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Growth, Yield and Yield Component Response of Tomato (Lycopersicon Esculentum Mill) to different rates of Organic and inorganic fertilizer at Ayehu Guagusa District, Awi Nationality Administration Zone, North Western Ethiopia

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Abstract

A field experiment was conducted at the Ayehu Guagusa District, Awi Nationality Administration Zone, North Western Ethiopia, during the 2024/2025 cropping season to determine optimum rates of organic and inorganic fertilizers for tomato production. The experiment comprised a 3 × 4 factorial combination laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatments consisted of three rates of farmyard manure (FYM: 0, 5, and 10 t ha^{-1}) and four rates of blended NPSB fertilizer (0, 100, 150, and 200 kg ha^{-1}). Data were processed using SAS version 9.3. The analysis of variance revealed highly significant ($P < 0.01$) main and interaction effects of blended NPSB and FYM on most growth, yield, and yield-related attributes. The highest total fruit yield (26.87 t ha^{-1}) was obtained from the combination of 200 kg ha^{-1} NPSB and 10 t ha^{-1} FYM, which was statistically identical to the application of 150 kg ha^{-1} NPSB combined with 10 t ha^{-1} FYM. Crucially, the maximum marketable fruit yield (24.37 t ha^{-1}) was achieved under the 150 kg ha^{-1} NPSB + 10 t ha^{-1} FYM treatment combination, while the control (unfertilized) plots produced the lowest marketable (4.63 t ha^{-1}) and total (5.30 t ha^{-1}) yields. Partial budget analysis corroborated these trends: the highest marginal rate of return (MRR) of 812.60% was achieved by the integrated application of 150 kg ha^{-1} NPSB and 10 t ha^{-1} FYM. Consequently, this specific treatment combination is recommended for smallholder production of the 'Melka Shola' tomato variety in the study area and analogous agro-ecologies.

1. Introduction

Tomato (*Lycopersicon esculentum* Mill. / *Solanum lycopersicum* L.) stands as one of the most widely grown and commercially viable vegetable crops across both global systems and smallholder production landscapes in Ethiopia (Melkamu *et al.*, 2022). Rich in vital dietary components, tomato serves as a premier source of minerals, carbohydrates, vitamins, amino acids, and potent antioxidants like lycopene and carotene varieties, which collectively promote human health and combat chronic physiological diseases (Alhrout et al., 2018).

Despite its profound economic and dietary value, the productivity of tomato in Ethiopia remains critically constrained. Contemporary agricultural assessments highlight severe challenges including continuous soil fertility decline, inadequate or unbalanced nutrient utilization, poor agronomic workflows, and escalating pest and disease pressures (Melkamu *et al.*, 2022). Throughout sub-Saharan Africa, and specifically within the intensive cropping blocks of Ethiopia, macro- and micronutrient balances remain profoundly negative due to historic reliance on low-efficiency, non-blended fertilizers (Tesfay et al., 2018).

Traditional localized management programs have focused heavily on standard blanket applications of nitrogen and phosphorus via Urea and Di-Ammonium Phosphate (DAP). This rigid regime neglects widespread sulfur (S) and boron (B) deficiencies inherent to these specific highly weathered regional soils (Tamene et al., 2017). Driven by these deficiencies, the Ethiopian Ministry of Agriculture introduced multi-nutrient blended matrices like NPSB to systematically substitute DAP across regional crop

ecosystems (Hailu et al., 2021). However, exclusive reliance on chemical fertilizers compromises soil physical structures and remains economically prohibitive for resource-poor smallholder farmers.

Integrated Plant Nutrition Systems (IPNS) which merge inorganic blended inputs with organic resources like farmyard manure (FYM) offer a robust strategy to stabilize soil aggregates, optimize cation exchange capacity, and supply long-term slow-release macro- and micronutrients (Laily et al., 2021). Because crop responses to blended inputs and organic manures are highly site-specific and depend strongly on baseline soil properties, localized validation studies are crucial (Tamene et al., 2017). Imbalanced feeding can severely harm yields: over-fertilization encourages succulent growth and field pathogen susceptibility, while under-fertilization leads to severe nutrient deficiency and unmarketable fruit development.

This study addresses these gaps by evaluating the spatial response of the 'Melka Shola' tomato variety within the specific environmental conditions of the Ayehu Guagusa District. Therefore, Application of optimum rate and kind (Organic and inorganic) of fertilizer with appropriate agronomic practices in the specific environment is necessary for obtaining a good yield of tomato. Depending on the above fact, it is essential to conduct location specific experiment to find out optimum and economic rate of NPSB (inorganic) and farmyard manure (organic) to get high yield of tomato for the study area.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted during the 2024/2025 cropping season within the Ayehu Guagusa District, located in the Awi Nationality Administration Zone of the Amhara Region, North Western Ethiopia. The district features a diverse landscape spanning approximately 68,432 hectares, bounded by coordinates 10°31'3"N to 10°50'59"N latitude and 36°36'50"E to 36°56'59"E longitude. Spanning an altitudinal range from 1,400 to over 2,000 meters above sea level, the district encompasses both lowland (Kolla) and mid-highland (Woina Dega) agro-ecological configurations.

2.2. Experimental Materials, Treatments and Experimental Design

The trial utilized the improved open-pollinated tomato variety 'Melka Shola', originally released by the Melkassa Agricultural Research Center. Blended NPSB fertilizer served as the inorganic nutrient input, composed of 18.9% N, 37.7% P_2O_5, 6.95% S, and 0.1% B. Decomposed farmyard manure (FYM), derived from local dairy cattle production matrices and stabilized using standard bedding structures, supplied the organic nutrient component. The experiment followed a 3 × 4 factorial scheme arranged in a Randomized Complete Block Design (RCBD) with three replications. Treatments crossed four blended NPSB levels (0, 100, 150, and 200 kg ha^{-1}) with three FYM levels (0, 5, and 10 t ha^{-1}), yielding 12 treatment combinations. Gross plots measured 3.0 m × 3.5 m (10.5 m^2), maintaining an intra-row

spacing of 30 cm and an inter-row spacing of 70 cm. The net harvesting zone was isolated to the middle rows (2.7 m × 2.8 m = 7.56 m²) to minimize plot boundary interactions.

2.3. Nursery and Experimental field management

Seedlings were raised on well-prepared, shaded nursery beds (1 m × 5 m). Standard watering, sanitation, and physical hardening-off regimes were applied systematically. Uniform, vigorous seedlings exhibiting 3–5 true leaves were transplanted late in the afternoon to minimize transpiration shocks. Chemical NPSB fractions were banded carefully along the rows during transplanting, while the designated FYM inputs were incorporated into the soil structure two weeks prior to transplanting. Standard regional weed, irrigation, and crop protection management protocols were applied uniformly across all blocks

2.4. Soil and Farmyard manure Sampling and Analysis

Prior to establishing the plots, composite soil cores (0–30 cm depth) were gathered across the experimental footprint to assess initial physicochemical baselines. Samples were processed and analyzed at the regional laboratory facility using standard analytical workflows. Farmyard manure samples were also dried, ground, and evaluated for key structural nutrient loads.

2.5. Data Collection

Phenological parameters (days to 50% flowering and days to 50% fruit setting) were documented on a whole-plot basis. Growth and yield-component traits: including plant height, primary branch count, leaf production, fruit numbers per plant, cluster counts, average fruit weights, and segregated fruit yields (marketable, unmarketable, and total yield sets) were collected from five randomly selected and tagged plants within the net plot areas.

2.6. Data Analysis

Data were evaluated using standard analysis of variance (ANOVA) protocols within SAS software version 9.3. Mean separations were performed using the Least Significant Difference (LSD) verification test at a 5% confidence probability threshold (P = 0.05).

2.7. Economic Analysis

Partial budget estimations were conducted following standard CIMMYT (1988) economic models. Total variable costs (TVC) incorporated prevailing local market prices for NPSB (35.76 ETB kg^{-1}), mechanical FYM preparation labor, and application labor (250 ETB per day). Gross benefits (GB) were computed based on a field gate price of 60 ETB kg^{-1} for marketable fruit, adjusting gross yields downward by 10% to mirror realistic smallholder losses. Marginal rates of return (MRR) were calculated for non-dominated treatments to identify the most economically profitable combination:

$$\text{MRR}\ (\%)\ = \frac{(\Delta \text{NB})}{(\Delta \text{TVC})} \times 100$$

3. Results and Discussion

3.1. Selected physicochemical property of the experimental soil

Baseline laboratory evaluations characterized the experimental soil as a heavy clay matrix (50% clay, 30% silt, 20% sand) with a slightly acidic pH value of 6.8, which fits within the optimal range for tomato nutrient uptake. Initial organic carbon (1.09%) and organic matter (1.88%) contents were low, indicating a clear need for organic amendments. Cation exchange capacity (CEC) was high (61.0 meq/100g), reflecting the high surface-charge densities of the dominant clay fractions (Hazelton and Nurphy (2007).

The analyzed FYM material displayed high nutrient qualities, containing 2.99% total nitrogen, 67.22% available phosphorus, and 2.56% available sulfur, verifying its suitability as a restorative soil amendment (Manjula *et al.*, 2012). Regarding the exchangeable bases, the value record from the study area for Calcium and Magnesium was 49.7 and 8.4 meq/100g of the soil respectively (Table 1). As per the rating set by FAO, the basic Cation record from the study area was classified as medium for Calcium and Magnesium (FAO, 2006). This might be due to leaching of surface soil by excessive rainfall. Total Nitrogen content of the study area was 0.12% (Table 1). According to Ethio SIS interpretation, the total Nitrogen content of the soil with in the ranges of less than 0.1, 0.1–0.15, 0.15–0.3, 0.3–0.5 and greater than 0.5 was rated as very low, low, medium, high and very high respectively (Ethio SIS, 2013). Regarding on this range, the total Nitrogen content of the study area falls under low range.

According to the rating of Hazelton and Murphy (2007), the soil of experimental site is clay textural classes, which is adequate for tomato production and total CEC of the testing site was high. Regarding farm yard manure the total Nitrogen, available phosphorous and sulfur were rated as high. Therefore, farmyard manure is adequate for supplying those listed essential plant nutrients for successful production of tomato.

Table 1
Physicochemical property of the experimental soil

Soil property	Value	Rating
PH	6.8	Slightly acidic
OC (%)	1.09	Low
OM (%)	1.88	Low
EC (bs/l)	0.64	Non-saline
CEC (meq/100g)	61.0	High
TN (%)	0.12	Low
AvP (ppm)	14.54	Deficient
AvS (ppm)	17.92	Deficient
Ca (meq/100g)	49.7	Moderate
Mg (meq/100g)	8.4	Moderate
C:N	9.08	Balanced
Textural fraction (Sand (%)/Clay (%)/Silt (%))	20/50/30	Clay textural class
Farm yard manure Characteristics TN (%)/AvP (%)/AvS (%)	2.99/ 67.22/ 2.56	High nutrient quality
Source: Injibara university Soil and Water laboratory		

3.2. Phonological parameters

3.2.1. Days to 50% flowering and fruit setting

The main effects of both chemical NPSB rates and organic FYM additions highly significantly ($P < 0.01$) modified the duration to 50% flowering and 50% fruit setting. Thus, Maximum vegetative delays to flowering (53.67 days) and fruit setting (74.69 days) occurred under the highest chemical applications (200 kg ha^{-1} NPSB). In contrast, the unfertilized control plots flowered and set fruit much earlier (37.39 and 66.89 days, respectively; Table 2). This acceleration in control plots reflects a standard survival mechanism, where nutrient deprivation limits vegetative growth and forces the plants into early reproductive phases. Conversely, rich nutrient availability encourages strong vegetative development, delaying flowering and lengthening reproductive timelines (Alhrout et al., 2018). The highest number of days for fruit setting from highly fertilized plants might be due to sufficient nutrients, which in turn further application of organic manure along with NPSB and micronutrient, which might have accelerated

the vigorous growth increase the days to set flower and fruit of tomato plant as reported by Yadav *et al.* (2004).

Table 2
Main effects of NPSB and FYM on tomato flowering and fruit setting timelines

Treatment	Days to 50% flowering	Days to 50% fruit setting
NPSB (kg ha^{-1})		
0	37.39^{c}	66.89^{c}
100	44.21^{b}	68.46^{c}
150	51.68^{a}	71.59^{b}
200	53.67^{a}	74.69^{a}
LSD (5%)	2.98	2.47
Significance level	**	**
Farmyard manure (ton ha^{-1})		
0	42.00^{c}	69.32^{b}
5	47.03^{b}	72.55^{a}
10	51.17^{a}	69.35^{b}
LSD (5%)	2.57	2.14
Significance level	**	**
CV (%)	**6.52**	**3.60**

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

3.3. Growth parameters

3.3.1. Plant Height and Primary Branch Development

ANOVA confirmed highly significant main effects ($P < 0.01$) and significant interaction effects ($P < 0.05$) on overall plant height and primary branch counts. The treatment combination of 200 kg ha^{-1} NPSB and 10 t ha^{-1} FYM produced the tallest plants (88.00 cm) and the highest number of primary branches (5.37), though its height was statistically identical to the 150 kg ha^{-1} NPSB + 10 t ha^{-1} FYM treatment (Table 3). The unfertilized control plots recorded the lowest vertical height (46.67 cm) and primary branches (3.22). This structural expansion under high-input combinations highlights the benefits of combining

organic and inorganic fertilizers. FYM improves structural aeration and water retention, while the chemical inputs supply readily available ions to satisfy early vegetative growth demands (Adekiya & Agbede, 2009).

In line with this result, Patil *et al.* (2004) in tomato and Suge *et al*. (2011) in brinjal reported that applying higher doses of fertilizers improves the vegetative growth. Ruiz and Romero (1998) also pointed out combined application of organic and inorganic fertilizer improves the plant height of tomato crops. Similarly, Frank (2000) also reported that there is a general increase in the vegetative growth when organic manure are applied to plants, because organic manure (farm yard manure) is known to be rich in N, P and K with other micro nutrients that when decomposed add nutrients to soil which will result in better growth and yield. In addition, Hardjowigeno (2003) reported that the highest plant height was obtained by application of inorganic fertilizer (240 kg/ha NPS) in combination with organic manure and concluded that the function of nitrogen as fertilizer is to improve plant vegetative growth and help the process of forming proteins.

Table 3
Interaction effects of NPSB and FYM on tomato vegetative growth parameters

Treatments		**Parameters**	
NPSB (kg ha^{-1})	**FYM (ton ha^{-1})**	Plant height (cm)	Number of primary branches (No.)
0	0	46.67^{g}	3.22^{h}
	5	62.67^{de}	3.32^{h}
	10	67.43^{d}	4.27^{cde}
100	0	55.67^{f}	3.77^{fg}
	5	65.32^{d}	4.13^{def}
	10	79.33^{bc}	4.20^{cde}
150	0	54.33^{f}	3.73^{g}
	5	64.00^{d}	4.37^{bcd}
	10	83.33^{ab}	4.73^{b}
200	0	58.67^{ef}	3.97^{efg}
	5	74.34^{c}	4.52^{bc}
	10	88.00^{a}	5.37^{a}
LSD (5%)		5.22	0.38
Significance level		*	*
CV (%)		**4.83**	**5.46**

FYM= Farmyard manure, Means with the same letter within a column are not significantly different each other.

3.3.2 Leaf Production per Plant

The total number of leaves per plant was highly significantly altered ($P < 0.01$) by the main effects of the independent treatments, while their interaction remained non-significant. Maximized leaf counts (32.89) were recorded under the 200 kg ha^{-1} NPSB chemical treatment, which was statistically equivalent to the 150 kg ha^{-1} NPSB application rate (31.33). Similarly, applying 10 t ha^{-1} FYM maximized organic leaf production (32.92), whereas the control plots produced the lowest leaf counts (Table 4). This increase in leaf counts directly expands the plant's photosynthetic source capacity, supporting greater dry matter accumulation in the harvestable fruit sinks (Degefa et al., 2019).

The higher number of primary branches obtained from the plots, which received higher dose of organic, and NPSB fertilizer might be due to the improvement of the physical condition of the soil and nutrient supplied by the farmyard manure. This result is supported by Akinfasoye and Akanbi (2005) who concluded that the use of organic manure cannot be over emphasized because of its usefulness in the improvement of physical soil condition as well as microbial properties and the nutrient it supplies for crop productivity. This finding is also in agreement with the previous findings of Yitbarek and Geletaw (2019) who reported that increased the primary branches as the NPS rate increased and a higher rate of NPS promote primary branches, during vegetative development and also help to maintain functional branches during the vegetative growth.

Table 4
Main effects of fertilizer inputs on leaf production per plant

Treatment	**leaf production per plant (No.)**
NPSB (kg ha^{-1})	
0	27.11^{c}
100	30.33^{b}
150	31.33^{ab}
200	32.89^{a}
LSD (5%)	2.13
Significance level	**
Farmyard manure (ton ha^{-1})	
0	28.00^{c}
5	30.33^{b}
10	32.92^{a}
LSD (5%)	1.85
Significance level	**
CV (%)	**7.19**

*FYM * = Farmyard manure, Means with the same letter(s) within a column are not significantly different each other.*

3.4 Yield and Yield Components

3.4.1 Fruit Count, Cluster Count, and Individual Weight Characteristics

The interaction between blended chemical arrays and organic manures highly significantly ($P < 0.01$) dictated fruit counts per plant, fruit counts per cluster, and average individual fruit weights. The treatment combination of 200 kg ha^{-1} NPSB + 10 t ha^{-1} FYM generated the highest values across all three traits: 37.53 fruits per plant, 6.27 fruits per cluster, and an individual fruit weight of 0.57 kg (Table 5). However, these values were statistically identical to those obtained from the 150 kg ha^{-1} NPSB + 10 t ha^{-1} FYM combination. Conversely, the control treatments consistently produced the lowest values.

The balanced availability of boron from the NPSB fertilizer promotes efficient pollen tube elongation, which enhances fruit set numbers per cluster. Concurrently, the steady supply of potassium and phosphorus facilitates smooth carbohydrate transfer to the developing fruit sinks, maximizing final fruit weight (Hailu et al., 2021).

Increasing level of macro and micronutrients in the form of blended and organic fertilizer can increase fruit number and resulted in highest number of fruits per plant as reported by Campos *et al*. (2008). In line with this finding, Balemi (2008) reported that major plant nutrients supply resulted in better performance in fruit formation. Similarly, Mishra *et al.* (2004) also reported higher fruit yields were obtained from more fertilized plots as compared to controlled plot in tomato. Moreover, Karim, (2015) also reported that optimum rates of blended fertilizer resulted in highest number of flower per plant, number of cluster per plant, fruit per plant, weight of fruit per plant and yield.

Table 5
Interaction effects of NPSB and FYM on tomato fruit and yield components

Treatments		**Parameters**		
NPSB (kg ha^{-1})	**FYM (ton ha^{-1})**	Number of fruits per plant	Number of fruits per cluster	Fruit weight per plant (kg)
0	0	23.47^{d}	3.67^{f}	0.11^{g}
	5	24.00^{d}	3.91^{ef}	0.15^{g}
	10	26.57^{c}	4.42^{d}	0.20^{f}
100	0	25.60^{cd}	3.92^{ef}	0.22^{f}
	5	27.90^{c}	4.27^{de}	0.36^{cd}
	10	30.30^{b}	4.53^{cd}	0.45^{b}
150	0	27.47^{c}	4.13^{def}	0.26^{e}
	5	32.47^{b}	4.93^{c}	0.40^{c}
	10	37.17^{a}	5.80^{ab}	0.56^{a}
200	0	32.10^{b}	4.20^{de}	0.31^{d}
	5	35.33^{a}	5.77^{b}	0.48^{b}
	10	37.53^{a}	6.27^{a}	0.57^{a}
LSD (5%)		2.37	0.49	0.04
Significance level		**	**	**
CV (%)		**4.00**	**5.71**	**6.31**

*FYM * = Farmyard manure, Means with the same letter(s) within a column are not significantly different each other.*

3.4.2 Marketable and Total Fruit Yield Responses

Marketable and total fruit yields (t ha⁻¹) exhibited highly significant ($P < 0.01$) responses to the interaction of the fertilizer inputs. The application of 150 kg ha⁻¹ NPSB combined with 10 t ha⁻¹ FYM produced the maximum marketable yield (24.37 t ha⁻¹), standing statistically equal to the yield from the higher 200 kg ha⁻¹ NPSB + 10 t ha⁻¹ FYM combination (24.27 t ha⁻¹; Table 6). Total fruit yield peaked at 26.87 t ha⁻¹ under the 200 kg ha⁻¹ NPSB + 10 t ha⁻¹ FYM treatment, which was statistically equivalent to

the 150 kg ha⁻¹ NPSB + 10 t ha⁻¹ FYM treatment (26.43 t ha⁻¹). The control treatment produced the lowest marketable yield (4.63 t ha⁻¹) and total yield (5.30 t ha⁻¹).

These results demonstrate that integrated nutrient management significantly boosts tomato productivity. Combining organic manure with chemical fertilizer improves resource use efficiency, sustains nutrient availability throughout the crop cycle, and maximizes marketable fruit development (Adekiya & Agbede, 2009). The highest number of fruits per cluster at higher doses of NPSB and farm yard manure might be due to maximum photosynthetic activity and accumulation of number of fruits might be due to increased number of flowers which might have formed into fruits due to adequate availability of major and minor nutrients during its growth and development. With the increment supply of essential nutrients to tomato, there availability, acquisition, mobilization and influx into the plant tissues increased and by this way improved of numbers of flower per cluster and numbers of fruits per cluster (Shukla *et al.*, 2009). In line with this finding, Naidu *et al.* (2002) and Rafi *et al.* (2002) reported that supplying sufficient rates of blended and organic fertilizers results in production of highest flowers and fruits in tomato.

The highest marketable fruit yield in the treatment combination of 150kg ha^{-1} NPSB and 10 ton ha^{-1} farm yard manure might be due to better solubilization of plant nutrients, which lead to, increased up take of NPSB fertilizer and resulted in production of more marketable fruit yields of tomato. In addition to this mixing of organic and inorganic nutrients, reduce the nutrient losses, improving the fertilizer use efficiency thus increasing the soil nutrient availability and optimizes the crop nutrient requirement and resulted in higher and more preferred tomato fruits. In line with this result, Ogundare *et al.* (2015) and Rajya *et al.* (2015) reported that maximum nutrient availability due to integrated use of organic and inorganic fertilizers increased nutrient uptake by the plant which in turn lead to dry matter production and marketable fruit yield of tomato.

The increase in fruit yield per plant, per plot and per hectare from higher rates of NPSB and farmyard manure might be due to the increased growth and flower attributes which in turn lead to the increased photosynthesis and dry matter production and resulted in higher number of tomato fruits and increase the total yield.

In addition to this, high fruit yield from highly fertilized plants could be due to organic fertilizers not only contained sufficient nutrients but also the nutrients are slowly released to the plants. This prevents nutrient loss and leaching, as well as improving nutrient use efficiency. All these facilitate higher production of economic part of the plant. It could be observed that the higher NPSB and farmyard manure contents of treatments, the better the plant performance in terms of fruit yield. Similarly, Rodge and Yadlod (2009) reported that increasing rates of Farmyard manure, poultry manure and NPS fertilizer increases the total fruit yield in tomato. Likewise, Kokebe *et al.* (2013) also reported that low levels of nitrogen have been associated with early fruit formation, stunting of plants and marketable yield reduction in tomato, which in turn increases unmarketable fruit yield. The total yield of tomato was increased with increasing levels of applied organic and inorganic fertilizers (Abu-Alrub *et al.*, 2019).

Table 6
Interaction effects of NPSB and FYM on marketable and total fruit yields

Treatments		**Parameters**	
NPSB (kg ha^{-1})	**FYM (ton ha^{-1})**	Marketable yield (ton ha^{-1})	Total yield (ton ha^{-1})
0	0	4.63^{g}	5.30^{g}
	5	5.70^{g}	6.90^{g}
	10	7.93^{f}	9.17^{f}
100	0	9.07^{ef}	10.30^{ef}
	5	15.00^{c}	17.33^{c}
	10	19.27^{b}	21.23^{b}
150	0	10.73^{de}	12.43^{e}
	5	16.83^{c}	18.73^{c}
	10	24.37^{a}	26.43^{a}
200	0	12.60^{d}	14.70^{d}
	5	20.33^{b}	22.77^{b}
	10	24.27^{a}	26.87^{a}
LSD (5%)		2.09	2.18
Significance level		**	***
CV (%)		**6.79**	**6.33**

*FYM * = Farmyard manure, Means with the same letter(s) within a column are not significantly different each other.*

3.4.3 Unmarketable Fruit Yield

Unmarketable fruit yield was highly significantly ($P < 0.01$) affected by the main effects of blended chemical rates, and significantly ($P < 0.05$) affected by FYM application rates. However, their interaction was not significant. The highest unmarketable fruit yield (2.38 t ha^{-1}) occurred under the maximum chemical treatment rate (200 kg ha^{-1} NPSB), while the lowest unmarketable yield (1.68 t ha^{-1}) was achieved at the 150 kg ha^{-1} NPSB rate (Table 7). For organic amendments, applying 10 t ha^{-1} FYM resulted in higher unmarketable yields (1.97 t ha^{-1}) due to excessive physiological fruit expansion and structural cracking. In contrast, the 150 kg ha^{-1} NPSB application rate supplied optimal, balanced

nutrition, minimizing physiological sorting issues and maximizing marketable quality (Gessesew *et al.*, 2015).

The highest unmarketable bulb yield in higher NPSB blended fertilizer and farmyard manure rates might be attributed due to less competition for nutrients that resulted in large sized tomato fruits, which are not preferred on the market due to their large surface area, which resulted in higher transpiration and inturn, resulted in decay loss. On the other hand, the minimum unmarketable fruit yield obtained from plants which received 150kg ha^{-1} NPSB fertilizer rate might be attributed due to presence of sufficient nutrients for optimal growth, which resulted in good and attractive sized tomato fruits which increases the preference of those fruits in the market and increase the marketable fruit yield of tomato and decreases the unmarketable fruit yield.

In line with this result, Morsy *et al*. (2012) also reported that highest unmarketable fruit yield of tomato was recorded from high rate application of blended fertilizers and controlled treatment. Similarly, Yohannes *et al*. (2017) reported that the maximum value of unmarketable fruit yield was recorded from nil fertilizer treated plots. Similarly Gessesew *et al*. (2015) also reported that maximum unmarketable yield was recorded in the control treatment and the lowest unmarketable fruit yield was observed in plots supplied with optimum rates of blended fertilizer rates and organic fertilizers.

Table 7
Main effects of nutrient inputs on unmarketable tomato fruit yield

Treatment	Unmarketable yield (ton ha^{-1})
NPSB (kg ha^{-1})	
0	1.84[b]
100	1.89[b]
150	1.68[c]
200	2.38[a]
LSD (5%)	0.41
Significance level	**
Farmyard manure (ton ha^{-1})	
0	1.42[b]
5	1.96[a]
10	1.97[a]
LSD (5%)	0.36
Significance level	**
CV (%)	**15.99**

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

3.5 Economic Partial Budget Evaluation

Partial budget estimations following the CIMMYT methodology showed that the highest net financial benefit (1,308,686.00 ETB) was generated by combining 150 kg ha^{-1} NPSB with 10 t ha^{-1} FYM, involving a total variable cost of 7,114.00 ETB (Table 8).

Table 8
Partial budget profit structures for tomato production across treatments

Treatment Combination	MY(t ha^{-1})	AMY(t ha^{-1})	GI (Eth Birr)	CF (Eth Birr)		LCFA (Eth Birr)	TVC(Eth Birr)	NB (Eth Birr)
				NPSB	FYM			
0*0	4.63	4.17	250,200	0	0	0	0	250,200
0*5	5.70	5.13	307,800	0	0	500	500	307,300
0*10	7.93	7.14	428,400	0	0	1000	1000	427,400
100*0	9.07	8.16	489,600	3576	0	500	4076	485,524
100*5	15.00	13.5	810,000	3576	0	1000	4576	805,424
100*10	19.27	17.34	1,040,400	3576	0	1500	5076	1,035,324
150*0	10.73	9.66	579,600	5364	0	750	6114	573,486
150*5	16.83	15.15	909,000	5364	0	1250	6614	902,386
150*10	24.37	21.93	1,315,800	5364	0	1750	7114	1,308,686
200*0	12.60	11.34	680,400	7152	0	1000	8152	672,248
200*5	20.33	18.30	1,098,000	7152	0	1500	8652	1,089,348
200*10	24.27	21.84	1,310,400	7152	0	2000	9152	1,301,248

MY=marketable yield, AMY=adjusted marketable yield, CF=cost of fertilizer, FYM=Farmyard manure, LCFA=labor cost for fertilizer application, TVC=total variable cost, NB = net benefit

Dominance analysis eliminated the 150 and 0, 150 and 5, 200 and 0, 200 and 5, and 200 and 10 treatments because their higher net costs generated lower returns than alternative options (Table 9).

Table 1
Dominance analysis of fertilizer treatment variations

Treatment Combination	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	Dominance selection
0*0	0	250,200	Un-dominated
0*5	500	307,300	Un-dominated
0*10	1000	427,400	Un-dominated
100*0	4076	485,524	Un-dominated
100*5	4576	805,424	Un-dominated
100*10	5076	1,035,324	Un-dominated
150*0	6114	573,486	**Dominated**
150*5	6614	902,386	**Dominated**
150*10	7114	1,308,686	Un-dominated
200*0	8152	672,248	**Dominated**
200*5	8652	1,089,348	**Dominated**
200*10	9152	1,301,248	**Dominated**
TVC=total variable cost, NB = net benefit, DA=dominance analysis			

Marginal rate of return calculations showed that the 150 kg ha^{-1} NPSB + 10 t ha^{-1} FYM combination delivered a peak MRR of 812.60% (Table 10). This far exceeds the standard minimum economic acceptable threshold of 50%, making it the top pick for smallholder production.

Table 2
Marginal rate of return calculations for un-dominated tomato treatments

Treatment Combination	TVC(Birr ha^{-1})	NB(Birr ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)	Rank
0*0	0	250,200	0	250,200	0	
0*5	500	307,300	500	57,100	114.2	5
0*10	1000	427,400	500	120,100	240.2	4
100*0	4076	485,524	3076	58,124	18.90	6
100*5	4576	805,424	500	319,900	639.8	2
100*10	5076	1,035,324	500	229,900	459.8	3
150*5	7114	1,308,686	2038	273,362	**812.60**	1

Where: MC=marginal total cost, MRR (%) = marginal rate of return, TVC=total variable production cost ha^{-1}, MC= marginal cost, NB = net Benefit, MB = marginal benefit

4. Conclusions and Recommendations

4.1 Conclusions

This study demonstrates that tomato growth, yield, and economic returns in the Ayehu Guagusa District respond strong to integrated applications of inorganic blended NPSB and organic farmyard manure. In balanced amounts, these inputs significantly improve growth metrics, increase fruit clusters, and maximize individual fruit weights.

The application of 150 kg ha^{-1} NPSB combined with 10 t ha^{-1} FYM optimized production, yielding the highest marketable fruit yield (24.37 t ha^{-1}) and providing the greatest net economic benefit (1,308,686.00 ETB). This combination achieved a peak marginal rate of return of 812.60%, demonstrating that integrated nutrient management is highly effective for sustainable tomato production.

4.2 Recommendations

For smallholders cultivating the 'Melka Shola' tomato variety within the Ayehu Guagusa District and adjacent agro-ecologies, the integrated application of **150 kg ha^{-1} blended NPSB fertilizer and 10 t ha^{-1} farmyard manure** is highly recommended. Because these findings are based on a single season and location, further multi-season and multi-location trials are recommended to validate these conclusions across broader environmental gradients.

Declarations

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Author Information and contribution

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Contributions

Alefe Tesfahun executed the experiment, supervised the research, collected data, analysed and wrote draft, reviewed the manuscript, and approved the final version of the manuscript.

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Ethical Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The author declares no competing interests.

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Data availability statement

“The data supporting the findings of this study are available from the corresponding author upon reasonable request.”

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