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RESEARCH ARTICLE

Tomato Yield and Economic Performance Under Vermicompost and Mineral Fertilizer Applications

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Abstract:

Background:

Optimum vermicompost and mineral fertilizer application is crucial for tomato production. However, farmers still use inadequate nutrient inputs and inefficient combinations. As a result, unbalanced soil nutrient compositions ultimately lead to a reduction in tomato fruit yield.

Methods:

An experiment was conducted to evaluate tomato yield and economic performance under vermicompost and mineral fertilizer applications using drip irrigation during 2016/2017. Shanti-PM variety of tomato was used as a test crop and eight vermicompost and mineral fertilizer combinations were laid out in a randomized complete block design with three replications. Agronomic data were analyzed using analysis of variance procedure. Besides, an economic analysis was carried out using partial budget analysis, to indicate economically superior treatments over the control treatment by estimating the varying costs and benefits based on the current local market prices for 2017.

Results and Conclusion:

Tomato fruit yield was markedly influenced by vermicompost and mineral fertilizer combinations. The better marketable, unmarketable and total fruit yield were recorded when 8 ton ha^{-1} vermicompost combined with 50% recommended a dose of mineral fertilizer was applied. Even though this treatment appeared to be superior in yield, the results of partial budget analysis suggested that tomato cultivated using 4 ton ha^{-1} vermicompost with 50% recommended mineral fertilizer was economically feasible to be acceptable by farmers. Therefore, application of 4 ton ha^{-1} vermicompost with 50% recommended mineral fertilizer appeared to be agronomically superior and economically affordable for farmers to adopt.

Keywords: Marketable yield, Unmarketable yield, Partial budget analysis, Marginal rate of return, Vermicompost, Mineral fertilizer.

1. INTRODUCTION

Tomato (*Solanumlycopersicum* L.) is one of the most important vegetables grown all over the world for their edible fruits. It is an excellent source of vitamins, minerals, and antioxidants [1]. At present, the consumption of tomatoes has been associated with its role in the prevention of several human diseases [2, 3]. Despite its importance, the average productivity of tomato in Ethiopia is around 10 ton ha^{-1} [4]. This is very low as compared to the world average productivity of 17.27ton ha^{-1} [5]. In Africa, particularly Ethiopia, soil nutrient balances are always negative due to

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inappropriate and low fertilizer utilizations, and soil nutrient depletion is a major reason for decreasing agricultural productivity [6]. Phosphorus (P) and Nitrogen (N) sourced fertilizers namely, Di-Ammonium Phosphate (DAP) and Urea have been used in Ethiopia permanently for several years which have led to mining of the other essential nutrients [7]. Soil fertility is a major constraint that affects all aspects of crop production [8]. This has been exacerbated by continuous cultivation without adequate soil fertility enhancement measures [9, 10]. Use of vermicompost fertilizers can improve crop yields but its use is limited due to scarcity, high cost, and nutrient imbalance [11]. The increase in the cost of mineral fertilizers; coupled with related ecological concerns has changed agricultural practice using mineral fertilizer to integrated nutrient management strategy using the combinations of both mineral fertilizer and vermicompost nutrient sources [12]. The combined use of vermicompost and mineral fertilizer reduces the cost and amount of fertilizer required by crops [13]. Rio *et al*. [14] observed that integration of vermicompost with mineral fertilizers increased the yield of potato. One of the unique features of vermicompost is its high level of plant available nutrients like nitrate or ammonium nitrogen, exchangeable phosphorous and soluble potassium, calcium and magnesium derived from the organic wastes [15]. Nutrients, when applied in adequate quantity, increase fruit quality, fruit size, colour, and fruit taste of tomato. According to Mengistu *et al*. [16], optimum vermicompost and NP mineral fertilizer application for tomato production has been reported to be 7.5 ton ha^{-1} and 50% NP mineral fertilizer, respectively. However, farmers in Ethiopia still use inadequate nutrient inputs and inefficient combinations. Thus, unbalanced soil nutrient compositions ultimately lead to a reduction in crop yield [17]. Although mineral fertilizer application improve crop yield, the economic affordability by smallholder farmers should also be considered. Therefore, maintenance of balanced plant nutrients supply in an integrated manner is essential for crop nutrition improvement [18] and economic benefit. As integrated nutrient supply is the most efficient and practical way to mobilize all the available, accessible and affordable plant nutrient sources in order to optimize the productivity and economic return to the farmer [19]. Therefore, the objective of this experiment was to determine agronomically suitable and economically affordable combinations of vermicompost and mineral fertilizeron tomato under field conditions.

2. METHODOLOGIES

2.1. Experimental Design and Treatments

The present study was carried out in Northern Ethiopia, at Aksum University Selekleka Demonstration Site during 2016/2017. The experimental area is situated at 14° 08' 57"N latitude and 38° 17' 02" E longitudes at an altitude of 1864m. According to the climatic zone classifications of Ethiopia, Alemneh [20] which was based on altitude, rainfall, average annual temperature and length of growing season; the study areas belong to cool sub-humid agro-climatic zone. The study area receives mono-modal type of rainfall with the main rainy season extended from June to September with a long-term average annual rainfall of 1031.3mm. The average temperature of these study area for the past 15 years revealed 20.92°C with a mean maximum temperature record (30.97°C) in April and the mean minimum (11.4°C) in January.

Shanti-PM variety of tomato was used as a test crop to evaluate the agronomic and economic performance of tomato under vermicompost and mineral fertilizer (Urea and NPS) combination levels using drip irrigation. Eight fertilizer combination treatments were laid out in RCB design with three replications. The treatments were:

1. Control (zero vermicompost and mineral fertilizer use)
2. Full recommendation of mineral fertilizer (150kg ha^{-1} NPS and 150kg ha^{-1} urea)
3. 4 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer
4. 4 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer
5. 6 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer
6. 6 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer
7. 8 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer
8. 8 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer

The recommended amount of mineral fertilizer used was 150kg ha^{-1} urea combined with150 kg ha^{-1}NPS fertilizer for tomato production [21]. The nitrogen content in 100kg urea is 46kg. Whereas, 100kg NPS fertilizer constitutes 46kg phosphorus, 18kg nitrogen and 7kg sulfur. Vermicompost was applied 14 days before sowing and thoroughly mixed in the upper 15-20cm soil depth. The blended fertilizer was applied all during sowing. To minimize loss and increase efficiency, urea was applied as a split at planting and during the flowering period. Tomato seeds were sown in a flat nursery bed of 1m by 5m area. Seedlings were transplanted from nursery after 35 days and planted in the main field at a spacing of 45cm between plants and 120cm between rows. The plot size was 4.5m by 6m. All agronomic practices such as weeding, cultivation, irrigation, diseases and insect-pest control were kept the same for all the experimental plots throughout the growing season.

2.2. Data Collection and Analysis

A composite soil sample was taken from two depths of 0-20cm and 21-40cm using auger prior to transplanting to represent the entire experimental field. From this study area, 30 subsamples were collected, dried, composited, and sieved through 2mm sieve to have a 1kg composite sample. The collected soil samples were then analyzed for selected soil properties mainly soil texture, pH, EC, organic matter content, at Shire Soil Laboratory and total N, available P, and available S at National Soil Testing Center, Addis Ababa. Routine soil analysis procedures described in the soil and plant laboratory manual by Sahlemedhin and Taye [22] were followed to determine the selected pre-planting characteristics of the experimental soil. Total Nitrogen was determined by macro Kjeldahl method [23]. Available phosphorous content of the soil was determined by Olsen method [24] and available S was determined using the turbidimetric method [25].

The fresh marketable, unmarketable and total tomato fruit yield was recorded from the three middle rows of 12 tomato plants to avoid border effect. Harvesting of fresh tomato was done four times and the values were added to determine total yield. All the data collected from each plot were first checked for their normality and analyzed statistically through Analysis of Variance (ANOVA) using Statistical Analysis System version 16 software package [26]. Least Significance Difference (LSD) tests were used for mean comparison among treatments.

Besides, an economic analysis was carried out for every treatment using the Partial budget analysis (also known as marginal analysis) based on the CIMMYT (International Maize and Wheat Improvement Center, known by its Spanish acronym CIMMYT for *Centro Internacional de Mejoramiento de Maíz y Trigo*) approach [27]. The partial budget analysis was carried out to indicate the economic superiority of alternative treatments over the control treatment by estimating the varying costs and benefits based on the current market prices for 2017.

The varying fertilizer and labour costs were estimated based on the existing rate of fertilizer purchase and daily labourer payment. Since vermicompost was prepared from the locally available decomposable raw materials, only labour cost for the vermicompost preparation was included and the cost of locally available raw materials was excluded. For the partial budget analysis, only costs that vary among all the treatments (fertilizer and labour costs) were considered to obtain Total Varying Cost (TVC). Basically, partial budget analysis is the computation of Marginal Rate of Return (MRR) compared with Acceptable Minimum Rate of Return (AMRR).

Identification and elimination of inferior treatments (dominance analysis) was carried out first by listing the treatments in order of increasing cost variation. The marginal rate of return was compared with the farmers' minimum acceptable rate of return to identify the economically preferable treatment. Farmer's acceptable minimum rate of return to adopt an alternative treatment/technology ranges between 40% and 100% [27, 28]. However, many researchers [29 - 31] suggested a minimum rate of return to be 100%, especially for poor farmers in developing countries. Accordingly, in this study, 100% minimum acceptable marginal rate of return was considered.

3. RESULTS AND DISCUSSION

3.1. Pre-Planting Soil Properties of the Study Area

According to Soil Survey Staff [32], textural class of the study soil was silt clay loam. Besides, soil of the study site has low organic matter content with around neutral pH and low EC level indicating nonsaline soil (Table **1**). Value of the soil parameters decreases across depths except, pH level, which showed a relative increase with depth. Besides, nutrient status of the experimental soil prior to transplanting of tomato seedlings was low in both soil depths, except the concentration of phosphorus which was rated as high.

Table 1. Soil characteristics of the study area.

Parameters	Soil Depth (cm)		Standard Values	References
	0-20	21-40		
Total N (%)	0.084	0.075	>1 very high 0.5-1 high 0.-0.5 medium 0.1-0.2 low <0.1 very low	London [33]
Available S (ppm)	6.4	5.8	0-6.9 deficient 7-12 adequate	Havlin*et al.* [34]
Available Olsen P (ppm)	16.8	12.7	>12 high 8-11 medium 4-7 low ≤3 very low	
OM (%)	1.4	1.22	>5.17 high 2.59-5.17 medium 0.86-2.59 low <0.86 very low	London [33]
pH (1:2.5 water)	6.67	6.8	Optimum pH for crop production 5.5-6.8	Havlin*et al.* [34]
EC (ds/m)	0.17	0.08	Tomato is tolerant up to 2.5 (ds/m)	Soil Survey Staff [32]

OM: Organic Matter; EC: Electronic Conductivity

The soil property of the study area was in conformity with that of ATA [35], except the rate of P which was reported by ATA as very low in the study district.

3.2. Yield and Yield Parameters

It is evident that tomato fruit yield was markedly influenced by vermicompost and mineral fertilizer combinations (Table **2**). Significantly surpassing marketable, unmarketable and total fruit yield performances were recorded when 8ton ha^{-1}vermicompost combined with 50% recommended dose of mineral fertilizer was applied. This result agrees with the findings of Singh *et al*. [12] who found that application of 7.5 ton ha^{-1} of vermicompost along with 50% of recommended NPK fertilizer (60:30:30 kg ha^{-1}) was optimum for obtaining better quality and productivity of field grown tomatoes. Similarly, Mengistu *et al*. [16]; Islam *et al*. [36]; Chatterjee *et al*. [37]; Ogundare *et al*. [38]; Olatunji and Oboh [39]; and Togun *et al*. [40] also reported an increased tomato yield when vermicompost and mineral fertilizer were applied in combination.

Table 2. Marketable, unmarketable and total tomato fruit yield as affected by vermicompost and mineral fertilizer combinations.

Treatments	Marketable Fruit Yield (ton ha^{-1})	Unmarketable Fruit Yield (Ton ha^{-1})	Total Yield (Ton ha^{-1})
Control (no fertilizer application)	13.21 ± 2.19^{d}	2.26 ± 0.53^{b}	$15.47+1.84^{d}$
Full recommendation of mineral fertilizer	20.35 ± 2.22^{bcd}	3.39 ± 0.31^{ab}	$23.74+2.26^{bcd}$
4 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	15.79 ± 3.03^{cd}	3.32 ± 0.37^{b}	$19.11+2.12^{cd}$
4 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	23.64 ± 1.84^{abc}	3.97 ± 0.15^{ab}	$27.61+1.77^{bc}$
6 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	20.95 ± 1.14^{bcd}	3.85 ± 0.44^{ab}	$24.80+1.17^{bcd}$
6 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	25.21 ± 1.30^{abc}	3.88 ± 0.46^{ab}	$29.10+0.94^{ab}$
8 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	26.71 ± 2.47^{ab}	4.64 ± 0.45^{a}	$31.35+1.29^{ab}$
8 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	33.08 ± 2.56^{a}	5.37 ± 0.28^{a}	$38.45+2.29^{a}$
CV	5.07	3.92	4.78
LSD	6.04	1.27	5.77

Levels not connected by same superscript are significantly different at 5% probability level

All the fertilizer combination treatments had a marketable yield advantage over the control and over the sole mineral fertilizer, except the treatment which received 4 ton ha^{-1}vermicompost together with 25% dose of recommended mineral fertilizer scored lower marketable fruit yield than the full dose of mineral fertilizer recommendation. As suggested by Srivastava *et al*. [41], the integrated application of vermicompost and mineral fertilizer in appropriate ratio resulted in a more balanced nutrient supply to crops. This might have led to increased uptake of essential nutrients which in turn resulted in the increased vegetative growth of the plant to help for better carbohydrate build up that subsequently contributed to higher fruit yield and quality components [42].

Moreover, as Namazi *et al*. [43] elaborated, adding vermicompost to the soil not only increased the nutritious elements needed for the plant but also improved the soil environment, encouraging the proliferation of roots to draw more water and nutrients from larger areas, finally resulting in an improved biological function of the plant. However, almost all of the unmarketable yield records in the present study were due to the occurrence of the blossom end rot. The incidence of blossom end rot increased with increasing application rates of vermicompost and mineral N. The highest unmarketable yield, 5.37 ± 0.28 and 4.64 ± 0.45 ton ha^{-1} were recorded when the tomato was cultivated under 8 ton ha^{-1} vermicompost combined with 25% and 50% mineral fertilizer levels, respectively. This implies, though plant nutrients sourced from vermicompost and mineral fertilizer increase tomato fruit yield, this yield may not be marketable due to the occurrence of blossom end rot which might be caused due to imbalanced water and nutrient levels.

3.3. Partial Budget Analysis

The result displayed in Table **3** reveals that, higher net return, 10760.88 USD was recorded when the tomato was cultivated using 8 ton ha^{-1}of vermicompost combined with 25% mineral fertilizer recommendations. Lower net return, 5630.86 USD was observed when the tomato was grown with no any fertilizer applications. The maximum MRR, 1362.09% was analyzed when the tomato was cultivated using full recommendation of mineral fertilizer followed by 1147.20% MRR recorded from tomato cultivated using 8 ton ha^{-1}vermicompost with 50% recommended mineral fertilizer. Nevertheless, result of the stepwise treatment comparison (also known as dominance analysis) indicated that the higher marginal rate of return, 5681.07% was recorded from tomato produced under the application of 4 ton ha^{-1}vermicompost combined with 50% mineral fertilizer recommendation.

Table 3. Marginal Rate of Return (MRR) and dominance analysis in USD.

-	Treatments	Returns and Costs				
		Gross Return	Total Varying Cost	Net Return	Net Income Over Control	MRR (%)
Comparison with control	Control (no fertilizer application)	5630.86	0.00	5630.86	0.00	0.00
	Full recommendation of mineral fertilizer	8674.34	208.16	8466.18	2835.32	1362.09
	4 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	7230.6	340.85	6889.75	1258.89	369.34
	4 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	9076.73	389.49	8687.24	3056.38	784.71
	6 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	8930.1	483.96	8446.14	2815.28	581.72
	6 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	10745.95	538.6	10207.35	4576.49	849.70
	8 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	11385.34	624.46	10760.88	5130.02	821.51
	8 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	14100.6	679.1	13421.5	7790.64	1147.20
Dominance analysis	Control (no fertilizer application)	5630.86	0.00	5630.86	0	0.00
	Full recommendation of mineral fertilizer	8674.34	208.16	8466.18	2835.32	1362.09
	4 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	7230.6	340.85	6889.75	1258.89	**-1188.05**
	4 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	9076.73	372.49	8704.24	3056.38	5681.07
	6 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	8930.1	483.96	8446.14	2815.28	**-216.29**
	6 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	10745.95	538.6	10207.35	4576.49	3223.30
	8 ton ha^{-1}vermicompost + 25% recommended mineral fertilizer	11385.34	624.46	10760.88	5130.02	644.69
	8 ton ha^{-1}vermicompost + 50% recommended mineral fertilizer	14100.6	679.1	13421.5	7790.64	4869.36

Values shown in bold are dominated.

However, treatments which received 4 ton ha^{-1} and 6 ton ha^{-1}vermicompost combined with 25% recommended mineral fertilizer were dominant and resulted in a rate of return that was below the farmer's minimum acceptable rate of return (100%). This implies that, when changing from no fertilizer application to 4 ton ha^{-1}vermicompost with 50% mineral fertilizer application, farmers can recover one USD plus an extra of 56.8 USD in net return for each one USD on average invested. On the other hand, application of 25% mineral fertilizer with 4 ton ha^{-1} or 6 ton ha^{-1}vermicompost could lead to negative return of 11.88 USD/ha and 2.16 USD/ha for 1 USD invested, respectively. This was associated with the yield obtained from the application of 25% of the mineral fertilizer which was not significantly different from the yield obtained from the application of 50% mineral fertilizer in combination to 4-6 ton ha^{-1}vermicompost. However, the cost of their application has a difference. Therefore, the application of more than 4 ton ha^{-1}vermicompost in combination with mineral fertilizer was economically inferior in this study. However, Mengistu *et al*. (2017) reported that tomato cultivation using 50% recommended a dose of mineral fertilizer together with 7.5 ton ha^{-1}vermicompost was found to provide the highest rate of return.

CONCLUSION AND RECOMMENDATION

Many fertilizer combination alternatives, though are agronomically superior, they may fail to be accepted by farmers because of their economic feasibility. The highest values for the yield parameters were recorded when 8 ton ha^{-1} vermicompost was applied in combination with 50% recommended mineral fertilizer level. This implies that 8 ton ha^{-1}vermicompost can supplement the 50% recommended mineral fertilizer during the first tomato production season. However, the higher economic return was recorded at the application of 4 ton ha^{-1} vermicompost combined with 50% mineral fertilizer. Though application of 8 ton ha^{-1}vermicompost combined with 50% recommended mineral fertilizer appeared to be superior in yield, from the economic benefit point of view, the application of 4 ton ha^{-1}vermicompost combined with 50% mineral fertilizer is reasonable to accept by farmers. Accordingly, this treatment could be considered agronomically suitable and economically affordable for farmers to adopt easily. However, this report is based on one season experiment and hence it is better if such studies are done for repeated production seasons/years as the organic sources of fertilizer combined with mineral fertilizers affect yield, economic return, soil quality and essential nutrient supply of the soil.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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