Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.12, No.11, 2021

Integrated Effects of Vermicompost and Nitrogen on Yield and Yield Components of Tomato (Lycopersicum esculentum L.) in Lowlands of Eastern Harerghe

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Abstract
Availability of insufficient amount of nutrients in the soil is among the main factors which constrained productivity of the tomato. Due to this gap the experiment was conducted in Sofi district, Harari People Regional State, Ethiopia in 2016 and 2017 cropping season to investigate the effect of vermicompost and nitrogen rate on yield and yield components of tomato. Experimental treatments were vermicompost rate (0, 1.4, 2.8 and 4.2 t ha^{-1}) and nitrogen rate (0, 50, 100 and 150 kg ha^{-1}). A total of 16 treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Melkashola Variety was used for the experiment. . The result showed that plant height was significantly ($P<0.05$) influenced by the application of vermicompost while number of branches, number of clusters, number of fruits, average fruit weight and fruit yield were significantly ($P<0.05$) affected due to the interaction effect of vermicompost and nitrogen.. The highest plant height was rerecorded at 2.8 t ha^{-1} of vermicompost whereas the lowest was for the rest rates. Maximum number of clusters, number of fruits and fruit yield were obtained at combined application of 2.8 t ha^{-1} of vermicompost with 100 kg ha^{-1} N while maximum number of branches and average fruit weight were recorded at 2.8t ha^{-1} with 150 kg ha-1 N and 4.2t ha^{-1} with 50 kg ha^{-1} N respectively. Maximum economic return (461,606 birr ha^{-1}) was also recorded at 2.8 t ha-1 and 100 kg ha^{-1} vermicompost and nitrogen, respectively with acceptable marginal rate of return. In general, the combination of vermicompost and nitrogen at 2.8 t ha-1 and 100 kg ha^{-1} was the best combination for the study area.
Keywords: Melkashola, Nitrogen, Tomato, Vermicompost
DOI: 10.7176/JNSR/12-11-03
Publication date: June 30th 2021

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the important vegetable crops grown throughout the world and ranks next to the potato and sweet potato in terms of area, but ranks first as a processing crop (FAO, 2010). The cultivated area under tomato was 4100 hectares with a total production in Ethiopia of 51000 metric tons (FAO, 2016). Tomato is grown in the summer and winter seasons in Ethiopia; however, production varies in various regions due to varieties, seasons, and climatic conditions, planting time, management practices and soil properties (Gabal *et al.*, 1984; and Nandwani, 2014).

Most soils in Africa are poor compared with other parts of the world (Bationo *et al*, 2006). African soil nutrient balances are often negative due to a low level of fertilizer inputs, and soil nutrient depletion is a major reason for decreasing or stagnation of agricultural productivity (Sanchez, 1997). Mbah (2006) asserts that soil fertility is a major overriding constraint that affects all aspects of crop production. As is the case in other regions in Africa, local farmers use inadequate nutrient inputs, inappropriate quality and inefficient combinations of fertilizers, which in the end prove to be very costly (Palm, 1997). A consequence of this trend is a deeply unbalanced soil nutrient composition that ultimately leads to a reduction in crop yield potential (Tonfack *et al.*, 2009). Nutrients, when in adequate quantity, increases fruit quality, fruit size, colour, and fruit taste of tomato (Azad, 2000).

The organic production system aims at supporting and sustaining healthy ecosystems, soil, farmers, food production, the community, and the economy. Reduction and elimination of the adverse effects of synthetic fertilizers and pesticides on human health and the environment is a strong indicator that organic agriculture is gaining worldwide attention (Aksoy, 2001; Chowdhury, 2004). Organic fertilizers are environmentally friendly, since they are from organic sources (Oyewole *et al.*, 2012). The current global scenario firmly emphasizes the need to adopt eco-friendly agricultural practices for sustainable food production.

Organic fertilizer; vermicompost are produced through the interaction between earthworm and microorganism by the breakdown of organic wastes. It is a stabilized, finely-divided peat-like material with a low C: N ratio and high water holding capacity that constitute a source of plant nutrition which is released gradually through mineralization whenever the plant needs it (Mathivanan *et al.*, 2012). Earlier work by Theunissen *et al.* (2010) on the growth and nutrient status of vegetables have revealed a positive effect on plant nutrition, photosynthesis, chlorophyll content and nutrient content of different plant components namely roots, shoots and fruits.

Earthworms play a vital role in plant growth and productivity. The ability of some species of earthworm to consume and breakdown a wide range of organic residues such as sewage sludge, animal wastes, crop residues and industrial refuse is well known (Edwards *et al*., 1985; Kaushik and Garg, 2003). Recycling bio-waste of different resources in the form of compost can be an alternative to meet the increasing demands for organic manures; this will also help to reduce environmental pollution arising out of accumulated bio-wastes (Kumar, 2005). Bio-wastes could be recycled by adopting simple and suitable techniques in compost making and preparing enriched manure. These improved technologies not only reduce the quantity but also improve the quality of compost with better plant nutrients (Jagadeesan, 2005).

There is accumulating scientific evidence that vermicompost can influence the growth and productivity of plants significantly (Edward, 1998). The study conducted by Tomati and Galli (1995) and Atiyeh *et al*. (2000) showed that growth and yield parameters such as leaf area, dry shoot weights and weight of fruits were significantly affected by applying vermicompost. Maynard (1995) reported that tomato yields in field soils amended with compost were significantly greater than those in the untreated plots. The available nutrient status of soil was greatly enhanced by the application of vermicompost as an organic source (Prabha *et al*., 2007). Vermicompost enhanced phosphorous concentration and uptake in soil, increasing the solubilisation of phosphorous either by microorganism activation with excretion of organic acids likes citric, glutamic, tartaric, succinic, lactic, oxalic, malic and fumaric (Sainz *et al*., 1998).

Nitrogen is the most limiting nutrient to crop production (Pionke *et al*., 1990). Like many vegetables, tomato is often heavily fertilized. Large amounts of nitrogen are often lost to leaching below the root-zone of vegetable crops (Pionke *et al*., 1990). Nitrogen deficiency can seriously decrease yield and crop quality. The nitrogen composition of plant tissue has important nutritional consequences, since plants are a major source of proteins in human diet (Below, 1995). Nitrogen is also a constituent of a large number of important compounds found in living cells, such as (enzymes) amino acids and nucleic acids (RNA and DNA) (Lea and Lee gold, 1993). Hence, nitrogen is critical in improving growth, yield and quality of vegetable crops.

In Eastern Ethiopia, vegetable crops, especially tomato is produced in both season in winter and summer under irrigation and rain fed. Heavy doses of chemical fertilizers in irrigation and pesticides are being used by the farmers to get a better yield of various vegetables and field crops. These chemical fertilizers and pesticides decreases soil fertility and causes health problems to the consumers. Due to adverse effects of chemical fertilizers, interest has been stimulated for the use of organic manures and cow dung through collecting and storing during offseason. However, in the study area; there is no information related to recent research work into the effects of vermicompost, nitrogen fertilizer and their combined effect utilization on vegetable crops, particularly on tomato. Therefore, the main aim of this study was to determine the influence of different rates of vermicompost and combination with nitrogen rate on yield and yield parameters of tomato under field conditions.

2. MATERIALS AND METHODS

2.1 Experimental Site

The Experiment was conducted in Sofi district, Harari, Ethiopia, on farmers land. The district was geographically lies at an altitude of 1300-1800 meters above sea level. The mean annual maximum and minimum rain fall is 500mm and 300mm, respectively. Like some part of Ethiopia, Sofi district is characterized by the bimodal rainfall pattern. . The first season is characterized by the short rainy season (*Belg*), which extends from March to May, while the second season is the most important main rainy season (*Meher*) which extends from July to October. The dry-spell period extends from June to July and based on its duration, it may affect crop growth. The minimum and maximum temperature of the area is 25 ^{0}C and 35 ^{0}C, respectively with the annual average of 30 ^{0}C (Harari BoA, 2016, unpublished).

2.2 Experimental Treatments and Design

For this experiment, tomato variety “Melkashola” was used as a test crop which was potentially produced by the farmers’ in the area. The experimental treatments consisted of four vermicompost (0, 1.4, 2.8 and 4.2 tons ha^{-1}) and four nitrogen fertilizer rates (0, 50, 100 and 150 kg N ha^{-1}). A total of 16 treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Each treatment combination was assigned randomly to experimental units within a block. The plant and row spacing of 30 cm and 70 cm, respectively, was used for all treatments. A plot size of 2.1m in width and 2.1m in length were used. Each plot consisted of four rows and about eight plants were planted per row. Data were recorded from the two central rows of each plot.

2.3 Experimental Procedures

The experimental field was cultivated to a depth of 25-30 cm by a tractor. The experimental plots were harrowed to a fine tilth manually before planting. The beds were supplied with supplementary irrigation during the shortage of rainfall. Finally, hardened, healthy and uniform seedlings of pencil size were transplanted at 3 to 5 leaves developed. All cultural practices were conducted as per recommendation of the area and each and every data planned to be collected were taken on time by using data record sheet. The nitrogen fertilizer (N) was applied uniformly in the form of urea whereas phosphorus (P) in the form of Triple Super phosphate (TSP) during sowing of the seed on nursery.

Earthworms were collected from Haramaya University for this experiment. Vermicompost was prepared by feeding earthworms with different weeds and cow dung through wetting with water frequently. These inputs were estimated to the cost of vermicompost preparation. Vermicompost was applied to the field according to specified rate before transplanting seedlings into the field. Nitrogen was applied at two equal splits (3 weeks after transplanting and the rest half 6 weeks after transplanting) as basal application according to the rate specified in the treatments. All treatments were randomly assigned to the experimental plots.

2.4 Data Analysis and management

2.4.1 Data collected

Data were collected from plant height (cm), number of branch per plant, number of cluster per plant, number of fruit per cluster, number of fruits per plant, yield per hectare, average fruit weight. Plant height was measured using ruler from the base of the plant to the tip of the shoots from ten plants of the central rows. The average numbers of branches were counted from ten plants. The numbers of clusters per plant and average numbers of fruits per cluster were counted from ten plants of the central rows. All fruits harvested were counted to estimate the number of fruits per plant. The average fruit weight was weighted from ten fruits which harvested from central rows of the plots. The average fruit weight was expressed in gram. During harvesting, all harvest cycle fruits were weighted by using digital balance and expressed in tons per hectare.

2.4.2 Statistical data analysis

Data were subjected to analysis of variance using Gen-STAT Statistical Software package. Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance.

3. RESULT AND DISCUSSION

3.1 Soil chemical properties

The analysis of soil sample for experimental site (Table 1) indicated that the soil was sandy clay loam in texture and moderately basic in reaction (pH = 8). According to Bruce and Rayment (1982) range, the soil was medium in total nitrogen (0.171%). Similarly, according to Olsen *et al*. (1954), the experimental site had low available phosphorus (2.893 mg kg^{-1} soil). According to Emerson (1991) range of organic matter content of soil, the experimental soil had moderate organic matter (2.277) contents. This moderate content of organic matter indicated that the experimental soil was moderate in structural condition and stability. According to Metson (1961), the soil of the experimental site had low cation exchange capacity (7.13 cmol kg^{-1} soil) and high in exchangeable potassium (9.026 cmol (+) kg^{-1} soil) (Table 1).

Vermicompost was also analysed and the physical texture was observed as clay loam. The pH of the vermicompost was mildly alkaline (7.7). The pH of vermicompost from different wastes have also been reported like sheep manure- 8.6 (Gutierrez-Miceli *et al*., 2007), sewage sludge-7.2 (Masciandaro *et al*., 2000). Vermicompost contained very high total nitrogen, available phosphorous, exchangeable potassium, organic carbon and CEC as indicated in the result (Table 1)

3.2 Plant height and number of branches

The result revealed that vermicompost significantly ($P<0.05$) affected plant height (Figure 1). Increasing vermicompost from nil to 2.8 t ha^{-1} linearly increased plant height though it was statistically parity. Plant height was declined beyond 2.8 t ha^{-1} vermicompost. Thus, application of 2.8 t ha^{-1} vermicompost recorded the highest plant height (72.32 cm) while the lowest value (66.48 cm) was at 4.2 t ha^{-1}. In line with current result, Kashem *et al*. (2015) stated that application of vermicompost at (20 t ha^{-1}) and NPK fertilizer (200 kg ha^{-1}) showed an increment of 36.34cm and 23.34cm of shoot length respectively, as compared to control.

On the other hand, number of branches were significantly ($P<0.05$) affected due to combined application of vermicompost and nitrogen fertilizer. The highest numbers of branches were recorded at 2.8 t ha^{-1} vermicompost with 150 kg ha^{-1} nitrogen while the lowest was recorded at 2.8 t ha^{-1} with 0 kg ha^{-1} nitrogen (Table 2). Plant growth parameters such as shoot length, root length, number of leaves, fresh weight and dry weights were better in vermicompost treated plants rather than the control plant (Vaidyanathan and Vijayalakshmi, 2017).

3.3 Clusters and fruits per plant

Clusters and fruits per plant were significantly ($P<0.05$) affected due to the interaction effect of vermicompost and nitrogen application. Combined application of vermicompost with nitrogen at the rate of 2.8 t ha-1 and 100 kg ha-1 recorded the highest number of clusters (16.9) and fruits per plant (51.4) while the lowest value was observed at control treatment (Tables 2 and 3). Increasing application of vermicompost from nil to 2.8 t ha^{-1} linearly increased fruit clusters at application of 100 kg ha^{-1} nitrogen. Application of vermicompost and nitrogen at 2.8 t ha^{-1} and 100 kg ha^{-1}, respectively, resulted in an increment of about 55 % fruit clusters and 50.6% fruits per plant respectively over the control treatment. Ogundare *et al.* (2015) also reported that the number of fruits per plant, fruit yield per plant, fruit yield per plot and tomato yield were significantly affected by combined use of organic and inorganic fertilizer.

3.4 Average fruit weight and fruit yield

Average fruit weight and fruit yield were significantly ($P<0.05$) affected due to the interaction effect of vermicompost and nitrogen fertilizer. The highest average fruit weight (74.9 g) was recorded at combined application of 4.2 t ha^{-1} vermicompost and 50 kg ha^{-1} nitrogen while lowest value was recorded for control treatment. On the other hand, the highest fruit yield (65.3t ha^{-1}) was recorded at combined application 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen fertilizer. The result revealed that combined application of 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen resulted in an increment of 54.7% to 56.7% fruit yield as compared to combined application of 0 kg ha^{-1} vermicompost with all the rest nitrogen rates (Table 4). Kashem *et al.* (2015) also reported that application of cow manure vermicompost had significantly influenced all the studied growth parameters and fruits yield of tomato plant rather than inorganic nitrogen fertilizer.

Table 1. Soil and vermicompost physical and chemical properties of the experimental site

Samples	pH	CEC	OC	Mg^{2+}	Ca^{2+}	Exch. Na	Exch. K	Avail P	TN	Texture
Soil	8.00	7.13	1.32	9.36	8.96	0.40	9.03	2.89	0.17	Sandy clay loam
Vermicompost	7.70	27.83	8.16	29.95	18.55	0.40	35.43	39.26	0.58	Clay loam

pH (soil to water ratio 1:2.5), CEC (cation exchangeable capacity: meq 100 g^{-1} soil), OC (Organic carbon:%), Mg^{2+} (Magnesium: cmol (+) kg^{-1} soil), Ca^{2+} (Calcium: cmol (+) kg^{-1} soil), Exch. Na (Exchangeable Sodium: cmol (+) kg^{-1} soil), Exch. K (Exchangeable Potassium: cmol (+) kg^{-1} soil), Avail. P (Available phosphorous: mg kg^{-1} soil), TN (Total Nitrogen: %).

Table 2. Interaction effect of vermicompost and nitrogen rate on branches and fruit clusters per plant over the two years (2016 and 2017)

	Branches				Clusters			
	Nitrogen (kg ha-1)							
Vermi-compost (t ha-1)	0	50	100	150	0	50	100	150
0	5.9ab	5.6ab	5.2ab	6.0ab	7.6e	10.0c-e	10.7b-e	10.3c-e
1.4	5.2ab	6.3ab	6.2ab	6.4ab	8.5de	10.7b-e	13.2a-c	9.2c-e
2.8	4.8b	5.7ab	5.8ab	**6.8a**	12.1b-d	12.0b-d	**16.9a**	14.6ab
4.2	5.7ab	6.2ab	5.3ab	6.2ab	8.7de	9.7c-e	10.1c-e	10.9b-e
LSD (0.05)		1.46				3.48		
CV (%)		21.8				27.7		

Table 3. Interaction effect of vermicompost and nitrogen fertilizer on fruit weight and number of fruits per plant for the 2016 and 2017

	Average Fruit weight(g)				Fruits per plant			
	Nitrogen (kg ha^{-1})							
Vermi Compost (t ha^{-1})	0	50	100	150	0	50	100	150
0	42.9f	65.3a-c	53.8b-f	61.4a-d	25.4f	26.4ef	27.6d-f	27.6d-f
1.4	46.0ef	66.6a-c	56.5b-e	61.5a-d	28.5d-f	36.1b-f	39.2b-d	37.7b-f
2.8	48.7d-f	67.7ab	56.8b-e	62.0a-d	27.6d-f	38.3b-e	**51.4a**	48.3ab
4.2	52.9c-f	**74.9a**	58.4b-e	62.2a-d	28.6d-f	32.2c-f	41.1a-c	37.5b-f
LSD (0.05)	11.89					10.662		
CV (%)	17.7					26.8		

Table 4. Interaction effect of vermicompost and nitrogen fertilizer on fruit yield over the two years (2016 and 2017)

	Nitrogen (kg ha^{-1})			
Vermicompost (t ha^{-1})	0	50	100	150
0	29.6b	29.6b	28.7b	28.3b
1.4	31.2b	45.9ab	53.5ab	40.3ab
2.8	45.9ab	44.9ab	**65.3a**	54.5ab
4.2	30.6ab	33.7b	50.8ab	48.5ab
LSD (0.05) =	25.09	CV (%)	= 25.8	

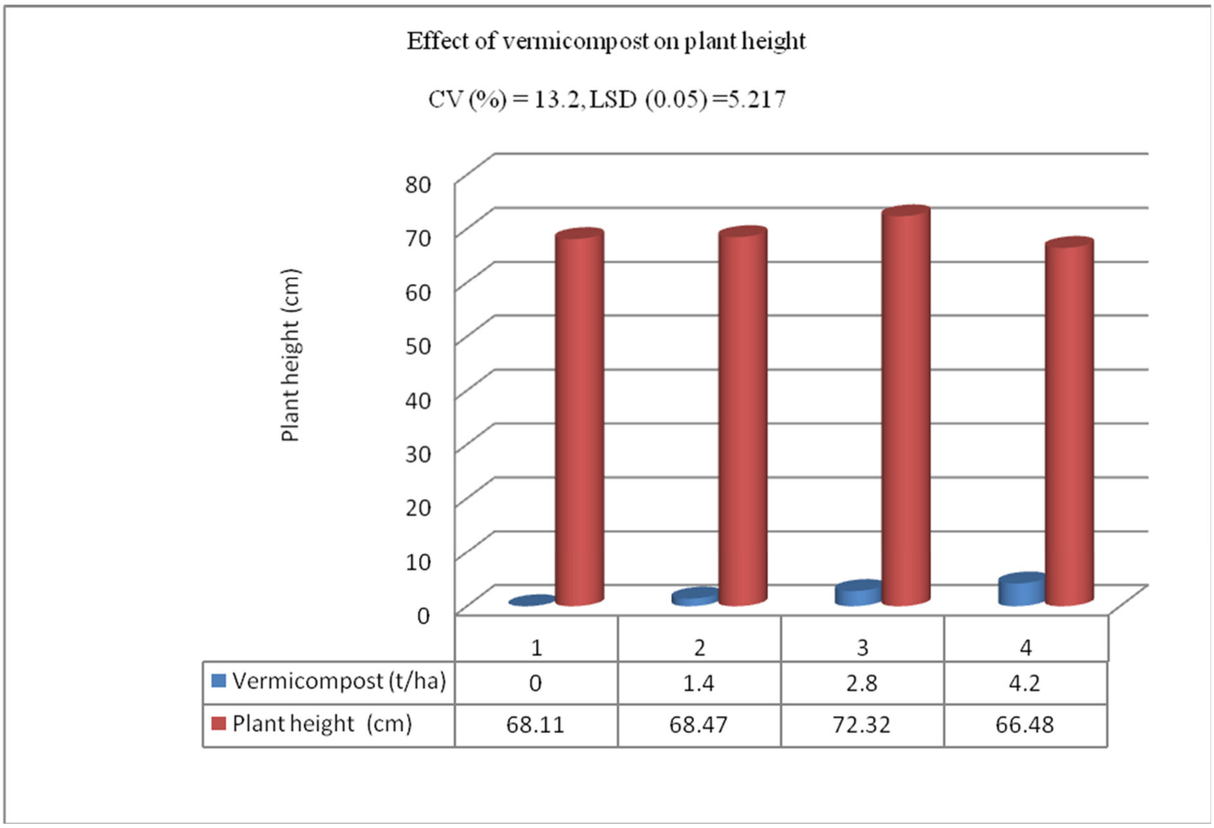

Figure 1. Effect of vermicompost on plant height of tomato

3.5 Partial cost analysis

The partial cost analysis was conducted based on the average price fluctuation of tomato in two years. At local market, the price of tomato is about 8 birr kg^{-1}, but fluctuate through times. The total variable costs were the combinations of fertilizer, vermicompost (crop residues, water, cow dung) and labor costs. The combined application of vermicompost and nitrogen at 2.8 t ha^{-1} and 100 kg ha^{-1}, respectively, was resulted maximum net return of 461,606 birr ha^{-1} with acceptable marginal rate of return. Application of nitrogen without vermicompost recorded the lowest net returns in all treatments.

Table 5. Partial budget analysis of vermicompost and nitrogen applied on tomato

(Vermi + N)	UFY (kg ha^{-1})	AFY (kg ha^{-1})	GR (birr ha^{-1})	TVC (birr ha^{-1})	NR (birr ha^{-1})	MRR (%)
0 - 0	29610	26649	213192	2894	210298	
0 - 50	29600	26640	213120	5074	208046	D
0 - 100	28700	25830	206640	5654	200986	D
1.4 - 0	31200	28080	224640	5944	218696	6107
0 - 150	28300	25470	203760	6234	197526	D
1.4 - 50	45900	41310	330480	6544	323936	40777
1.4 - 100	53500	48150	385200	7104	378096	9671
2.8 - 0	45900	41310	330480	7394	323086	D
1.4 - 150	40300	36270	290160	7684	282476	D
2.8 - 50	44900	40410	323280	7974	315306	11321
2.8 - 100	65300	58770	470160	8554	**461606**	25224
4.2 - 0	30600	27540	220320	8904	211416	D
2.8 - 150	54500	49050	392400	9134	383266	74717
4.2 - 50	33700	30330	242640	9484	233156	D
4.2 - 100	50800	45720	365760	10064	355696	21128
4.2 - 150	48500	43650	349200	10644	338556	D

Note: UFY=Unadjusted Fruit Yield, AFY Adjusted Fruit Yield=, GR= Gross return, TVC= Total Variable Cost, NR= Net Return, MRR=Marginal rate of Return,

4. CONCLUSION

The experiment was conducted for two consecutive cropping season to determine the effect of Vermicompost and nitrogen fertilizer rate on tomato yield and yield parameters. The soil of the area needs additions of nutrients for the optimum growth of the crop. The result over the two years revealed that there were significant differences among treatments for plant height due to the application of vermicompost. Significant differences also observed among the treatments for number of branches, number of clusters, fruits per plant, average fruit weight and fruit yield due to the interaction effect of vermicompost and nitrogen. Generally, application of vermicompost at 2.8 t ha^{-1} and nitrogen at 100 kg ha^{-1} recorded the highest number of branches, number of clusters, number of fruit per plant and fruit yield. The highest economic return was 461,606 birr ha^{-1} with acceptable marginal rate at 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen application. The combined application of 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen were resulted 2.2 times net return than control treatment. Therefore, application of 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen was recommended for tomato production to the study area and similar agro-ecology.

ACKNOWLEDGEMENT

The authors greatly indebted to acknowledge the Oromia Agricultural Research Institute and AGP-II for funding the study. We would like to grateful Ato Jemal Jibril the owner of the experimental field' for his commitment to manage the experimental field. Our heartfelt thanks also go to all staff members of the Fedis Agricultural Research Center for their support in ideas and facilitation for the success of this study.

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