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Effects of Organic Liquid and Inorganic Fertilizers on Tomato Yield in the Central Rift Valley of Ethiopia

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Abstract

This study investigates the effects of organic liquid fertilizers and inorganic fertilizers on tomato yield in the Central Rift Valley of Ethiopia, addressing the significant yield gap between Ethiopian tomato production. Results indicate that the application of combination of 100% recommended nitrogen and phosphorus with either 60 ha^{-1} and 45L ha^{-1} organic liquid fertilizer significantly increased tomato marketable and total yields at all locations, with the highest yield observed at Sankura (50.36 t ha^{-1}), Hawassa (46.6 t ha^{-1}) and Koka (36.7 t ha^{-1}). However, as the inorganic nitrogen-phosphorus application decreased below 100% can decline tomato yields at all sites. From an economic standpoint, applying 100% RNP without OLF yielded the best marginal rate of return (MRR). Additionally, the combination of 100% RNP with 60 L ha^{-1} of OLF not only demonstrated substantial yield advantages but also proved to be profitable. Based on financial considerations, the sole application of 100% RNP and its integration with 60 L ha^{-1} OLF best show a higher yield than the rest of the treatments. Therefore, the findings suggest that both approaches are recommended for optimizing tomato production in the central Rift Valley of Ethiopia, with the choice depending on farmers' financial capacity and long-term soil health considerations.

Key words: Tomato, Nitrogen, Phosphorous and organic liquid fertilizer

Introduction

Tomato (*Lycopersicon lycopersicum L)* is the second largest vegetable crop in the human diet worldwide, after potato, with a very high nutritional and economic value (Barros *et al.*,2012). Tomato is a key vegetable crop in Ethiopia, being both a significant source of income for smallholder farmers and an important provider of employment. Despite its significance, Ethiopia's national average yield of tomatoes (9.4 tons per hectare) remains substantially lower than the global average of 38.3 tons per hectare (Wiersinga *et al.,* 2009). Some production is observed throughout the year for continuous supply (Edossa *et al*., 2013b). As it is a relatively short-duration crop with a high yield, it is economically attractive, and the area under cultivation is increasing daily (Naika *et al.,*2005). This relatively low productivity can be attributed to several factors, including the prevalence of diseases and pests and suboptimal and imbalanced fertilizer applications. Soil nutrients are one of the most important factors influencing yield and crop quality in food production (Ogbonna, 2008).

Tomato crops require a large amount of nitrogen and other chemical fertilizers. Driven by global demand and economic interests, farmers generally use excessive chemical fertilizers to pursue high yields. However, the extensive application of chemical fertilizers can lead to a decrease in soil pH, reducing the abundance of bacterial communities, reducing soil biodiversity, increasing risk of soil-borne disease outbreaks, and seriously threatening agriculture's sustainable development. Similarly, Drechsel *et al.* (2001) reported that applying recommended mineral fertilizers does not improve the negative nutrient balance due to the higher nutrient removal from the soils. The cost of inorganic fertilizers is increasing enormously because they are out of reach for small and marginal farmers.

Research supports integrated soil amendment practices, as a single method cannot address existing soil issues [7] (Canali, *et al.,* 2004). While mineral fertilizers boost crop productivity, they do not improve long-term soil fertility due to nutrient depletion from harvest residues (Bekunda *et al.*, 2010). Therefore, farmers utilize integrated nutrient management, combining mineral fertilizers and organic amendments like compost and manure to enhance soil fertility sustainably (Lander *et al.*, 1998). Organic sources not only supply nutrients but also improve soil health and nutrient availability and more effective and sustainable (Dick & Gregorich, 2004). Studies show that using organic options like vermicompost alongside inorganic fertilizers can enhance tomato yield and soil quality (Tesfu *et al.*, 2017; Fan *et al.*, 2023). Additionally, reliance on synthetic fertilizers can diminish crop nutritional value, while organic fertilizers offer similar benefits and help control pests (Bulluck *et al.*, 2002).

Liquid organic fertilizers enhance plant growth by supplying essential nutrients, amino acids, and beneficial microorganisms that improve soil fertility and nutrient uptake efficiency. They facilitate the synthesis of amino acids and proteins, which are vital for robust plant development. Potassium in these fertilizers supports critical metabolic processes and cell elongation, while their complete solubility ensures even nutrient distribution, preventing localized buildup. Research indicates that liquid organic fertilizers effectively address nutrient deficiencies and boost yields. A study by Darwin *et al.*, 2019 found that using 60 ml L^{-1} or 100 L ha^{-1} of liquid organic fertilizer for sweet corn is a cost-effective alternative to traditional inorganic fertilizers. Additionally, findings from Maintang, *et al.* 2021 suggest a potential 25% reduction in inorganic fertilizer use for maize production. Ramesh highlighted that mixing 50% nitrogen from urea and 50% from vermicompost enhances rice yields and nutrient absorption. These organic solutions are promising for improving agricultural practices and sustainability.

Explore the benefits of Ethio-Garden Organic Liquid Fertilizer, designed to optimize plant growth with a pH of 6.6 and electrical conductivity of 5.7 dS m^{-1}. This 100% organic fertilizer contains 1.6% nitrogen, 0.8% phosphorus, 1.05% potassium, and essential micronutrients like iron and zinc. It is fully water-soluble and derived from natural sources such as water hyacinth, promoting improved crop yields and healthier plants (EIAR, 2022).

This environmentally sustainable, odorless fertilizer also strengthens cell walls, enhancing resistance to diseases and pests. Its easy-to-use consistency makes it a popular choice among farmers. Currently, smallholder practices in Ethiopia often deplete soil nutrients, leading to reduced productivity. While some research has explored organic fertilizers for vegetables, there is a need to study the effectiveness of liquid organic fertilizers in replacing inorganic options for tomato production. This study aims to determine the ideal ratio of liquid organic to chemical fertilizers to achieve profitable tomato yields in the central Refit Valley of Ethiopia.

Materials and Method

Description of study areas and experimental design

This research was carried out for two consecutive years (2023 and 2024) across three districts in the central Rift Valley of Ethiopia: Koka, Hawassa, and Sankura. The geographic locations are N 08.44°, E 39.04° E, an altitude of 1617m asl for Koka; N 7.070 N, E 38.050 at an altitude of 1700m asl for Hawassa; and N 7.540, E 38.170 at an altitude of 1890m asl for Sankura. The average annual rainfall in Koka, Hawassa, and Sankura was 831.1 mm, 960 mm, and 970 mm, respectively. The long-term yearly average minimum and maximum temperatures are 13.2 and 28.6; 12.9 and 27.0; and 11.6 and 26.4 °C, respectively. Most dominant crops of in research sites where onion, tomato, and maize

Design and treatment set-up

The experiment was laid out in randomized complete block design with 3 replications. The Eight (8) treatments were used for each study site. These are, *Negative control, 100 % R-NP (Recommended rate of nitrogen and phosphorous), 100 % R-NP + 45 L* ha^{-1} *OLF (Organic liquid fertilizer),100 % R-NP + 60 L* ha^{-1} *OLF, 75 % R-NP + 45 L* ha^{-1} *OLF, 75% R-NP + 60 L* ha^{-1} *OLF, 50 % R-NP + 45 L* ha^{-1} *OLF, 50% R-NP + 60 L*ha^{-1}*OLF*. The recommended dose of N and P for tomato (Roma VF) is 105 and 40 kg ha^{-1}, respectively (EARO 2004). Improved high Galilea hybrid tomato variety was used as the test crop. The gross plot size was 5 meters by 4 meters, with plant and row spacing of 0.3 m and 1 m, respectively. Organic liquid fertilizer produces different organic wastes materials, like vegetables, grass, and animals' waste. This fertilizer is soluble in water and can improve the quality and quantity of crop yield. Its attributes of 100% water solubility, free flowing and friendly environment contribute a lot to their wide demand.

Fertilizer and mode of application

The source of fertilizers were organic liquid fertilizer, Urea, and TSP. The full dose of phosphorus from TSP and half dose of nitrogen (N) from Urea fertilizer were applied during transplanting and the remaining half dose of N was side dressed two weeks after transplanting. Organic liquid fertilizer liquid organic fertilizer was easily applied by foliar application using a knapsack sprayer on the plant's leaves and stem. One-third of each treatment was applied in 3 rounds, with the first application at 25-30 days after transplanting, the second 3 weeks later, and the third 3 weeks after the second application. Organic liquid fertilizer was mixed with water at a ratio of 1 L to 40 liters of water. All other agronomic practices were carried out uniformly for all treatments as recommendation.

Tomato fruit yield data collection

The tomato yield was collected from the internal rows, leaving a row on each side. Fruits were graded as marketable and unmarketable yield at each harvest using the tomato crop's established procedure (Lemma *et al*., 2003). Bruised, insect-bitten, small-sized (2.5-3.5 cm in diameter), physiologically disordered, and sunburned fruits were deemed unmarketable, whereas fruits free of visible damage and with a diameter greater than 3.5 cm were deemed marketable.

Economic analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance and marginal analyses were carried out. The average yields of tomato fruits were adjusted downwards by 10% to account for the yield differences between the experimental plot and the farmers' fields for the same treatment. The analysis was based on a two-year (2023-2024) average farm gate price of ETB 30.00 kg^{-1}. For treatment to be considered as a worthwhile option to farmers, the minimum acceptable rate of return should be greater than or equal to 100% (CIMMYT, 1988). The farm gate market prices of urea (40.4 ETB kg^{-1}) and NPS (44.77 ETB kg^{-1}) were obtained from the Bureau of Agriculture's respective district agricultural offices (2023-2024). The farm gate price of 70 ETB L^{-1} was used for the Organic liquid fertilizer organic liquid fertilizer product. Inorganic fertilizer application and transport cost was estimated at ETB 3350 ha^{-1}. Organic liquid fertilizer application cost was estimated to be ETB 123.3 L^{-1}.

Data analysis

The yield data were subjected to analysis of variance using SAS statistical software, version 9.4 (SAS Institute, 2020). When yield data was found to be significantly different due to treatment differences, mean separations between treatments were made using the least significant difference at 5% probability (Gomez & Gomez, 1984).

Results and Discussions

Characterization of organic liquid fertilizer

The nutrient status of the liquid organic fertilizer, as shown in Table 1, indicates a range of macro- and micronutrients that are essential for plant growth.

Analysis for pH and electrical conductivity (EC) of the liquid organic fertilizer were performed in extracts of 1:10 (w/v) compost: distilled water ratio as described by Ndegwa and Thompson (2001). The pH of the liquid organic fertilizer is 6.62, which falls within the slightly acidic to neutral range, making it suitable for a wide variety of plants. A pH in this range is generally favorable for nutrient uptake and microbial activity in the soil. The electrical conductivity (EC) is 5.66 dS m^{-1}, indicating that the fertilizer has a moderate to high salinity level. High EC values could potentially affect the uptake of water and nutrients by plants, especially if applied in large quantities or in soils with poor drainage. It is essential to monitor the application rate to avoid salinity stress, particularly in sensitive crops. Therefore, this liquid organic fertilizer contains a balanced composition of macro- and micronutrients that can support a wide range of plants. The high nitrogen and organic carbon content make it particularly suitable for promoting vegetative growth and improving soil health. The moderate phosphorus and potassium levels, along with enough essential micronutrients, further enhance its suitability for diverse agricultural applications. However, the relatively high electrical conductivity

(EC) suggests that care should be taken in managing application rates to avoid potential salt buildup in the soil.

Total N was measured by the Kjeldahl method. Total organic carbon (C) was determined by the Walkley and Black method (Walkley and Black 1934). The nitrogen content of the liquid organic fertilizer is 1.6%, which is relatively high and suggests that the fertilizer can support the nitrogen needs of plants. Nitrogen is a critical element for plant growth, as it is a major component of amino acids, proteins, and chlorophyll. This concentration of nitrogen is adequate for promoting vegetative growth, particularly in crops that require a high nitrogen input. The organic carbon content is 310 g kg^{-1}, which is relatively high and suggests that the fertilizer has a significant amount of organic matter. Organic carbon is essential for improving soil structure, water retention, and microbial activity in the soil. The presence of organic carbon also indicates that fertilizer may contribute to enhancing soil fertility over time.

The determination of available phosphorous was carried out following the Olsen extraction method (Olsen *et al.* 1954). The phosphorus content of the liquid organic fertilizer is 0.8%, which is moderate. Phosphorus is vital for energy transfer, root development, and flowering in plants. While this level may be sufficient for some crops, it may need to be supplemented in soils with low available phosphorus or for crops with high phosphorus demands. The potassium content of 1.05% is an important feature of this fertilizer. Potassium is crucial for regulating various physiological processes in plants, including water regulation, photosynthesis, and disease resistance. The concentration of potassium is suitable for promoting overall plant health and resilience.

Available micronutrients (Fe, Mn, Zn and Cu) were extracted with di-ethylene tri-amine penta-acetic acid (DTPA) as described by Lindsay and Norvell (1978) and their amounts in the extracts were determined by atomic absorption spectrophotometer. The micronutrient content of the liquid organic fertilizer indicates the presence of essential trace elements. The iron content is 3800 ppm, which is considered a high level, suggesting that this fertilizer may be particularly beneficial for plants prone to iron deficiency. Manganese (410 ppm) and zinc (95 ppm) are present in moderate amounts, which can help prevent deficiencies of these micronutrients in crops, particularly for plants requiring these elements for enzyme activation and metabolic processes. Copper (40 ppm) is also present, though at lower levels. These micronutrients are vital for overall plant health and support various physiological functions, such as photosynthesis and enzyme activity.

Table 1. Nutrients Status of liquid organic fertilizer

Nutrients	N (%)	P (%)	OC (g kg $^{-1}$)	K (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	pH	EC (dS m^{-1})
Level	1.6	0.8	310	1.05	3800	410	95	40	6.62	5.66

Soil sample collection and laboratory analysis

Prior to treatment application, surface soil samples were collected from depths 0 - 20 cm. The collected composite soil samples were air-dried and ground to pass a 2-mm sieve before being subjected to laboratory analysis to determine selected soil parameters using standard laboratory procedures. The determination of particle size distribution (texture) was carried out using the Boyoucous hydrometer method (Bouyoucos, 1962). Based on the result, the particle size distribution of the Hawassa site was (43%, 31%, 26%) and the textural class of the is loam. The particle size distribution Sankura (56.1%, 22.3%, and 20.6%) is sandy loam, and Koka (61.0%, 19.0%, and 20.0) is sandy loam (Bouyoucos, 1962). Soil pH was determined from a suspension of 1:2.5 of soil: water ratio using a glass electrode attached to a digital pH meter. Hawassa, Sankura, and Koka sites soil pH values were 6.43, 6.17, and 6.83%, respectively (Jackson, 1958). (McLean 1982).

The organic carbon (OC) was determined by the dichromate oxidation method and subsequent titration with ferrous ammonium sulphate (Walkley & Black, 1934) and % organic matter (OM) was obtained by multiplying %OC by 1.724 assuming that the average C concentration of organic matter is 58%. The total soil nitrogen was estimated using the Kjeldahl procedure. Based on analysis results, TN% and OM% of Hawassa (0.25% and 3.01%), Sankura (0.27% and 3.42%), and Koka (.017% and

2.78%) (Walkley and Black, 1934 and Bremner, 1996). The determination of available phosphorous was carried out following the Olsen extraction method (Olsen *et al.*, 1954). The site's available P content was 5.78 mg kg^{-1}, 6.18 mg kg^{-1}, and 5.12 mg kg^{-1}, respectively. Exchangeable bases (Ca, Mg, K, and Na) and cation exchange capacity (CEC) were determined by leaching method with ammonium acetate solution (1 M NH4OAc). The concentration of exchangeable Ca and Mg were measured from the extract with an atomic absorption spectrophotometer, while exchangeable K and Na were with a flame photometer (Van Reeuwijk, 2002). Based on analysis results, the cation exchange capacity of the sites was 17.56 Cmolc kg-1, 19.22Cmolc kg^{-1}, and 13.6 Cmolc, respectively.

Effect of organic liquid and inorganic n and p fertilizers on tomato growth and yield

The analysis of variance indicated that the application of organic liquid and inorganic N and P fertilizers had a highly significant effect across all locations for both marketable and total yields, indicating that the applied treatments had a strong and consistent impact on yield performance in all sites. The interaction between year and treatment was significant for marketable yield in Koka and Hawassa, and for total yield in Koka, suggesting that the effectiveness of the treatments varied depending on annual climatic conditions. In contrast, there is no significant yield interaction year-treatment in Sankura site. The mean marketable yields ranged from 32 (Koka) to 43 (Sankura), and the mean total yields ranged from 37.6 (Koka) to 53.7 (Sankura), reflecting the varying productivity across locations (Tables 2 &3).

The significant treatment effects across all locations for both marketable and total yields reinforce the effectiveness of the treatments in enhancing yield outcomes. The consistency of treatment effects across locations and years suggests that the applied interventions were generally successful in improving yields. However, the year   treatment interaction observed in some locations suggests that the impact of treatments may vary depending on the specific climatic conditions of each year, necessitating an adaptive management approach to maximize the effectiveness of such interventions in varying environmental contexts. The significant effects of location, year, and treatment, as well as the interactions between these factors, highlight the complexity of agricultural production and the importance of considering environmental and temporal factors when developing strategies for yield improvement. Future research should focus on refining treatment strategies based on location-specific needs and exploring the potential for optimizing agricultural practices under varying climatic conditions to further enhance yield stability and productivity.

Table 2: Result of ANOVA of marketable and total yield combined over years (2023-2024)

		Mean marketable yield			Mean total yield		
Source	DF	Koka	Hawassa	Sankura	Koka	Hawasa	Sanku
Rep	2	NS	NS	NS	NS	NS	NS
Year	1	***	NS	***	***	NS	***
Trt	7	***	***	***	***	***	***
Year*Trt	7	*	*	NS	NS	NS	NS
mean		32	39.6	43	37.6	49	53.7
CV		20.8	13.06	13.6	17.2	10.6	12.5
RMSE		6.7	5.17	5.9	6.5	5.2	6.7

Table 3. Result of ANOVA combined analysis of marketable and total yield over and year's location

Source	DF	Ym	Ytot
Rep	2	NS	NS
Year	1	***	NS
Loc	2	***	***
Trt	7	***	***
Year*Trt	7	***	*

Loc*Trt	14	NS	NS
Year*Loc	2	***	***
Mean		38.3	46.9
CV		15.3	12.8

The results of the study evaluating the effect of organic liquid fertilizer (OLF) in combination with different levels of nitrogen-phosphorus (NP) fertilizers on marketable tomato fruit yield across three locations Hawassa, Sanukra, and Koka reveal significant differences in yield performance among the various treatments. The negative control (no fertilizer) consistently produced the lowest marketable yields at all locations, with an average of 23.9 t ha^{-1}, underscoring the detrimental effect of the absence of fertilization. This treatment consistently resulted in the lowest yield across all locations, highlighting the importance of proper fertilization for achieving acceptable tomato productivity. The combination of 100% R-NP with 60 L ha^{-1} OLF and across three locations Hawassa (46.6 t ha^{-1}), Sanukra (50.3 t ha^{-1}), reveal significant differences in yield performance among the various treatments. However, the maximum tomato yield Koka site 36.9 t ha^{-1} were obtained from application 100% R-NP with 60 L ha^{-1} OLF fertilizer, albeit marginally higher than 100% R-NP alone. The combination of 100% R-NP with 60 L ha^{-1} OLF and 100% R-NP with 45 L ha^{-1} OLF produced yields that were comparable to or slightly higher than those from 100% R-NP alone. This result aligns with the findings of numerous studies that emphasize the essential role of nitrogen and phosphorus in tomato production (Jadhav *et al.,* 2020; Neves *et al.,* 2018).

Nitrogen is critical for vegetative growth, while phosphorus is crucial for root development and fruit formation, both of which are fundamental for high-yielding tomato crops. This finding suggests that organic fertilizers, at appropriate application rates, can enhance the efficiency of synthetic fertilizers by improving soil fertility, nutrient availability, and microbial activity. These results are consistent with other studies indicating that organic amendments can boost crop yields by fostering a more conducive environment for nutrient uptake and enhancing soil health (Khoshgoftarmanesh *et al.*, 2016).

Application of 100% R-NP + 60 L ha^{-1} OLF treatment yielded an average of 44.4 t kg ha^{-1} while the 100% R-NP + 45L ha^{-1} OLF treatment resulted in an average of 42.3 t ha^{-1}. 75% R-NP + OLF treatments also demonstrated promising results, particularly the combination with 60 L ha^{-1} OLF, which produced an average yield of 42.5 t ha^{-1}, the highest yield within the reduced NP fertilizer treatments. In contrast, the treatment with 45 L ha^{-1} OLF yielded an average of 40.8 t ha^{-1}, suggesting that the higher OLF application rate within this treatment resulted in better yield performance (Table 4). Suggesting that while organic inputs can supplement reduced synthetic fertilization, there is an optimal level of both organic and synthetic nutrients required to achieve high yields. This aligns with other studies that have suggested organic amendments can partially replace synthetic fertilizers, but a balanced approach is necessary to avoid yield losses (Bationo *et al.,* 2018).

The 50% R-NP + OLF treatments resulted in the lowest yields among the NP + OLF combinations, with average yields of 33.6 t ha^{-1} for 45 L ha^{-1} OLF and 35.7 t ha^{-1} for 60 L ha^{-1} OLF. This demonstrates that reducing synthetic NP fertilizer application to half of the recommended dose, even with the addition of organic fertilizer, is insufficient to achieve optimal yields. The 50% R-NP treatments consistently resulted in the lowest yield observed across all locations, reflecting the importance of maintaining an adequate level of synthetic NP fertilization to support tomato production. This result clearly indicates that reducing synthetic NP fertilizer to 50% of the recommended rate, even with the addition of organic fertilizer, does not provide sufficient nutrients to achieve optimal tomato yields (Table 4). The reduction in NP fertilizer likely limits the availability of essential macronutrients required for maximum crop productivity. Similar findings have been reported in previous studies, where reduced fertilization rates, even with organic supplements, failed to support optimal crop yields (Bationo *et al.,* 2018; Ayoub *et al.,* 2017).

The variation in yield across the three study locations Hawassa, Sanukra, and Koka further underscores the importance of environmental factors in determining fertilization outcomes. For example, Sanukra consistently exhibited higher yields across treatments, likely due to more favorable soil conditions and climatic factors that better supported tomato growth. In contrast, Koka produced relatively lower yields, possibly due to less fertile soil or environmental stress factors such as water scarcity. This highlights the need for location-specific fertilization strategies and the importance of considering local soil properties and climate in optimizing fertilizer applications (Ayoub *et al.,* 2017).

Table 4. Effect of Organic liquid fertilizer liquid organic fertilizer and NP on marketable tomato fruit yield (t ha^{-1}) (Combined over years)

Treatment	Hawassa	Sanukra	Koka	Combined
Negative control	25.9^{c}	28.4^{d}	18.3^{b}	23.9^{c}
100% R-NP	44.3^{ab}	46.6^{ab}	36.5^{a}	42.5^{a}
100% R-NP + 45 L ha^{-1} OLF	46.1^{a}	48.2^{a}	32.1^{a}	42.3^{a}
100% R-NP + 60 L ha^{-1} OLF	46.6^{a}	50.4^{a}	36.7^{a}	44.4^{a}
75% R-NP + 45 L ha^{-1} OLF	37.7^{ab}	47.9^{a}	35.6^{a}	40.5^{a}
75% R-NP + 60 L ha^{-1} OLF	45.9^{a}	45.9^{ab}	35.7^{a}	42.5^{a}
50% R-NP + 45 L ha^{-1} OLF	34.8^{bc}	37.4^{c}	28.5^{a}	33.6^{b}
50% R-NP + 60 L ha^{-1} OLF	35.3^{bc}	39.6^{bc}	31.9^{a}	35.6^{b}
CV (%)	13.2	12.9	19.2	16.8
LSD	6155.9	7130.5	5781.0	6521.7

Note: R-NP- Recommendation R-NP, OLF- organic liquid fertilizer, Means with the same letter along the column are not significantly different at p ≤ 0.05,

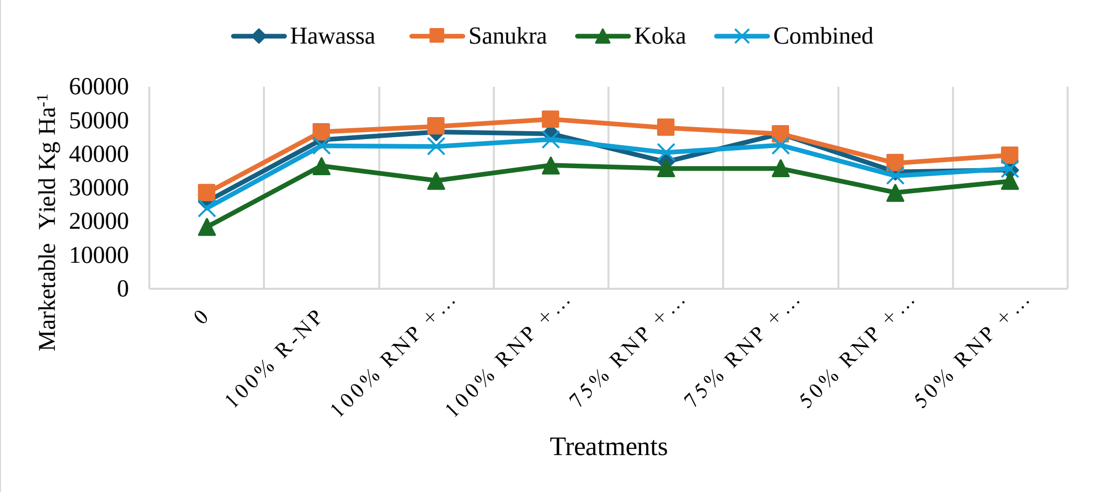

Figure 1: Marketable yield data combined over locations and years

Partial budget analysis

The result of the economic analysis of the marketable yield of tomatoes is shown in Table 5. The evaluation of fertilization treatments revealed insights into crop yield and economic feasibility. Negative Control had a baseline yield of 21.5 t ha^{-1} with no financial gain. In contrast, the 100% R-NP Treatment yielded the highest at 38.3 t ha^{-1}, generating a substantial net benefit of ETB 1135925 and an MRR of 4238.7%, indicating an adequate return on investment. The 50% R-NP + 45 L ha^{-1} OLF produced 30.2 t ha^{-1}with ambiguous economic efficiency due to a lack of MRR data, while 75% R-NP + 45 L ha^{-1} OLF yielded 36.5 t ha^{-1} with a high MRR of 7372.9%. The 100% R-NP + 45 L ha^{-1} OLF yielded 38.1 t ha^{-1}, achieving a notable net benefit of ETB 1121825 and an exceptional MRR of 8567.9%. While the 75% R-NP + 60 L ha^{-1} OLF treatment yielded 38.3 t ha^{-1}, its lower MRR of 1230.0% suggested modest economic returns.

The 100% R-NP + 60 L ha^{-1} OLF had the highest yield at 40.0 t ha^{-1} but a reduced MRR of 1956.9%, emphasizing the need to analyze input costs. Overall, increased R-NP applications significantly enhance yields, especially with organic liquid fertilizers (OLF). The varying MRR values across treatments illustrate differing economic efficiencies, with higher MRR treatments justifying their implementation. In conclusion, balanced nutrient management improves crop yield and financial returns. Future research should focus on optimizing R-NP and OLF levels to maximize yield and profitability further.

Table 5: A partial budget analysis based on marketable yield data combined over locations & years

Treatment	Yield $_{adj}$ (t ha^{-1})	GFB (ETB-ha^{-1})	TVC (ETB- ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Negative control	21.5	645300	0	645300	
100% R-NP	38.3	1147500	11575	1135925	4238.7
50% R-NP + 45 L ha^{-1} OLF	30.2	907200	15288	891912	D
75% R-NP + 45 L ha^{-1} OLF	36.5	1093500	17781	1075719	7372.9
50% R-NP + 60 L ha^{-1} OLF	32.0	961200	18188	943012	D
100% R-NP + 45 L ha^{-1} OLF	38.1	1142100	20275	1121825	8567.9
75% R-NP + 60 L ha^{-1} OLF	38.3	1147500	20681	1126819	1230.0
100% R-NP + 60 L ha^{-1} OLF	40.0	1198800	23175	1175625	1956.9

Note: R-NP- Recommendation R-NP, OLF- Organic liquid fertilizer, GFB-Gross field benefit

Conclusion and Recommendation

This study evaluated the effects of the integrated application of organic liquid fertilizer and chemical fertilizers on tomato fruit yield across three locations over two growing seasons in the Central Rift Valley of Ethiopia. The agronomic analysis revealed that combining 100% of the recommended nitrogen and phosphorus with either 60 or 45 L ha^{-1} of organic significantly improved tomato fruit yields at all locations. However, as the proportion of inorganic NP fertilizer decreased, so did the fruit yield, underscoring the importance of chemical fertilizers for enhancing tomato production. The combination of 100% RNP & 60 Lha^{-1} organic liquid fertilizer yielded the highest marketable output among all treatments.

In terms of economic performance, the treatment that provided the highest marginal rate of return (MRR) was applying 100% RNP without adding organic liquid fertilizer. Therefore, when considering agronomic and economic outcomes, the treatment with the highest MRR can be recommended as the optimal choice for tomato production under irrigation in Ethiopia's Central Rift Valley. Nonetheless, the contribution of organic liquid fertilizer in enhancing tomato yields when used in conjunction with 100% RNP is notable. Based on farmers' financial capacities, the 100% RNP alone and the combination of 100% RNP with 60 L ha^{-1} organic liquid fertilizer are economically viable options for improving tomato production in the region.

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