*. (2011), nitrogen enhances tomato vegetative growth and fruit output, and its use later in the growing phases promotes fruit development.

2.7.2. Tomato Response to Phosphorus

Phosphorus is recognized as the second most crucial nutrient for limiting plant growth (Tisdale *et al*., 1990). It constitutes around 0.2-0.5% of a plant's dry weight (Bieleski, 1973). Additionally, phosphorus is a component of sugar, as well as the membranes, chloroplasts, and mitochondria of plants. It also plays a role in a variety of biochemical and physiological processes in plants. For these reasons, phosphorus was essential for energy transfer reactions and metabolic processes during seed production, fruit setting, and plant maturation (Brady and Weil, 2002).

Phosphorus is a component of nucleoproteins and plays a role in the energy transfer of compounds such as ADP and ATP (Siddesh, 2006). It also significantly contributes to energy transfer during metabolic processes. Phosphorus is thought to produce a higher yield and fruits with a redder hue (Matta and Cotter, 1994). According to Gould (1983), the needs for fertilizer change based on soil type and the history of previous crops, therefore, a proper nutrient balance is necessary for optimal output. Phosphorus promotes the start of tomato root growth, which facilitates the early establishment of the plant following seeding or transplanting. To promote early root development and soil establishment, tomato plants are typically treated with a starter solution high in phosphorus within a few days of transplanting. P stimulates vigorous root development, which aids in the efficient use of water and other nutrients in the soil and supports robust stem growth and healthy foliage. The availability and absorption of phosphorus (P) by plants are significantly impacted by soil pH, with the majority of P being taken as the primary orthophosphate ion (HPO4 and H2PO4) (Gupta 2011).

According to Abdalla *et al*. (2001), phosphorus is a component of nucleic acids. As a result, it aids in the early development of tomatoes and the early formation of seeds and fruits, which boosts the quantity and yield of tomato fruits and raises the levels of total soluble solids and acidity. Additionally, it enhances the vitamin C content, flavor, firmness, and color of the skin and pulp. P deficiency causes tomatoes to grow slowly, with dark green upper leaves and purple veins. Phosphorus deficiency is a major limitation to crop production in many tropical soils (Needham, 1973). Most soils worldwide are phosphorus deficient for either low phosphorus content in the soil or high phosphorus fixation (Batjes, 1997; Zaidi and Mohammad, 2005).

2.7.3. Tomato Response to Sulfur

Sulfur is also a crucial nutrient for plants, necessary for their growth and development. Sulfur has several crucial functions in plant growth and development, according to Melaku (2019). Sulfur is a crucial element of cysteine and methionine, two amino acids that are essential for protein synthesis, as well as for the production of certain hormones, vitamins, and glutathione.

According to Lewandowska and Sirko (2008), sulfur is considered the fourth most important element after nitrogen, phosphorus, and potassium. As a vital macronutrient, sulfur is a component of amino acids and proteins. Because it is not readily translocated within the plant, symptoms of deficiency first appear in the younger leaves. Plants grown under sulfur deficiency exhibit reduced root development and typically lower shoot-to-root ratios (Clark, 1993). The overall dry matter output of crops rises with increasing sulfur fertilization, improving the yields of onion, cabbage, and barley in comparison to NPK fertilization. As a result, the greatest yields were seen following the addition of 40 kg S and 80 kg S (Skwierawska *et al*., 2008).

2.7.4. Tomato Response to Zinc

According to Potarzycki and Grzebisz (2009), zinc has a significant impact on fundamental plant life processes, including nitrogen metabolism, photosynthesis, protein quality, and resistance to biotic and abiotic factors. As the quantity of Zn increased, plant height, total chlorophyll, and biomass decreased. Zn concentration in the soil rises above the adequate level for crops (Mirshekal *et al*., 2012).

In Ethiopia, the use of blended fertilizers containing zinc and boron micronutrients along with nitrogen, phosphorus, and potassium macronutrients has been shown to increase nutrient concentration, uptake, and yield (Feyera *et al*., 2014).

According to Abdel-Samad *et al*. (1996a), a high phosphorus level in the soil can also decrease zinc availability to tomatoes, leading to a lack of nutrients. On the other hand, excessive zinc in the soil might be harmful to tomatoes. The plants are stunted and spindly, with smaller leaves. Younger leaves display inter-veinal chlorosis and a purple underside, while older leaves curl downward. The use of water collected from corroded galvanized pipes and the addition of zinc-contaminated organic materials, like sewage sludge, can cause zinc toxicity.

2.7.5. Tomato Response to Boron

Boron is relatively immobile in plants, and its accessibility is crucial at every stage of growth, especially during seed and fruit development. Due to its impact on plant metabolism, cell membranes, and cell wall structure, boron has also contributed to lowering disease severity in certain crops (Dordas, 2009).

According to Fageria and Barbosa (2006), boron is a necessary micronutrient for plants, and their need for this nutrient is lower than that of all other micronutrients, with the exception of copper and molybdenum. It is the only non-metal among the micronutrients and the only one that exists as a neutral molecule rather than an ion over a wide pH range (Epstein and Bloom, 2005). According to Ahmad *et al.* (2014), the amount of boron in the soil solution, rather than the overall boron content of the soil, regulates how plants absorb boron. The meristematic tissues experience cambium cell hypertrophy, degeneration, and disintegration as a result of the boron deficiency. Boron also contributes significantly to cell division, hormonal action, nitrogen metabolism, and the processes of flowering and fruiting (Nonnecke, 1989). Boron has also contributed to lowering disease severity in plants due to its effects on cellular walls, cell membranes, and plant metabolic processes (Dordas, 2008). Plants take up boron as boric acid, which may be readily leached from soils. Zinc is the most significant micronutrient limitation in crops worldwide, but B deficiency has been identified as the second most important. It aids in plants' carbohydrate metabolism, water absorption, and carbohydrate translocation (Haque *et al*., 2011).

2.8. Effects of NPSBZn Combined Fertilizers on Tomato Fruit Quality

2.8.1. Effects of Nitrogen on Tomato Quality

Some early nitrogen fertilizers were required for improving quality in young seedlings according to Bos Land and Votava (2000). Nitrogen fertilization impacts quality and vegetative growth because it is related to enhancing photosynthetic source capacity (Tei *et al.*, 2002). Since excessive nitrogen can cause an excess during the vegetative stage, growers typically try to limit their nitrogen application.

In fact, it leads to low-quality products by causing a delay in fruit development, reducing yields, increasing disease and insect damage, and producing poor flower development, fruit set, and fruit size. It also promotes vegetative growth over reproductive growth. To enhance

fruit quality, nitrogen (N) levels are increased during fruit set and throughout reproductive growth (Bos land and Votava, 2000).

2.8.2. Effects of Phosphorus on Tomato Quality

Phosphorus, another macronutrient vital to plants, is needed in far lesser amounts than nitrogen, according to Heuvelink (2005). It is linked to early root growth and quality, particularly when phosphorus levels are low. Additionally, it has been demonstrated to impact the quantity and quality of seeds and flowers. One of the most noticeable signs is that the leaves' color changes from dark green to purplish, typically beginning with the older leaves. Conversely, an excess of phosphorus is linked to a deficiency of micronutrients such as zinc, copper, and iron. The ability of tomato plants to photosynthesize is impaired by a lack of phosphorus. This particularly impacts fruit quality by decreasing stomatal opening, especially at temperatures that are lower than ideal (Zhou *et al*., 2009).

2.8.3. The Effects of Sulfur on Tomato Quality

Sulfur an essential plant nutrient necessary for the production of the amino acids cysteine methionine, enzymes and proteins. It is crucial for the quality and yield of agricultural products. The element exists in the soil as both organic and inorganic forms. More than 90% of sulfur (S) in most soils is composed of various organic forms (Tei *et al*., 2002). Although small amounts can be taken in through leaf stomata as the gas forms, the majority of plants absorb S through their roots as an inorganic sulfate form. Sulfur deficiency is frequently mistaken for other deficient elements, such as nitrogen. It has been proposed that sulfur fertilizer rates be recommended based on the available S in the soil and the requirements of the crop in order to reduce S leaching and achieve high yields. The same research found that pre-plant sulfur application resulted in lower leaf sulfur levels than treatments where sulfur was delivered via drip irrigation, and that fine sandy soils were ineffective at providing sufficient sulfur for six weeks of growth (Susila, 2001).

2.8.4. The Effects of Zinc on Tomato Quality

Zinc is another crucial essential micronutrient that contributes to the formation of tryptophan, which is a precursor of IAA and is responsible for stimulating growth (Mallick and Muthukrishnan, 1980). Additionally, it is essential for the production of the carbonic anhydrase enzyme, which facilitates the transport of CO2 during photosynthesis (Alloway, 2008).

2.8.5. Effects of Boron on Tomato Quality

Another crucial nutrient for the high quality and abundant production of crops is boron (Dale and Krystyna, 1998). It plays a role in the synthesis and integrity of the cell wall, lignification of the cell wall, metabolism of RNA, carbohydrates, phenols, and indole acetic acid (IAA), as well as respiration and cell membrane integrity (Parr and Loughman, 1983).

Boron deficiency causes leaf drop and wilting, which negatively impact the quality of the yields of numerous vegetables, particularly tomatoes (Imtiaz *et al*., 2010). During the growing season, particularly at the reproductive growth stage (Sajid, 2009), both foliar and soil application can meet its needs for plants.

2.9. Effects of Variety on Yield and Quality Characteristics

The effect of variety on yield and quality has been established by Stevens *et al*. (1977). The yield of tomatoes is determined by the quantity and size of the fruit, and Balibrea et al. (1997) found a positive relationship between the two. According to Adedeji *et al*. (2006), significant quality parameters of tomato fruits, such as fruit size, volume, juice, specific gravity, and maturity, fluctuate with the cultivar type. Additionally, specific gravity, juice, and fruit size are particular to certain varieties and may be utilized to assess maturity stages and plan harvesting. According to Duguma (2000), the lack of flaws such as sunburn, cracks, blossom end rots, decays, and so forth is also a crucial factor in determining the marketable quality of tomatoes.

Numerous tomato varieties have been made available in Ethiopia for both small-scale farming and commercial production. Compared to the global average of 34 tons per hectare, Ethiopia's average tomato yield is low at 8 tons per hectare. This may be due to inadequate access to and utilization of improved commercial tomato varieties, poor production management, and lack of adaptation based on FAOSTAT (2012).

2.10. Interaction Effects of Fertilizer Type and Variety

Inorganic fertilizers significantly impact plant growth and yield, as well as promote improved soil activities, enhanced cell division and enlargement, and lush growth due to the availability of adequate plant nutrients (Fashina *et al*., 2002). Because of better nutrient and solar radiation usage, the lush growth that follows fertilizer application results in higher dry matter production (Obi *et al*., 2005; Saeed *et al*., 2001). According to Adediran and Banjoko (2003), the use of inorganic fertilizers increased crop yield.

The quality and quantity of fertilizers applied have a big impact on the yield and growth of vegetable crops, according to Chang *et al*. (2010). According to Lemma (2002), it is common practice to apply the national recommendations of 92 kg ha-1 P2O5 and 46 kg ha-1 nitrogen-containing fertilizers to all tomato varieties and at all sites. However, Baligar *et al*. (2001) demonstrated that there are significant differences among species or cultivars of the same species in their ability to absorb, translocate, and utilize mineral nutrients. Additionally, adopting a "low-input" strategy to address soil fertility issues in crop production necessitates a considerable reduction in fertilizer usage and the selection of genotypes with high nutrient use efficiency (Sorgona *et al*., 2006). Moreover, growing tomatoes can be difficult because the fruit itself must satisfy specific market standards. Consumers' preference is influenced by three factors: flavor, firmness, and physical characteristics (color, size, shape, imperfections, and decay) (Nzanza, 2006).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was carried out in Cheha district's Wurerber Kebele, Guraghe zone (Figure 1). The experimental site is 25 kilometers from Wolkite, the Guraghe zone's capital, and 180 kilometers from Addis Ababa. The site's altitude and geographic coordinates are 1948 meters above sea level and latitude 8°10′N, and longitude 37°51′E. Silt loam is the area's soil type (CWADO, 2023).

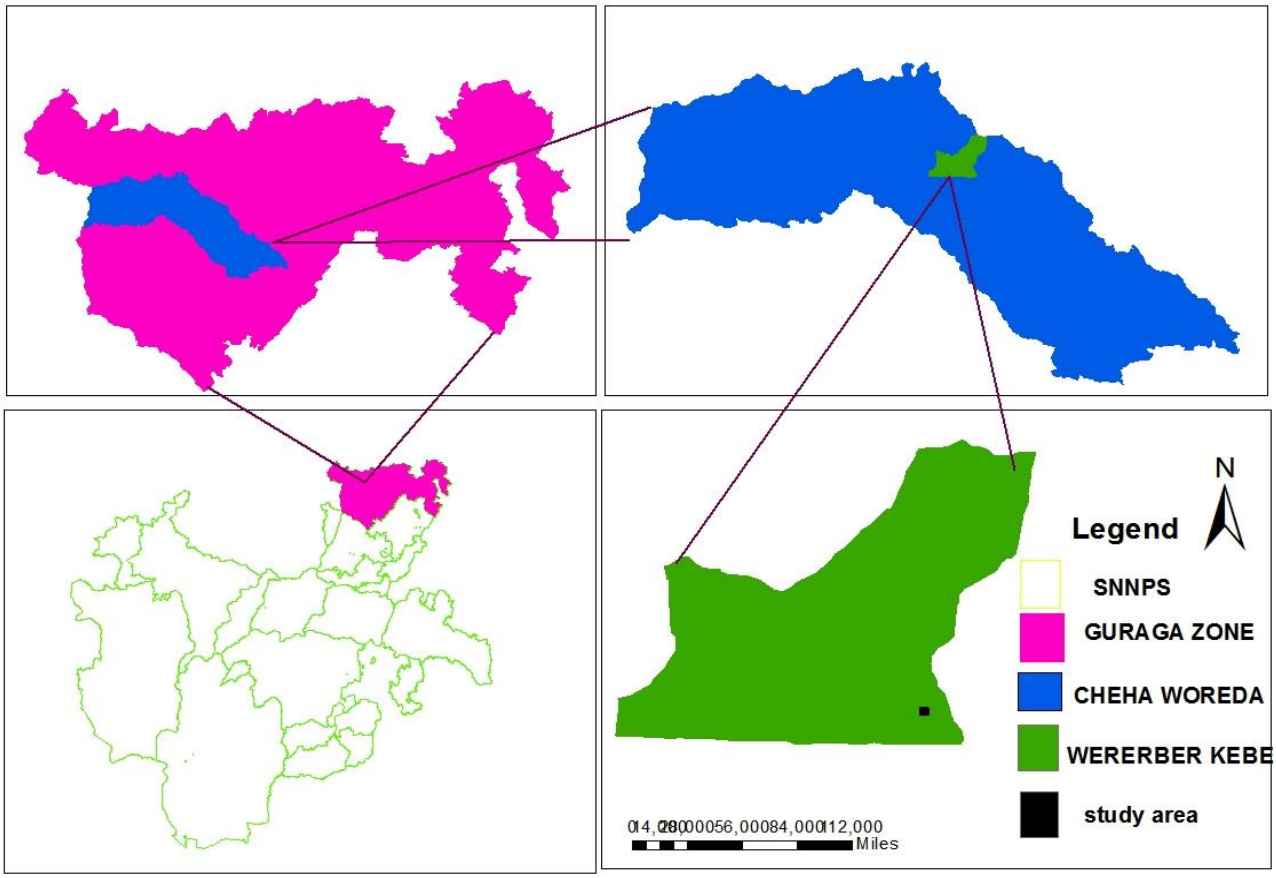

Figure 1.Map of the study area

3.2. Climatic Condition of the District

The rainfall and temperature conditions depend on elevation like other parts of Ethiopia. Based on the evidence of Ministry of Agriculture (MoA) (1998), the agro ecology of Cheha district was classified into three traditional agro-ecological zones. These agro-ecological zones include Dega or highlands (2300–3200 m.a.s.l), Weyna Dega or midlands (1500–2300 m.a.s.l), and Kola or lowlands (500–1500 m.a.s.l) (EIAR, 2011; Bereket *et al*., 2018 and Mohammod, 2016). According to CWADO (2025) the agro-ecology of the district was 20% Dega, 78% Wayna Dega and 2% is Kola.

The area receives bimodal rainy season (Belig and Mehir). Belig includes the month from March to May and the main rainy season (Meher), which accounts for around 70-90% of the total annual rainfall occurs from June to October. Two main distinct seasons, dry and wet seasons are recognized in the area. The 10 years mean annual rainfall of the district was about 1265.7 mm (Fig 2). The mean annual maximum and minimum temperatures were 27 and 7.9 °C, respectively (EMISCSSWERMSC, 2025).

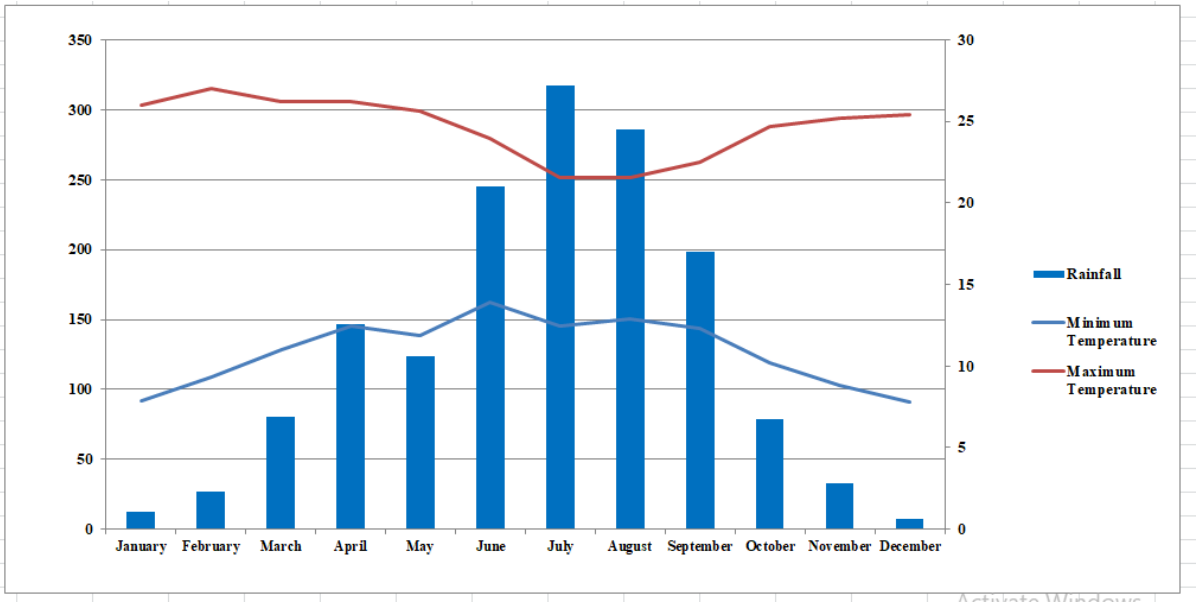

Figure 2**:** Mean monthly rain fall, maximum and minimum temperatures for 10 years of the study area.

Source: - Ethiopian Metrology Institute Sidama, Central, South and South West Ethiopian Region Metrology Services Center (EMISCSSWERMSC) for a period of (2015-2025).

3.3. The Experimental Materials

3.3.1. Planting Material

Planting materials of four nationally released tomato varieties (Chali, Melkasalsa, Melkashola, and Gelilema) were collected from Melkasa Agricultural Research Center and used for the experiment (Table 1).

Table 1: Descriptions of planting materials

Variety Name	Breeding Center	Years of release	Altitude (m.a.s.l)	Yield ton ha^{-1} (On research site)
Chali	MARC	2007	700-2000	35
Melkasalsa	MARC	1998	700-2000	32
Melkashola	MARC	1998	700-2000	43
Gelilema	MARC	2015	700-2000	46.3

Source: Regassa *et al*. (2012), Source: (MoANR, 2016)

3.3.2. Fertilizers

Four blended fertilizer types NPS (19.0% N, 38.0% P_2O_5, 7% S); NPSB (18.9% N, 37.7% P_2O_5, 6.9% S, 0.1% B), and NPSZn fertilizer with the ratio of 17.7% N, 35.3% P O, 6.5% S and 2.5% Zn and NPSBZn (16.9% N, 33.8% P2O5, 7.3% S, 0.67% B, and 2.23% Zn) was used.

3.4. Experimental Design and Treatment

The experiment was designed as a Randomized Complete Block Design (RCBD) with three replications and involved sixteen treatments, including four tomato varieties (Chali, Melkashola, Melkasalsa, and Gelilema) and four types of blended fertilizers (NPS, NPSB, NPSZn, and NPSBZn). The treatments were assigned factorially. The single plot size was 7.56 m^2 (4.2 m × 1.8 m), with a 70 cm distance between rows and 30 cm spacing between plants (EARO, 2004). Each plot contained 36 plants in total, with six rows and six plants in each row. Plots and blocks were spaced 50 cm and 1 m apart, respectively. The total experimental area was 486.42 m^2 and net experimental area was 328.32 m^2.

Table 2: **Varieties, blended fertilizer types and combination for the study area**

Treatment number	Varieties name	Blended fertilizer	Combinations
1	Gelilema	NPS	Gelilema x NPS
2	Melkashola	NPS	Melkashola x NPS
3	Melkasalsa	NPS	Melkasalsa x NPS
4	Chali	NPS	Chali x NPS
5	Gelilema	NPSB	Gelilema x NPSB
6	Melkashola	NPSB	Melkashola x NPSB
7	Melkasalsa	NPSB	Melkasalsa x NPSB
8	Chali	NPSB	Chali x NPSB
9	Gelilema	NPSBZn	Gelilema x NPSBZn
10	Melkashola	NPSBZn	Melkashola x NPSBZn
11	Melkasalsa	NPSBZn	Melkasalsa x NPSBZn
12	Chali	NPSBZn	Chali x NPSBZn
13	Gelilema	NPSZn	Gelilema x NPSZn
14	Melkashola	NPSZn	Melkashola x NPSZn
15	Melkasalsa	NPSZn	Melkasalsa x NPSZn
16	Chali	NPSZn	Chali x NPSZn

3.5. Experimental Methods

The experimental field was hand-tilled and prepared to prevent cobbles and ensure leveling. The treatment was assigned randomly to the experimental plots within block after the field design was created. The four tomato varieties' seedlings were grown in a well-prepared seedbed with better management to promote the seedlings' easy uprooting and later successful establishment in the field. Therefore, at roughly 35 days of growth (Lemma, 2002), in a state suitable for transplanting, seedlings were moved to the principal field of the experimental plots.

The rates of blended NPS, NPSB, NPSZn and NPSBZn fertilizers were determined by the national recommendation for DAP fertilizer, which calls for 200 kg ha-1 (92 kg, P2O5 ha-1) and 100 kg Urea ha-1 (46 N kg ha-1) (Lemma, 2002).

All other agronomic practices were consistently followed according to the crop's recommendations. The recommended 100 kg ha-1 of urea was applied in a split application, with 50% at planting and the remaining 50%, 45 days after transplanting (Lemma, 2002). Everything was done at planting time.

3.6. Cultural Practices

Cultural practices like weeding, hoeing, watering, staking, and managing diseases and pests were used consistently across all therapies to generate robust and healthy seedlings. Fungicide (Mancozeb and Ridomil) was administered to manage leaf blight and bacterial disease and (Tutan and Diazinol) was used for leaf miner during the study because incidence was noted.

3.7. Data collected

3.7.1. Soil Sampling and Testing

Prior to planting, soil samples were collected randomly from 5 (Five) locations in the experimental field at a depth of 20 cm and combined to create a soil composite. The composite soil samples were air-dried, crushed in a mortar, and sieved through a 2 mm sieve. A 1 kg portion of this mixture was taken for laboratory analysis at the Wolkite soil laboratory to determine soil texture, pH, organic carbon, total nitrogen, available phosphorus, boron, zinc, available sulphur and cation exchange capacity (CEC), following standard laboratory procedures (FAO, 2003).

3.7.2. Phonological Parameters

Days to 50% flowering: The number of days from transplanting to the point at which 50% of the plants in each plot had bloomed was recorded.

Days to 50% fruiting: The number of days from the transplanting date to the date when 50% of the plants in each plot bear fruit was recorded.

Days to maturity: was determined by counting the days from the transplant date until 50% of the plants in each plot first reached physiological fruit maturity. In other words, days to maturity was noted when about half of the plants in a plot reached their first harvest.

3.7.3. Growth Parameter

Plant height (cm): At flowering, the height of five randomly chosen plants was measured from ground level to the tip of the highest part in each plot.

3.7.4. Yield Parameters

Number of clusters per plant: The total number of clusters per plant was determined by counting those from five randomly chosen plants at full maturity.

Number of fruit per cluster: The total number of fruits per cluster was determined by counting the fruits from five randomly chosen plants at the fruit's red ripening stage.

Individual fruit size (grams): The average weight of five randomly selected fruits from five chosen plants in each plot was recorded.

Fruit diameter (cm): The diameter of three fruits of varying sizes (large, medium, and small) was measured with a caliper after being gathered from each chosen plant. The average diameter of a fruit was calculated by totaling the diameters of all the selected fruits and dividing that total by the quantity of fruits that were selected.

Marketable fruit yield (t ha^{-1}): was determined by weighing the total harvest of marketable fruits from each plot and calculating it in tons per hectare.

Unmarketable fruit yield (t ha^{-1}): was determined by weighing every harvest of unmarketable fruit. Fruits from each of the plots were computed in tons per hectare.

The total fruit yield (t ha^{-1}): was calculated by adding the weights of both marketable and Unmarketable fruit output and was switching to tons per hectare.

Total fruit yield = Weight of marketable fruits + Weight of unmarketable fruits

3.7.5. Fruit Quality

Dry weight (gm.): The percentage dry weight was calculated by reweighing the dried sample after randomly selecting five fruits from each plot and drying a chopped fruit at a constant weight of 70 °C. The dried sample was being re-weighted to calculate the percent dry weight.

Total soluble solid (%): The juice was extracted from three fruits that ripened simultaneously in each plot, and the amount of soluble solids in the juice was measured by placing a drop of the sample onto a refractometer.

Fruit pH: From each plot, three fruits that ripened simultaneously were gathered as a sample. The mean pH of the fruit was calculated by combining the pH of the three samples and dividing the total by the number of samples.

3.8. Partial Budget Analysis

To determine economically viable combinations of blended fertilizers (NPS, NPSB, NPSZn, and NPSBZn) and tomato varieties, the Partial budget analysis was carried out using the method outlined by CIMMYT (1988). Variable costs included the expense of blended fertilizer types, tomato variety, and the labor required for this task. The CIMMYT (1988) formula was used as the foundation for the net advantages and other economic analysis.

Adjusted Fruit Yield (AFY) (kg ha-1): The AFY was calculated as the average yield adjusted downward by 10% to account for the difference between the experimental yield and the farmers' yield.

Gross field benefit (GFB) in ETB ha-1: was calculated by multiplying the field or farm gate price that farmers receive for the crop when they sell it by the adjusted yield. The formula for GFB is as follows: GFB = AFY × field/farm gate price of the crop.

Total variable cost (TVC) (ETB ha-1): The TVC was determined by adding the costs that fluctuate, such as the cost of fertilizers at planting. The expenses of other inputs and production methods, including the labor costs associated with land preparation, planting, weeding, and harvesting, were viewed as constant across all treatments or plots.

Net benefit (NB) in ETB ha-1: For each treatment, NB was determined using the formula NB=GFB–TVC, where GFB is the gross field benefits and TVC is the total variable costs.

The marginal rate of return (MRR %): was determined by dividing the net benefit change by the cost change, which reflects the rise in return from boosting input.

3.9. Data Analysis

Data were analyzed using SAS software version 9.4 with Analysis of Variance (ANOVA) and the General Linear Model (GLM). When treatment effects were significant at the 5% probability level, means were separated using Duncan's New Multiple Range Test (DMRT). Correlation analysis for selected parameters was also carried out using Pearson simple correlation coefficient.

4. RESULTS AND DISCUSSION

4.1. Soil Sample Analysis

4.1.1. Soil Physical and Chemical properties

The soil particle size distribution of the experimental site was 24% sand, 51% silt, and 25% clay, Table 2. The soil was classified as silty loam textural class using the soil textural triangle of the International Society of Soil Science (Rowell, 1994).

The soil pH was 6.2, indicating that it was mildly acidic (Table 3) (Landon, 1991). According to Ogundare *et al*. (2015), the ideal pH range for growing tomatoes is between 6.0 and 6.5. According to Papadopoulos and Rendig (1983), fruits are smaller when soils are acidic or saline. The CEC value of 42.0 cmol kg^{-1} for the soils in the experimental plot places it in the high CEC category. The soil organic carbon content of 2.83% in the study area is in the very high range. The zinc content of the soil in the study area is very low at 0.2 ppm (Table 3).

Table 3: Soil physical and chemical characteristics of study area

Soil Properties	Values	Rating	Source
PH	6.2	Slightly acidic	Hazelton and Murphy (2016)
Organic Carbon (%)	2.83	Very High	Hazelton and Murphy (2016)
Available P (mg/kg)	10.5	Low	Hazelton and Murphy (2016)
CEC (cmol (+)/kg)	42.0	Very High	Landon (1991)
Available S (mg/kg)	20	Medium	Horneck et al, (2011)
Available B (mg/kg)	1.2	Optimum	Benton (2003)
Available Zn (mg/kg)	0.2	Very low	Benton (2003)
Particle size distribution			
Sand (%)	24		
Silt (%)	51		
Clay (%)	25		
Textural class		silt loam	Rowell (994)

P-phosphorous: CEC-cation exchange capacity: S –sulfur: B-boron Zn -zink

4.2. Days to 50% flowering

Analysis of variance showed that main effects of varieties and fertilizer were highly significant ($P < 0.01$) on days to 50% flowering however interactions effect is non-significant

(Appendix table 1). The longest days or delayed flowering (54.17 days) was recorded from Melkashola variety while the shortest days or early flowering (39.5 days) was obtained from Chali variety (Table 4). The range between the highest and lowest days to 50% flowering was about 14 days. This is to show that variety melkashola was late flowering but variety chali was early flowering type. All treatment combination of varieties and NPSBZn fertilizer delayed days to flowering as compared to all varieties grown with other fertilizer application. With fertilizer application, the longest (51.08) days to 50% flowering was recorded from NPSBZn fertilizer however, the shortest (45.08) days to 50% flowering was obtained from NPS fertilizer (Table 4). Days to flowering of tomato varieties significantly delayed at the NPSBZn might be attributed to the extension of the plants vegetative growth in response to the adequate or abundant supply of nutrients. is the result is in consistent with the finding of Parvej (2010) who reported that days to 50% flowering was one of the most important phonological parameters which is determining factors for growth and productivity of tomato crop. The result revealed that tomato varieties tested had showed differences in relation to days to 50% flowering. Such differences in days to 50% flowering among varieties could be associated to genetic attributes which further could impact crop maturity and fruit yields. This idea is also in agreement with report of Abdelmageed and Gruda (2009) who explained that difference in days to 50% flowering could be due to the genetic makeup of the varieties. In addition, early as well as late flowering situations have their own effect on fruit maturity as well as fruit yield of tomato.

The result is in line with the previous findings of Jasbir *et al.* (2018) who observed that the minimum days to a first flowering appearance on tomato can be obtained by the application of nitrogen and phosphorus and reasoned out that availability of boron and zink could be the factors for the difference. By reducing the sink strength of flowers in relation to vegetative tissues, NPSBZn fertilizer promotes vegetative growth and may have delayed reproductive development. Additionally, boron may be crucial for the flowering and fruit development of tomatoes (Nonnecke, 1989; Naz et al., 2012). According to Sainju *et al*. (2003), an excessive nitrogen level in the soil led to too much vegetative growth, which in tomatoes delayed flowering, fruit setting, and maturity.

4.3. Days to 50% fruiting

Days to 50% fruiting was significantly (P<0.01) influenced by the main effects of varieties and blended NPS fertilizer respectively, the interaction effect is non-significant (Appendix table 1). The delayed fruiting (66.67days) to 50% fruiting were recorded from melkashola variety while the earliness (59.58days) to 50% fruiting were obtained from chali variety (Table 4). The range between the highest and lowest days to 50% fruiting was about 5 days. This is to show that variety melkashola was late flowering but variety chali was early fruiting type.

on the other hand, the delayed for 50% fruit setting was recorded from NPS fertilizer while earliness (60.17) days recorded from plots treated with NPSZn fertilizer application All treatment combination of varieties and NPSBZn fertilizer delayed days to flowering as compared to all varieties grown without fertilizer application. The delayed days to flowering intensified as the rates of NPSBZn fertilizer increased with all varieties combinations.

Similar research findings had reported by (Sainju *et al.,* 2003; Edossa *et al,* 2013) and Jasbir *et al.* (2018) who reported that the minimum days to fifty percent fruiting were observed in the application of 162 kg/ha nitrogen and 62.5 kg/ha phosphorus because higher content of nitrogen accelerated protein synthesis, photosynthesis and carbohydrate production which promotes earlier floral primordial development. Similar to the present results, Nanadal et al. (1998) showed that the effect of four levels of each phosphorus and potash with tomato showed that increasing levels of phosphorus up to 50 kg P2O5 and potash up to 80 kg K2O/ha had improved days to 50% fruit set. The stimulating effect of nitrogen and phosphorus on vegetative growth, which forms the base for an early set of 50% fruiting (Aminifard et al.,2012). The result of this experiment is similar with the findings of (Ketema, *et al*., 2016) who had reported existence of variation for fruit setting among nine tomato cultivars. (Amjad *et al.,* 2001) had also suggested that the observed difference among tomato varieties could be genetic makeups of the cultivars.

4.4. Days to maturity

Analysis of variance showed that main effects of varieties and fertilizer a highly significant (P < 0.01) variation on days to maturity interaction is non-significant (Appendix table).The longest (93.25) and shortest (70.00) days to maturity was recorded for Melkashola and Chali varieties respectively (Table 5). The range between longest and shortest days to maturity was

23 days and this is showing that variety chali was early maturing type whereas variety melkashola was late maturing.

For blended fertilizer application, the longest (89.74) days and shortest (74.25) days were recorded from plots treated with NPSBZn and NPS respectively (Table 4). The earliest variety for flowering, and maturity had more number of harvests than varieties had delayed flowering, fruit setting and maturity. The observed difference due to the main effect of variety was mainly attributed to the genetic makeup of the cultivar (Amjad et al., 2001). The result was in line with the previous works of (Moraru *et al.,* 2004; Fayaz *et al.,* 2007; Abrar *et al*., 2011) that observed first harvesting period of 70-120 days after transplanting.

Delayed days to maturity of varieties because of the application of NPS fertilizer might be due to excess supply of N, P and S to plants that resulted in excessive vegetative growth and probably delayed reproductive growth by decreasing sink strength of flowers relative to vegetative tissues. The same concept has been reported that high N level, higher rates of P and application of S can promote excessive vegetative growth which can delay the setting and maturity of tomato fruits (Sainju *et al.,* 2003; Edossa *et al,* 2013). Lohar and Peat (1998) reported that the delay in flowering can correspondingly lead to the delay of fruit maturity in tomato.

4.5. Plant Height

The analysis of variance showed a highly significant effect ($P < 0.001$) for both variety and fertilizer types on plant height but interaction effect was non-significant (Appendix table 1). The mean value indicated that tallest plant height (67.69cm) was recorded from Melkashola variety while the shortest plant height (43.98cm) was obtained from Chali Variety. The tallest (60.37 cm) and shortest (51.98cm) mean of tomato were recorded with NPSBZn and NPSZn application respectively (Table 4). The possible reason for this result could be due to the variation in genetic makeup or cell division rate that result in change in plant height of different varieties. Abdul et al. (2014) also reported that tallness in wheat plants is mostly associated with the genetic makeup of the variety.

The findings of the current study are consistent with those of Meseret *et al*. (2012), who reported a mean plant height between 40.20 cm and 51.7 cm, and Masho *et al*. (2016), who reported a mean plant height between 115.5 cm. The observed variations may be attributed to the blended fertilizer's nutrient source, which contained boron and sulfur. These elements

play a crucial role in cell division and nitrogen absorption from the soil, both of which contribute to improved plant growth and, ultimately, increased plant height. NPSBZn promote vegetative growth.

The observed improvement of plant height due to the application of inorganic soil amendments might be by improving the soil physical, chemical and biological properties and leading to the adequate supply of nutrients to the plants which might have promoted the maximum vegetative growth. This might be because of the ability of nutrient to supply numerous plant nutrients and in creating suitable plant growing environment by improving moisture and nutrient condition of the soil which enhance growth and general performance of the plants. Due to the fact that nitrogen is an essential component of protein therefore a fundamental building material of the cells, as a constituent of all enzymes, which are specialized protein, nitrogen is involved in metabolic processes throughout the plant, as the result the plant grow vegetative very well with added N fertilizer. The possible reason for this result could be due to the variation in genetic makeup or cell division rate that result in change in plant height of different varieties.

Table 4: Man effects of tomato variety and fertilizer on days to 50% flowering, days to 50% fruiting, days to maturity and plant height

Treatments		Parameters			
		Days to 50% flowering	Days to 50% fruiting	Days to maturity	Plant height(cm)
Varieties	Melkashola	**54.17^{a}**	**66.67^{a}**	**93.25^{a}**	**67.69^{a}**
	Melkasalsa	53.08^{a}	65.58^{ab}	80.83^{b}	56.32^{b}
	Gelilema	46.58^{b}	63.66^{b}	73.83^{b}	59.87^{b}
	Chali	39.50^{c}	59.58^{c}	70.00^{c}	43.98^{c}
Fertilizer	NPS	45.08^{b}	**66.25^{a}**	**89.08^{a}**	57.66^{a}
	NPSB	46.17^{b}	65.5^{ab}	81.25^{b}	57.86^{a}
	NPSBZn	**51.08^{a}**	63.5^{b}	79.33^{b}	**60.37^{a}**
	NPSZn	51.00^{a}	60.17^{c}	74.25^{c}	51.98^{b}
CV (%)		6.07	4.8	5.9	7.69

Means followed by the same letter in a column are not significantly different at 5% probability level

4.6. Number of cluster per plant

The analysis of variance showed that the interaction effect of variety and blended fertilizer significantly (P≤ 0.001) influenced number of clusters per plant (Appendix table 2). Even though, most of the mean values statistically similar, highest (26.3) cluster number per plant was observed in Gelilema variety treated with NPS fertilizer while least value of (18.4) from Melkasalsa variety with NPSZn fertilizer (table 5).

The production of clusters is one of the major factors that determine fruits yields in tomato varieties (Pandey, 2006) and flower per cluster helps to estimate the potential of fruit set of certain variety or a given treatment. The fruit set percentage is the actual potential of tomato plants to produce mature fruits from developed flowers per cluster. Thus the treatments affecting the production of clusters per plant and flowers per cluster also affected the mature fruits harvested from clusters. Number of clusters per plant and fruit yields of tomato had positive relationships (Meserat *et al*., 2012).

The greater number of clusters per plant observed in those treated with NPS fertilizer with gelilema varieties may be related to the sufficient presence of vital nutrients (N, P, and S), which promote the tomato plants' overall growth and development. In particular, the increased P content of NPS fertilizer probably encouraged flower bud development, which in turn increased the number of clusters per plant. This finding aligns with Solaiman and Rabbani's (2006) observation that tomatoes receiving a full dose of NPS fertilizer had the highest number of clusters per plant, averaging 23.48. These findings validate the Gelilema variety's superiority over the Chali variety in terms of the number of clusters produced each plant. The higher numbers of cluster per plant also the higher numbers of fruit per cluster is gelilema variety interacted with NPS blended fertilizer.

4.7. Number of fruit per cluster

The analysis of variance revealed that the number of fruits per cluster was significantly influenced (P ≤ 0.001) by tomato varieties, blended fertilizer and Varity and fertilizer (Appendix table 2). The highest number of fruits per cluster (5.95) was recorded in the Gelilema variety, while the lowest (3.37) number was obtained in Chali variety (table 5). This difference is might be due to the genetic make-up of the varieties or their response to the applied nutrients. The higher the number of fruits per cluster the more fruit yield is expected, although fruit size also determines the yield estimation (Pandey *et al*., 2006).

The number of fruits per cluster is a key yield component in tomato, since the fruit yield increases with increasing number of fruits per cluster. This finding aligns with Pandey (2006) who expressed an increase in the number of fruits per cluster leads to more fruit yield. Kibiru *et al*. (2018) had also reported a significant variation in the number of fruits per cluster due to varietal differences. Comparable results were also reported by Saleem *et al*. (2013), Chernet *et al*. (2013), and Ketema *et al.* (2021). The higher number of flowers per cluster, number of fruits per cluster and fruit set percentage observed in plants that received higher amount of mineral nutrients from higher rates of NPS fertilizer might be attributed by the faster enhancement of vegetative growth and storing sufficient reserve food materials for differentiation of buds into flowers thereby flowers to produce fruits.

According to reports, tomato plants that received the most inorganic fertilizers produced the most fruits every cluster, whereas those that received no fertilizers produced the fewest fruits (Fiseha, 2014; Rodge and Yadlod, 2009; Poul *et al*, 2004; Naidu *et al*., 2002).

It might be due to the vigor of the plant by uptake and utilized soil nutrients for vegetative and reproductive growth. Increasing fruit number with increasing levels of nitrogen along with phosphorus is probably because nitrogen is the element to be absorbed in a larger quantity of plants of the Solanaceae family (Campos *et al*., 2008) which were in agreement with the findings of Oliveira *et al*. (1999) who stated that nitrogen is fundamental of growth and development of plants.

Mishra and Singh (2006) also reported that the application of 180kg N/ha produced the highest number of fruits per plant, thus nitrogen treatment in increasing levels improved the yield and yield attributing characters of tomato. Phosphorus treatment in increasing levels also improved the yield and yield attributing characters thus, application of 80kg P/ha produced the highest number of fruits per plant (Poulton *et al*., 2001).

This result supports the finding of Yahaya, *et al*. (2015) who found that more number of fruits plant-1 was recorded with the combined application of 10 t ha^{-1} organic manure with inorganic fertilizer. Similarly, these results are in agreement with the findings of Alabi (2006) who observed that P treatments significantly increased the number of fruits per plant. This result confirms with that of Zekri and Obreza (2003) who stated that higher concentrations of N and P may increase plant growth and fruit production due to their effects

in many aspects of plant growth and development including photosynthesis and carbohydrate production, ultimately resulting in increased fruit number per plant.

Table 5: Interaction effects of tomato variety and blended fertilizer on number of cluster per plant and number of fruit per cluster

Varieties	Fertilizer	Parameters	
		number of cluster per plant (no.)	Numbers of fruit per cluster(no.)
Gelilema	NPS	**26.3^{a}**	**5.95^{a}**
	NPSBZn	25.08^{ab}	4.38^{c}
	NPSB	24.5^{ab}	5.22^{b}
	NPSZn	23.5^{abc}	3.40^{f}
Melkashola	NPSBZn	**25.4^{ab}**	**4.30^{cd}**
	NPS	24.8^{ab}	4.16^{b}
	NPSB	23.8^{ab}	5.22^{b}
	NPSZn	22.8^{ab}	3.63^{ef}
Melkasalsa	NPSB	**24.6^{ab}**	**4.67^{bc}**
	NPSBZn	24.2^{ab}	4.38^{c}
	NPS	23.7^{abc}	5.45^{ab}
	NPSZn	18.4^{cd}	3.55^{f}
Chali	NPSB	**23.0^{abc}**	**4.10^{cde}**
	NPSBZn	20.5^{bc}	3.77^{def}
	NPS	20.2^{bc}	4.23^{cd}
	NPSZn	19.9^{b}	3.37^{f}
CV (%)		5.5	5.0

Means followed by the same letter in a column are not significantly different at 5% probability level

4.8. Individual fruit size

The analysis of variance indicated a highly significant effect ($P < 0.001$) due to the main effect of both variety and blended fertilizers on individual fruit size but interaction effect was non-significant (Appendix table 2). The largest fruit size (80.48gm) was recorded from Gelilema variety while the smallest fruit size (20.24gm) was obtained from Chali Variety.

The biggest (55.78 gm) and smallest (41.04 gm) fruit sizes were observed from NPS and NPSZn fertilizers, respectively (Table 6).The Gelilema variety and NPS blended fertilizer produced the biggest fruit size of all the tested types, according to this finding. This variation is caused by differences in genetic composition and how well organisms adapt to environmental factors. The finding confirmed Khan *et al*. (2017), who stated that the

beefsteak tomato group's fruit size was far larger than that of the cherry group. Similarly, Chernet *et al*. (2013) and Dufera (2013) found considerable differences in fruit weight among 21 and eight tomato genotypes, respectively. Similarly the use of NPS fertilizer increased photosynthetic activity, which in turn promoted plant growth and the formation of flower buds, resulting in the production of fruits with a larger size, as reported by Fandi *et al*. (2010) and Fiseha (2014). It might be due to that nitrogen and phosphorus rate has a positive effect on the fruit weight of tomato crop. Hence, nitrogen has a pronounced effect on the growth and development of tomatoes. Ruiz and Romero (1998) were also suggested that nitrogen fertilizer can increase the fruit mean weight of tomato crops. Similarly, Tesfaye (2008) indicated that increased rates of nitrogen and phosphorus had a significant effect on the yield performance of tomatoes.

4.9. Fruit diameter

The statistical analysis of variance indicated a very highly significant ($P < 0.001$) variation was observed among tested varieties and blended fertilizer types in fruit diameter but the interaction effect was non-significant (Appendix table 3). As a result, the highest measured fruit size (5.52cm) was recorded in Gelilema variety and the smallest fruit diameter was 3.74cm that of chali. The variation is in genetic makeup the Varity, environmental or soil factors.

In case of fertilizer types the largest fruit diameter (5.10cm) was obtained from NPS blended fertilizer and the smallest (4.38cm) from NPSZn blended fertilizer (Table 6). This idea was In line with current results, Salim *et al.* (2018) reported that fruit diameter varied among the genotypes significantly and ranged from 3.63 to 8.15 cm.

Yesmin *et al*. (2014) and Balcha *et al.* (2015) also noted similar trends in fruit diameter, observing a significant range of 3.64 to 5.71 cm in winter tomato cultivars. Jasbir *et al*. (2018) found that the maximum fruit diameter (53.85 mm) was achieved with the application of NPS fertilizers, which enhanced plant vigor by allowing for the absorption and use of soil nutrients for both reproductive and vegetative development.

Table 6:Main effect of variety and blended fertilizer on Individual fruit size and Fruit diameter

Treatments		Parameters	
		Individual fruit size (gm)	Fruit diameter (cm)
Varieties	Gelilema	**80.48[a]**	**5.52[a]**
	Melkashola	55.21[b]	5.15[b]
	Melkasalsa	38.62[c]	4.54[c]
	Chali	20.21[d]	3.74[d]
Fertilizer	NPS	**55.78[a]**	**5.10[a]**
	NPSB	50.51[ab]	4.85[ab]
	NPSBZn	47.17[b]	4.57[bc]
	NPSZn	41.04[c]	4.38[c]
CV (%)		14.8	8.5

Means followed by the same letter in a column are not significantly different at 5% probability level

4.10. Marketable fruit yield

The analysis of variance revealed that the varieties, blended fertilizers, and the interaction between variety and fertilizer type had a very highly significant effect ($P < 0.001$) on marketable fruit yield (Appendix table 2). The Gelilema variety with NPSB blended fertilizer produced the highest marketable fruit yield (73.33 tones), while the Chali variety with NPSZn fertilizer had the lowest marketable fruit yield (31.54 tones) (Table 7). Marketable fruit yield was significantly and positively correlated with fruit number per plant and single fruit weight which indicates that, varieties with higher fruit number per plant and higher single fruit weight gives high marketable fruit yield (Regassa *et al*., 2016).

The observed result agrees with Ketema *et al*. (2021), who found that the marketable fruit yield of tomato varieties varied significantly. Tesfaye (2008) reported similar results, demonstrating that tomato yield performance on verti-soils was significantly affected by nitrogen and phosphorus. This increment of marketable and total tuber yield in the response to the increasing rate of blended NPSB fertilizer indicates that the importance of blended NPSB for growth and productivity of potato. Similarly, total tuber yield and marketable tuber

yield increased significantly as the rate of sulfur increased, probably due to sulfur‟s role in the synthesis of sulfur-containing amino acids, proteins, energy transformation, activation of enzymes which in turn enhances carbohydrate metabolism and photosynthetic activity of plant with increased chlorophyll synthesis (Juszczuk and Ostaszewska, 2011). Boron application showed a significant increase in yield in this study probably due to its role in the regulation of carbohydrate metabolism and its transport within the plant beside the synthesis of amino acids and proteins (Debnath and Ghosh, 2011).

The difference in yield among this varieties and blended NPSB fertilizer might be related to their genetic makeup in the efficient utilization of inputs like nutrients, which is one of the four major categories of the factors that affect yields (soil, climatic, genetic and management practices) as reported by (Tisdale *et al*.,1995).

The current finding demonstrates the beneficial impact of fertilizer on marketable yield, consistent with the worldwide consensus that nutrients, particularly nitrogen and phosphorus in any form, should be added to increase yield. Previous research has demonstrated that adding nutrients to deficient soils increases marketable yield (Mensa, Mohammed, and Woldetsadik 2021). Similar findings to File and Tujuba (2021), the increased marketable yield seen with relatively high levels of micronutrients, such as boron, may be related to boron's role in energy production, protein synthesis, nucleic acid synthesis, and carbohydrate and lipid metabolism, all of which contribute to improved marketability.

Similarly, Increase in the number of marketable tubers might be due to application of boron and sulphur in soil increase the uptake of N and P which improves the N: S and IAA: ABA and cytokinin: ABA ratio, which induces the formation and growth of stolon mainly due to increase in gibberellin content of plant (Mohammad *et al*., 2013).

This might be due to the positive interaction and complementary effect between nitrogen, phosphorus, sulphur and boron in affecting and increasing the marketable tuber yield of potato. This increment of marketable yield in the response to increasing rate of blended NPSB fertilizer indicates that the importance of blended NPSB for growth and productivity of potato. This might be due to boron and sulphur contents of blended fertilizer fulfills the requirement of sulphur and boron in subsurface zone of soil which improves uptake of other macro and micronutrients resulting in enlarged potato tubers (Sud *et al*., 1996).

4.11. Unmarketable fruit yield

Tomato variety had a highly significant ($P \leq 0.001$) effect on unmarketable yield, as shown by the analysis of variance, with no significant effect from the type of fertilizer and interactions of both varieties and fertilizer types (Appendix table 2). The mean value indicated that highest unmarketable yield (5.8 t ha^{-1}) and lowest (3.87 t ha^{-1}) were recorded from varieties Chali and Gelilema respectively (Table 8).

This result is in line with finding of (Diriba and Tilaye, 2020); the mean values of unmarketable yields due to fertilizer types (NPS, NPSB and NPSZn) were not statistically different from each other. According to Lemma (2002), sun burnt, small sized cracked disease and insect pest damaged fruits are considered as unmarketable.

4.12. Total yield (ton/ha)

The total yield of tomatoes was significantly affected ($P < 0.01$) by the main effects of variety, application of mixed fertilizer types and interaction effect was significant according to an analysis of variance (appendix table 2). The mean values of varieties showed that maximum yield of (76.6) t ha^{-1} which is obtained from the interaction of gelilema Varity with NPSB fertilizer types and minimum value of (38.3) t ha^{-1} were recorded from Chali variety interacted with NPSZn fertilizer (Table 7). This agrees with the results of Ketema et al. (2021), who found that the fruit yield of tomato varieties differed significantly ($P\leq 0.001$). Variations in total fruit yield between cultivars may be attributable to differences in genetic potential. Variety Gelilema discovered an indeterminate tomato type through field observations and exhibited a persistent growth and fruiting behavior.

Comparing the role of fertilizer types on total yield, the highest total fruit yield (76.6t ha^{-1}) was recorded from NPSB fertilizer application where least yield of 38.3 t $ha^{-1}$was obtained from NPSZn fertilizer (Table 4). The increase in total tuber yield in response to the increased application of the combined NPSB fertilizers might be due to the increased photosynthetic activity and translocation of photosynthetic product to the root, which might have helped in the initiation of more stolen on potato (Annad and Krishinapp, 1989). In accordance with this study result, Arega (2018) also reported that further increase in the rate of blended the fertilizer NPS from 150 to 200 kg ha-1 increased the total tuber yield of the crop.

The result is consistent with Biswas *et al*. (2015), who found that applying a high rate of inorganic fertilizer produced the greatest total tomato fruit yield. Moreover, the highest total

fruit output for tomatoes was seen by Manoj *et al*. (2013) when NPS was used. Biramo *et al*. (2019) also noted that the greatest total fruit yield for tomatoes came from the use of nitrogen and phosphorus.

4.13. Dry weight

Analysis of variance revealed that the varieties, fertilizer and interaction effect of the Varity, fertilizer types and interaction effects showed that highly significant ($P < 0.01$) effect on dry matter content (Appendix table 3). The mean values indicated that maximum (10.12gm) dry matter was recorded when Melkashola variety treated with NPS fertilizer while the smallest dry matter (6.54 gm) obtained from Melkasalsa variety treated with of NPSZn fertilizer(Table 7).

Dry matter content in potato tubers depends on the environmental condition and their changes. However, the highest possible amount of dry matter is limited by genetic characteristics of the potato variety (Tesfaye *et al*., 2012). It also influenced by a wide range of factors that affected the growth and development of the crop including most importantly, environmental factors such as intercepted solar radiation, soil temperature, available soil moisture and cultural treatments (Storey and Davies, 1992). Singh *et al*. (1995) found significant increase in dry matter content in potato tuber with sulphur application. The maximum dry matter content of tubers was recorded at the integrated use of farm yard manure with mineral NP each (Pervez *et al*., 2000 as cited in Biruk ., 2015). Desta (2018) report that sulphur fertilization increased yield of potato tubers and improved tuber quality increased (content of protein, starch, carotene, vitamin C, macro and microelements).

In agreement with the current result, Alemayehu and Jembere (2018), had conducted experiment in potato varieties and blended fertilizer and reported that, significant variation in dry matter contents when applied with NPS. the observed differences could be resulted due to the syenergetic effects of the fertilizer and varieties and also could associated with high levels of irradiance, temperature, fertilization and other cultural practices as reported by (Ewing, 1997). This result is in line with the findings of Tesfaw *et al*. (2013) who revealed that plants with better stands and good vegetative growth showed better fruit dry matter percent. The same author reported that the positive correlation coefficients of growth and yield parameters with fruit dry matter indicated that fruits which are longer, wider, and having relatively larger number of fruits resulted in higher fruit dry matter.

Table 7: Interaction effect of variety and fertilizer types on Marketable fruit yield, Total fruit yield and Dry weight

Varieties	Fertilizer	Parameters		
		Marketable fruit yield (ton ha^{-1})	Total fruit yield (ton ha^{-1})	Dry weight (gm)
Gelilema	NPSB	**73.33^{a}**	**76.6^{a}**	8.83^{abc}
	NPS	50.26^{cd}	54.2^{bc}	8.00^{abcde}
	NPSBZn	47.15^{cde}	51.5^{bcd}	**9.21^{ab}**
	NPSZn	42.25^{bcd}	46.6^{cdefg}	7.9^{cde}
Melkasalsa	NPS	**57.50^{b}**	**70.7^{a}**	**8.41^{abcd}**
	NPSB	53.42^{bc}	56.3^{b}	7.05^{cde}
	NPSBZn	46.38^{bcd}	49.4^{bcde}	**6.75^{de}**
	NPSZn	44.70^{cde}	47.1^{cdef}	8.01^{abcde}
Melkashola	NPSB	**48.06^{cd}**	**52.2^{bcd}**	8.22^{abcde}
	NPSBZn	42.25^{edf}	46.4^{cdefg}	7.9^{cde}
	NPS	41.42^{edf}	46.6^{cdefg}	**10.12^{a}**
	NPSZn	37.82^{sdf}	42.4^{efg}	8.01^{abcde}
Chali	NPSB	**38.65^{bcd}**	**45.2^{defg}**	6.54^{e}
	NPSBZn	35.57^{h}	40.9^{fg}	**9.53^{ab}**
	NPS	33.35^{ef}	39.4^{fg}	8.11^{bcd}
	NPSZn	31.54^{gh}	38.3^{g}	8.00^{abcde}
CV (%)		5.0	8.8	5.78

Means followed by the same letter in a column are not significantly different at 5% probability level

4.14. Total soluble solid

According to the statistical analysis of variance, the main effects of the blended fertilizer application and the varieties were highly significant but interaction effect was non-significant ($P < 0.01$) for total soluble solid (appendix table 3). The highest (6.76) total soluble solid was recorded from Melkashola variety which was statistically similar value (6.56) with Gelilema variety.

A total soluble solid (TSS) is very important quality character and degree of sweetness is determined by TSS. Total soluble solids were varied among varieties. It has been reported that total soluble solids increase with the colour and maturity of tomato varieties (Salunkhe et al., 2000) which is in agreement with the present result. An increase in TSS of tomato fruits could be due to excessive moisture loss which increases concentration as well as the hydrolysis of carbohydrates to soluble sugars (Nath *et al*., 2011). Consistent with recent findings, several researchers have proposed that differences in the TSS content of tomatoes are related to the genetic composition of the varieties (Caliman *et al*., 2010) and that they are caused by excessive moisture loss, which promotes the hydrolysis of carbohydrates into soluble sugars (Nath *et al*., 2011). In terms of fertilizer impact, the lowest TSS (5.53) was observed in plots treated with NPSZn, while the other fertilizer kinds generated statistically comparable values (Table 8).

Furthermore, according to Manoj *et al*. (2013), the highest TSS was produced by fertilizing with nitrogen, phosphorus, and sulfur. The application of NPS may have resulted in improved nutrients and phyto-hormones, which could explain this.

4.15. Fruit pH

Tomato variety had a major impact on acidity (pH). PH was significantly influenced by variety, however, the fertilizer and the interaction effects between variety and fertilizer were both insignificant (appendix table 3). The Melkashola and Melkasalsa types had the highest (4.19) and lowest (3.98) pH readings, respectively (Table 8).

The varieties had acidic fruits as Caliman *et al*. (2010) indicated that tomato fruit juices are categorized as acidic with the pH value generally less than 5. Low pH values of tomato juice are associated with high fruit quality which is accounted to the flavor and sourness of the fruits (Masho *et al*., 2016). The genetic makeup of a variety determines the pH of the fruits and thus the flavor and sourness of the fruits (Ram, 2005).The high fruit quality associated with the low pH of tomato juice is attributed to the fruits' flavor and sourness (Masho *et al*., 2016).

Table 8: Main effect of variety and blended fertilizer on unmarketable yield, Total soluble solid and pH

Treatments		parameters		
		Unmarketable yield (ton ha^{-1})	Total soluble solid (^{o}Brix.)	pH
Varieties	Melkashola	4.52^{b}	**6.76^{a}**	**4.36^{a}**
	Gelilema	3.87^{c}	6.56^{a}	4.15^{ab}
	Melkasalsa	3.02^{c}	5.89^{b}	3.81^{c}
	Chali	**6.16^{a}**	5.20^{c}	3.96^{bc}
Fertilizer	NPS	4.58^{a}	**6.38^{a}**	4.06^{a}
	NPSB	4.11^{a}	6.32^{a}	4.29^{a}
	NPSBZn	4.18^{a}	6.19^{a}	4.02^{a}
	NPSZn	4.69^{a}	5.53^{b}	3.92^{a}
CV (%)		16.47	7.2	8.0

Means followed by the same letter in a column are not significantly different at 5% probability level

4.16. Correlation Coefficient Analysis

The correlation coefficients clearly indicated that the crop parameter variables were related to one another. Table 9 presents the phenotypic correlation coefficient values between yield and its characteristics.

The correlation study's findings showed a strong positive correlation between 50% flowering and 50% fruiting ($P<0.001$; $r=0.65$). Days to maturity showed a highly significant positive correlation with 50% flowering ($r=0.67$) and 50% fruiting ($r=0.53$), with a significance level of $P<0.001$. Plant height was significantly correlated with 50% flowering ($r=0.36$*) and 50% fruiting ($r=0.23$) at $P<0.05$. The number of clusters per plant was negatively correlated with 50% flowering (-0.40*), 50% fruiting (-0.31*), and plant height (-0.30*), and negatively correlated with days to maturity ($r=-0.08$). In a similar vein, the number of fruits per cluster exhibited a negative correlation with 50% flowering (-0.09) and days to maturity (-0.02), as well as a positive correlation with 50% fruiting (0.09) and the number of clusters per plant ($r=0.23$). Plant height was also significantly correlated ($P<0.05$) with these variables. The

individual fruit size was positively correlated with 50% flowering, days to maturity, and the number of clusters per plant, as well as being highly significant (P<0.001) and positively correlated with the number of fruits per cluster. The marketable fruit yield was positively correlated with the number of fruits per cluster and individual fruit size, and it was also highly significant (P<0.001). Additionally, it was positively correlated with 50% flowering and days to maturity, and it was significantly correlated with plant height at 50% fruiting. However, the unmarketable fruit yield was negatively correlated with the number of clusters per plant and negatively correlated with 50% fruiting, plant height, and the number of fruits per cluster. The marketable fruit yield was also negatively correlated with 50% fruiting. The total fruit yield was highly significant (P<0.001) and positively correlated with the number of fruits per cluster, individual fruit size, and marketable fruit yield, while it was also highly significant (P<0.001) and negatively correlated with unmarketable fruit yield. Dry weight was positively correlated with plant height (r=0.09), number of fruits per cluster (r=0.03), and individual fruit size (r=0.04), and it was significantly and negatively correlated with 50% flowering (r=-0.34*). It was also negatively correlated with 50% fruiting (r=-0.07), days to maturity (r=-0.13), marketable fruit yield (r=-0.13), and total fruit yield (r=-0.10). The fruit diameter was highly significant (P<0.001) and positively correlated with the individual fruit size (r=0.91) and marketable fruit yield (r=0.57). It was negatively correlated with days to maturity (r=-0.04) and positively correlated with 50% flowering (r=0.12), 50% fruiting (r=0.2), the number of clusters per plant (r=0.14), and dry weight (r=0.46). The total soluble solids were highly significant (P<0.001) and positively correlated with the number of fruits per cluster (r=0.58).

According to Meseret *et al*. (2012), there was a highly significant and favorable relationship between the marketable fruit yield of tomatoes and the number of fruits per plant. Similarly, Wegayehu (2013) stated that there was a highly significant and positive association between the total fruit yield of tomatoes and the number of fruits and plant height.

Table 9: The correlation coefficient among different parameters of tomato

	FL	FR	DM	PLH	NCPP	NFPC	IFS	MFY	UFY	TFY	DW	FD	TSS
FL	1.00												
FR	0.65**	1.00											
DM	0.67**	0.53	1.00										
PLH	0.36*	0.23	0.49	1.00									
NCPP	-0.40*	0.31*	-0.08	0.30*	1.00								
NFPC	-0.09	0.01	-0.02	0.38*	0.23	1.00							
IFS	0.26	0.28*	0.10	0.53	0.16	0.57**	1.00						
MFY	0.09	0.31*	0.05	0.35*	-0.06	0.68**	0.60**	1.00					
UFY	-0.51	0.37*	-0.25	0.30*	0.39*	-0.40*	-0.47	-0.63**	1.00				
TFY	0.13	0.23	0.03	0.37*	-0.01	0.77**	0.63**	0.82**	-0.62**	1.00			
DW	-0.34*	-0.07	-0.13	0.09	0.50	0.03	0.04	-0.13	0.40	-0.10	1.00		
FD	0.12	0.20	-0.04	0.47	0.15	0.40	0.91**	0.57**	-0.41	0.52	0.11	1.00	
TSS	0.00	0.07	0.12	0.42	0.35*	0.58**	0.51	0.45	-0.16	0.40*	0.38*	0.42	1.00

Whereas, FL= days to 50% flowering FR= days to 50% fruiting DM= days to maturity PLH=plant height NCPP=numbers of cluster per plant NFPC=numbers of fruit per cluster IFS=individual fruit size MFY=marketable fruit yield UFY=unmarketable fruit yield TFY=total fruit yield DW=dry weight FD=fruit diameter TSS=total soluble solid

4.17. Partial Budget Analysis

To determine economically viable blends of fertilizers (NPS, NPSB, NPSZn, and NPSBZn) and tomato varieties, the Partial Budget Analysis was conducted following the CIMMYT (1988) methodology. Variable expenses included the cost of blended fertilizer types, tomato cultivar, and the labor required for this task. The CIMMYT (1988) formula was used to calculate the net benefits and other economic analyses.

According to the findings, the partial budget analysis showed that the treatment using the NPSB blended fertilizer and Gelilema varieties offered a favorable advantage compared to the other treatments (Table 10). The highest net benefit of 1,278,200 birr, with a marginal rate of return (MRR) that was acceptable at 5219.6%. The chali varieties with NPS blended fertilizer; however, had the lowest net benefit of birr 525940 ha^{-1}.

The identification of a recommendation was based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return. From the economic point of view, all the treatments which have a marginal rate of return are advantages; however, it was apparent from the results that treatments receiving NPSB with Gelilema variety were more profitable than the rest of the treatment combinations.

Table 10: Partial budget and marginal rate of return analysis effects of blended fertilizer types and varieties

Varieties	Fertilizer types	Average marketable yield (ton ha^1)	Average marketable yield (kg ha^1)	Adjusted marketable yield (kgha^1)	Gross Field benefit (ETB)	Total variable	Net benefit (ETB)	Marginal rate of return (%)
Chali	NPSZn	31.5	31547	28393	567852	305750	525940	0
Chali	NPS	33	33335	30002	600030	305308	558330	-
Chali	NPSBZn	35.6	35571	32014	640272	305447	598322	28771
Melkashola	NPSZn	37.8	37822	34040	680802	305750	638890	13389
Chali	NPSB	38.7	38655	34790	695790	305854	653990	14519
Melkashola	NPS	41.4	41416	37274	745488	305308	703788	-
Melkashola	NPSBZn	41.6	41575	37417	748345	305447	706395	1876
Gelilema	NPSZn	42.2	42248	38023	760470	305750	718558	4014
Melkasalsa	NPSZn	44.7	44702	40232	804630	305750	762718	-
Melkasalsa	NPSBZn	46.4	46380	41742	834834	305447	792884	-
Gelilema	NPSBZn	47.2	47150	42435	848700	305447	806750	-
Melkashola	NPSB	48.1	48069	43262	865248	305854	823448	4103
Gelilema	NPS	50.3	50263	45236	904728	305308	863028	-
Melkasalsa	NPSB	53.4	53415	48074	961470	305854	919670	10374
Melkasalsa	NPS	57.5	57495	51746	1034910	305308	993210	-
Gelilema	NPSB	73.3	73333	66000	1320000	305854	1278200	52196

5. CONCLUTION AND RECOMMENDATION

Tomatoes are a commonly cultivated vegetable crop in Ethiopia, produced by farmers for both fresh fruit and as a source of income for growers. However, the crop's productivity is low due to many constraints, the most significant of which is the use of improper fertilizers, regardless of soil and variety differences. The experiment was thus carried out to evaluate Yield and Quality response of tomato variety under various blended fertilizer types and to estimate tomato production in Cheha district. The experiment conducted four tomato varieties (Gelilema, Melkashola, Melkasalsa and Chali) were evaluated with the application of four blended fertilizer types (NPS, NPSB, NPSZn, and NPSBZn) in factorial combination in randomized completely block design replicated three times. The fruits quality related parameters were measured at Horticulture laboratory of Wolkite University.

According to the analysis of variance, a majority of the dependent variables were significantly affected by the variety, fertilizer type, and the interaction between the two.

Number of cluster per plant, number of fruit per cluster, dry weight, marketable fruit yield and total fruit yield are significantly interacted to varieties and fertilizers.

Using the Gelilema variety of NPSB fertilizers produced the highest average marketable yield of 73.3 tons per hectare. According to the partial budget assessment, the Gelilema Varity and NPSB fertilizers produced the highest net return of birr 1,278,200 and a satisfactory marginal rate of return of 5219.6%.

However, this study cannot provide a solid recommendation because the research only one season of work was done in one place. For additional recommendations, it is preferable to repeat the study in various agro-ecological conditions and seasons.

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7. APPENDICES

Appendix table 1: Mean squares from analysis of variance (ANOVA) for phonological and growth parameter

Source of variation	Degree of freedom	Mean squares values			
		FL	FR	DM	PLH
Replication	2	1.08	48.06	21.27	42.45
Varieties	3	550.72**	116.69**	1089.79**	1170.06.68**
Fertilizer types	3	119.72**	88.87**	454.96**	151.02.61**
Var.×Fer.	9	17.18^{ns}	14.87^{ns}	40.59^{ns}	32.86^{ns}
Error	30	8.6	10.9	6.5	10.6
F- value		14.79	12.5	12.44	13.31

Ns =Non-significant at 5% probability level * and ** indicates significant and highly significant at 5% and 1% probability level, respectively
FL= days to 50% flowering FR= days to 50% fruiting DM= days to maturity PLH=plant height var.= varieties Fer=fertilizers

Appendix table 2: Mean squares from analysis of variance (ANOVA) for yield and yield related traits of tomato

Source of variation	Degree of freedom	Mean squares values					
		NCPP	NFPC	IFS	MFY	UFY	TFY
Replication	2	0.64	0.082	267.6	41.69	1.28	8.29
Varieties	3	38.01**	1.25**	7862.4**	837.9**	21.14**	709.3**
Fertilizer types	3	23.44**	4.53**	458**	440**	0.98^{ns}	456.5**
Var.×Fer.	9	6.21*	0.59**	109.8^{ns}	105.6**	0.55^{ns}	163.1**
Error	30	1.58	0.05	15.37	5.2	0.5	13.46
F- value		8.65	27.19	29.96	55.3	8.31	15.3

Ns =Non-significant at 5% probability level * and ** indicates significant and highly significant at 5% and 1% probability level, respectively
NCPP=numbers of cluster per plant NFPC=numbers of fruit per cluster IFS=individual fruit size MFY=marketable fruit yield UFY=unmarketable fruit yield TFY=total fruit yield

Appendix table 3: Mean squares from analysis of variance (ANOVA) for quality of tomato

Source of variation	Degree of freedom	Mean squares values			
		DW	FD	TSS	PH
Replication	2	0.61	0.05	0.101	0.17
Varieties	3	5.24**	7.19**	6.07**	0.77*
Fertilizer types	3	2.29**	1.14*	1.82*	0.17^{ns}
Var.×Fer.	9	1.91**	0.19^{ns}	0.36^{ns}	0.11^{ns}
Error	30	0.22	0.16	6.2	0.11
F- value		10.79	8.3	8.16	2.34

Ns =Non-significant at 5% probability level * and ** indicates significant and highly significant at 5% and 1% probability level, respectively

W=dry weight FD=fruit diameter TSS=total soluble solid PH=power of hydrogen

Appendix table 4 Land and Seedling preparation in the experimental field

Appendix table 5: Management practices under taken in the experimental field

Appendix table 6: Harvesting and data collection


Block 1 Plot 6
Gerstema V/s NPSB

Appendix table 7: Quality test at Wolkite University Laboratory


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