

Research Article

Evaluation of Vermi Compost Integrated with Chemical Fertilizer on Yield and Yield Components of Maize (*Zia Maize*) in Adami Tulu District of East Shoa Zone, Oromia

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Abstract

Integrated soil fertility management employs a combination of inorganic and organic fertilizers to sustain soil fertility and boost crop yields. This study was carried out in the East Shoa Zone, Adami Tulu J/K District, on farmers' fields to evaluate the combined effects of vermin compost (organic fertilizer) and NPS (inorganic fertilizer) on soil chemical properties and maize production. Five treatments were used: the recommended inorganic fertilizer rate, and vermin compost applied at 100%, 75%, 50%, and 25% of the nitrogen equivalent. All treatments received an equal recommended dose of 46 kg P₂O₅/ha. The experiment was arranged in a randomized complete block design with three replications. Analysis of variance revealed significant differences ($p < 0.05$) in maize grain yield among treatments. The highest yield (8205.20 kg ha⁻¹) occurred with the 100% vermin compost nitrogen equivalent treatment, while the lowest yield (7663 kg ha⁻¹) was from the recommended chemical fertilizer alone. Composite soil samples collected before compost application and after harvest assessed vermin compost's residual effects on soil physicochemical properties. Post-harvest analysis showed that soil pH was not significantly affected ($p > 0.05$) by vermin compost application rates, but soil organic carbon (SOC), cation exchange capacity (CEC), available phosphorus, and total nitrogen (TN) were significantly improved ($p \leq 0.05$). Initial soil analysis indicated low SOC, CEC, available phosphorus, and TN, suggesting a positive residual effect from vermin compost. Economic analysis determined the optimum rate of vermin compost integrated with chemical fertilizer, with the highest net benefit (126,527 Ethiopian Birr ha⁻¹) and marginal rate of return (146%) observed in the 100% vermin compost plus NPS treatment. The study concludes that integrating organic and NPS fertilizers enhances maize productivity and soil fertility in the study area. Therefore, applying 100% vermin compost nitrogen equivalent combined with 46 kg ha⁻¹ P₂O₅ is recommended for maize production and soil improvement in this and similar agro-ecologies.

Keywords

Soil Fertility, Soil Organic Carbon, Integrated Application, Organic and Inorganic Fertilizer

1. Introduction

Maize cultivation and consumption have rapidly increased worldwide due to its importance as a staple food and raw

material for various products. In Ethiopia, particularly in the mid-rift valley, maize is the largest and most productive crop.

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According to the Ministry of Agriculture and Natural Resources (2015/16), maize production reached 4.2 million tons, surpassing teff by 40%, sorghum by 56%, and wheat by 75%. However, maize productivity remains low, largely due to continuous reliance on inorganic fertilizers, which degrade soil chemical and physical properties and compromise overall soil health [12]. The sole use of chemical fertilizers has been linked to unsustainable yields over time [12, 13].

Excessive and improper use of chemical fertilizers has resulted in severe soil degradation, causing ecosystem imbalances and environmental pollution. Recently, greater attention has been given to addressing these global environmental concerns by promoting the use of organic inputs such as organic wastes, farmyard manure, compost, and poultry manure. The use of bio-products for plant nutrition has become a fundamental approach, with the Food and Agriculture Organization (FAO) advocating Integrated Plant Nutrition Management (IPNM) to foster sustainable agriculture in developing countries. Adequate Input Sustainable Agriculture (AISA) now emphasizes the integrated use of chemical and organic fertilizers, especially bio-fertilizers, as a sustainable alternative to maintain crop yields.

The Integrated Soil Fertility Management (ISFM) approach recognizes the need to combine organic (compost) and mineral inputs to sustain soil health and increase crop production, capitalizing on their positive interactions and complementarities [16]. [6] reported that compost application can double cereal crop grain yields compared to chemical fertilizers alone. Organic fertilizers improve crop growth by providing essential macro- and micronutrients and enhancing soil physical, chemical, and biological properties, thereby promoting better root development through improved soil structure [4].

Furthermore, the rising cost of inorganic fertilizers has become prohibitive for resource-poor smallholder farmers. Considering the environmental pollution caused by excessive chemical fertilizer use and its high cost, alternative biological nutrient sources are needed. Integrated soil fertility management, which partially or wholly replaces chemical fertilizers with vermin compost, offers both environmental and economic benefits for sustainable crop production. Vermin composting is an effective method to recycle agricultural and biodegradable wastes into high-quality compost. Earthworms consume biomass and excrete digested material called worm casts, or "black gold," enriched with nutrients, growth-promoting substances, beneficial soil microflora, and with properties that suppress pathogens. This stable, fine organic manure enhances soil quality and its biological and physicochemical properties [4]. Vermin composting is increasingly recognized as a key component of organic farming systems, meeting organic production standards.

Given these advantages, vermin compost is a suitable option for supporting sustainable agriculture as defined by FAO and the Sustainable Agriculture Initiative Platform. Likewise, the integrated use of organic matter and chemical fertilizers has proven beneficial in sustainably improving crop produc-

tion and soil fertility [9].

This study aims to evaluate the effects of vermin compost applied alone and in combination with chemical fertilizers on the yield and yield components of maize.

Objectives:

- 1) To evaluate the effect of vermin compost integrated with chemical fertilizer on maize yield and yield components.
- 2) To recommend the optimal combination rate of vermin compost and chemical fertilizer for improved maize production.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Adami Tulu J/K District, where maize is a primary crop for consumption. Vermin compost used in the experiment was prepared at Adami Tulu Agricultural Research Center from animal manure and haricot bean straw. Prior to the experiment, samples of the vermin compost were analyzed to assess their quality, particularly total nitrogen content, which was used to calculate equivalency between compost and chemical fertilizer.

2.2. Experimental Design and Treatments

The field experiment was carried out using a randomized complete block design (RCBD) with five treatments and three replications on plots measuring 3 m by 4 m. The maize variety BH546, widely cultivated by local farmers, was used in all treatments. Chemical fertilizer application rates were based on site-specific crop response and p-calibration studies recommended by the Ethiopian Institute of Agricultural Research (EIAR), Melkassa, in 2017. This report specified critical soil phosphorus (P-critical) as 10 ppm, initial available phosphorus as 3.2 ppm, optimal nitrogen requirement as 92 kg/ha, and phosphorus requirement factor as 3.04 for maize in the study district.

Treatments included:

T1: Recommended NP (nitrogen and phosphorus) chemical fertilizer alone.

T2: 100% equivalent nitrogen from vermin compost plus recommended phosphorus.

T3: 75% equivalent nitrogen from vermin compost + 25% recommended nitrogen + recommended phosphorus.

T4: 50% equivalent nitrogen from vermin compost + 50% recommended nitrogen + recommended phosphorus.

T5: 25% equivalent nitrogen from vermin compost + 75% recommended nitrogen + recommended phosphorus.

2.3. Data Collection

Composite soil samples were taken from a depth of 20 cm before planting and after harvest to evaluate the effects of vermin compost application on soil chemical properties. Yield

and yield component data were collected from all experimental plots at harvest. Additionally, data relevant to the economic evaluation of integrated soil fertility management practices were gathered.

2.4. Data Analysis

Collected data were entered into Microsoft Excel and analyzed using SAS software version 9.0. Soil and compost samples were analyzed for their physical and chemical properties following standard laboratory protocols. Economic analysis was conducted using the partial budget method developed by CIMMYT (1998) to identify the most economically viable combination of organic and inorganic fertilizers. The cost of vermin compost was estimated based on its total nitrogen content, a technique commonly used in various parts of Ethiopia and in the UK.

3. Result and Discussion

3.1. Grain Yield and Yield Components

The impact of integrated soil fertility management on the

yield and yield components of maize is summarized in (Table 1). The results unequivocally indicate that there were significant ($P \leq 0.05$) differences among the treatments in grain yield response (Table 1). On other hand, the mean of thousand seed weights, the number of cobs per plant and plant height were also unequivocally exhibited no significant difference ($P > 0.05$) between the treatments. However, treatment two (2) recorded the highest grain yield of 8205.55 kg/ha, where compost substituted nitrogen fertilizer by 100%, followed by treatment 3, where 75%equivalent vermin compost was applied. These findings definitively support previous studies by [17] and [7], who consistently reported an increase in maize yield when using conventional compost to substitute N fertilizer. Furthermore, research by [3] and [15] also demonstrated higher maize grain yield through the integrated application of organic and inorganic fertilizers, attributed to the ability of vermin compost to supplement both macro and micronutrients for improved nutrient use efficiency and grain development. Similar studies have also reported that 4 t/ha vermin compost integrated with inorganic fertilizer increased wheat grain yield during the first cropping season in the western Arsi zone [8].

Table 1. Effect of treatments on yield and yield components.

Treatments	Grain yield in kg /ha	Plant height (cm)	No. Cobs/plant	1000 seed weight (kg)
Recommended NP	7663.88 ^{bc}	183.07	1.13	0.36
100%Equiv. VC+RP	8205.55 ^a	182.25	1.29	0.35
75%Equiv.VC+25%N+RP	7886.71 ^{ab}	184.28	1.13	0.34
50%Equiv.VC+50%N+RP	7369.44 ^c	179.10	1.10	0.36
25%Equiv.VC+75%N+RP	7252.77 ^c	177.96	1.08	0.34
CV (%)	9.40	8.05	14.25	4.20
LSD (0.05)	249.60	17.19	0.38	0.017
Significance	**	NS	NS	NS

Means within column followed by the same letters are not significantly different at $P \leq 0.05$

3.2. Residual Effect of Vermin Compost and Chemical Fertilizer on Soil Properties

3.2.1. Effect of Vermin Compost on Soil pH

Soil pH is an excellent indicator of the suitability of a soil for plant growth. The report indicated that, soil pH levels that are too high or too low lead to a deficiency of many nutrients, decline in microbial activity, decrease in crop yields, and deterioration of soil health. Soil sample analysis indicated that

the pH values were not significantly affected by vermin compost ($P > 0.05$) (Table 2). However, the result varied numerically between treatments, namely the maximum pH value (7.83) was obtained from plots treated with 100%equivalent dose of vermin compost, while the minimum pH (7.10) was obtained from plots treated with 25%equivalent vermin compost (Table 2).

Similarly, soil pH level was not significantly varied between the soil analysis before planting and after harvesting. However, Post-harvest soil pH showed an increasing or positive trend as compared with their initial values at all experi-

mental plots (Table 2).

This was attributed relatively high contents of exchangeable calcium and magnesium in vermin compost. It was identified that vermin compost contains 8792.90 mg/kg calcium and 2662.5 mg/kg magnesium [3]. The result is also strongly in agreement with previous study by [14] indicating that application of vermin compost improves the overall physio chemical properties, and at the same time decreases exchangeable acidity which can support a release of alkaline nutrients such as exchangeable calcium, magnesium and potassium.

3.2.2. Effect of Vermin Compost on Soil CEC

Cation exchange capacity (CEC) is a measure of the total negative charges within the soil that adsorb plant nutrient cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+). As such, the CEC is a property of a soil that describes its capacity to supply nutrient cations to the soil solution for plant uptake. The CEC was significantly ($P \leq 0.05$) influenced by the rates of VC (Table 2). CEC showed a slight increase as the rate of VC increased. Thus, the highest CEC of the soil ($20.43 \text{ cmol kg}^{-1}$) was obtained from the plots treated with highest dose (100% equivalent) of Vermin compost, whereas the lowest ($12.24 \text{ cmol kg}^{-1}$) was from the application of the lowest dose (25% equivalent of vermin compost). This might have resulted from the humic acids contained in vermin compost that bind cations [11]. Similarly, post-harvest CEC values of plots treated with vermin compost were significantly higher than the control plot and CEC in initial soil analysis. Other similar study by [2], demonstrated that the application of vermin compost significantly increased soil organic matter content and soil CEC, leading to improved nutrient availability and plant growth. In addition, [4] reported that vermin compost application increased soil CEC, enhanced microbial activity, and improved soil structure, which collectively contributed to better growth and yield.

3.2.3. Effect of Vermin Compost on Soil Organic Carbon (SOC)

Soil organic carbon content was significantly ($P \leq 0.05$) influenced by application of different rates of vermin compost (Table 2). It showed an increasing trend as the rate of vermin compost was increased. Thus, the highest SOC of (3.24%) was obtained from the plots treated with highest dose (100% equivalent) of Vermin compost, whereas the lowest (0.71%) was identified from the application NP fertilizer alone. In addition, SOC content of the soil before planting and untreated plot were significantly lower than plots treated with different rates of vermin compost (Table 2). This is mainly due to the fact that vermin compost is rich in organic matter, which directly contributes to increasing the soil organic carbon content. The high organic matter content in vermin compost includes stabilized organic compounds like humic acids, which are vital for maintaining long-term soil fertility and carbon levels. Similar findings indicated that vermin compost increased the mi-

crobial biomass and enzymatic activity in soils, leading to higher SOC levels due to enhanced organic matter stabilization [1]. Vermin compost helps in the retention of carbon in the soil by reducing the rate of organic matter mineralization due to the presence of complex organic compounds in vermin compost that slows down decomposition, leading to a build-up of SOC. In addition, vermin compost application resulted in higher SOC levels compared to chemical fertilizers attributed to increased organic matter and improved soil microbial activity [10]. Vermin compost significantly increased SOC by adding organic matter and promoting soil microbial activity, leading to improved soil structure and fertility [5].

3.2.4. Effect of Vermin Compost on Total Nitrogen

Post-harvest total nitrogen content of the soil was significantly ($P \leq 0.05$) influenced by application of different rates of vermin compost (Table 2). It showed an increasing trend as the rate of vermin compost was increased. Thus, the highest TN of (0.21%) was obtained from the plots treated with highest dose (100% equivalent) of Vermin compost, whereas the lowest (0.14%) was identified from the application of 25% equivalent vermin compost and NP fertilizer alone. In addition, TN content of the soil before planting and untreated plot were significantly lower than plots treated with different rates of vermin compost (Table 2). Similar research demonstrated that vermin compost applications lead to higher soil nitrogen content, which correlates with increased strawberry yields [12]. The study provides evidence of improved nitrogen availability as a result of increased organic matter content of vermin compost. This organic matter contains nitrogen in organic forms, which are slowly mineralized to available forms (NH_4^+ and NO_3^-) by soil microorganisms. Vermin compost positively affects the total nitrogen content in soil by increasing organic matter, enhancing microbial activity, and providing a steady supply of nitrogen through mineralization [5]. Its use promotes sustainable agriculture by improving soil fertility and supporting plant growth without the adverse environmental effects associated with chemical fertilizers.

3.2.5. Effect of Vermin Compost on Available Phosphorous

Vermin compost, a product of the decomposition of organic matter by earthworms, has significant effects on soil health and fertility, including the availability of phosphorus (P). Post-harvest available phosphorous of the soil was significantly ($P \leq 0.05$) influenced by application of different rates of vermin compost (Table 2). It showed an increasing trend as the rate of vermin compost was increased. Thus, the highest available phosphorous (41.11 ppm) was obtained from the plots treated with highest dose (100% equivalent) of Vermin compost, whereas the lowest (25.03 ppm) was identified from the application of NP fertilizer alone. In addition, available phosphorous content of the soil before planting and untreated plot were significantly lower than plots treated with different

rates of vermin compost (Table 2). Other similar findings indicated that vermin compost enhances the availability of phosphorus in soil by Earthworms that break down organic matter and convert it into nutrient-rich humus [5]. The microbial activity in vermin compost plays a crucial role in the

mineralization of organic phosphorus compounds, converting them into forms that plants can readily absorb. It was also reported that vermin compost application significantly enhanced soil phosphorus availability leading to better plant growth and higher yields [12].

Table 2. Mean comparisons of post-harvest and initial Soil chemical properties.

Treatment description	Soil pH	SOC (%)	CEC	Avail.P in ppm	TN (%)
Recommended NP	7.17	0.71 ^d	11.90 ^c	25.03 ^b	0.14 ^c
100%Equiv. VC+RP	7.81	3.24 ^a	20.43 ^a	41.11 ^a	0.21 ^a
75%Equiv.VC+25%N+RP	7.59	2.28 ^b	19.03 ^a	40.78 ^a	0.19 ^{ab}
50%Equiv.VC+50%N+RP	7.42	1.64 ^c	16.00 ^b	35.20 ^a	0.16 ^{bc}
25%Equiv.VC+75%N+RP	7.35	0.98 ^d	12.24 ^c	27.60 ^b	0.14 ^c
Initial soil analysis	7.10	0.67 ^d	11.25 ^c	22.68 ^b	0.17 ^b
CV (%)	2.90	13.80	8.80	10.40	11.90
LSD (0.05)	0.67	0.29	1.65	4.20	0.023
Significance	NS	**	**	**	**

Means within column followed by the same letters are not significantly different at $P \leq 0.05$

3.3. Relationship of Soil Organic Carbon and CEC with Maize Grain Yield

Soil organic carbon and CEC have strong positive relations with maize grain yield (Figure 1). Grain yield was increased with increased in SOC ($R^2=51.8$) and CEC ($R^2=52.8$) indicating that their functional relationship is positive. It was reported that soil organic carbon (SOC) and increase CEC boost production and productivity by improving soil nutrient

content, adds to soil aeration, improves the rate of infiltration of water, and the ability of soil to store water [4].

Available phosphorous and total nitrogen have strong positive relations with maize grain yield (Figure 1). Grain yield increase was more related to increase in TN ($R^2=36.52$) and available p ($R^2=30.4$) indicating that their functional relationship is positive. It was reported that integrated application of vermin compost and chemical fertilizers application significantly improved plant height, fruit yield, and nutrient content compared to chemical fertilizers alone [8].

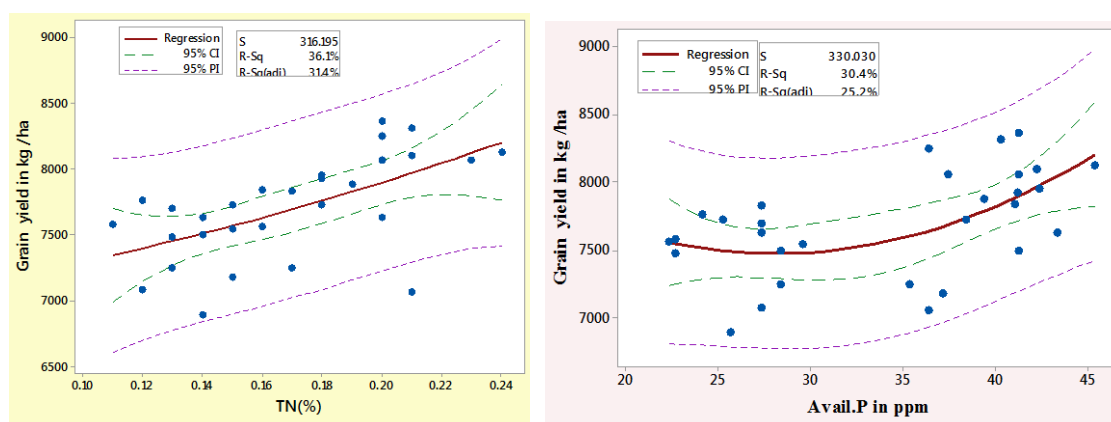


Figure 1. Relationships between grain yield on soil phosphorous and TN.

3.4. Relationship of Soil Available Phosphorus and Total Nitrogen with Maize Grain Yield

Available phosphorous and total nitrogen have strong positive relations with maize grain yield (Figure 2). Grain yield increase was more related to increase in TN ($R^2=36.52$) and

available p ($R^2=30.4$) indicating that their functional relationship is positive. It was reported that integrated application of vermin compost and chemical fertilizers application significantly improved plant height, fruit yield, and nutrient content compared to chemical fertilizers alone [8].

3.5. Relationship of Soil Organic Carbon and CEC

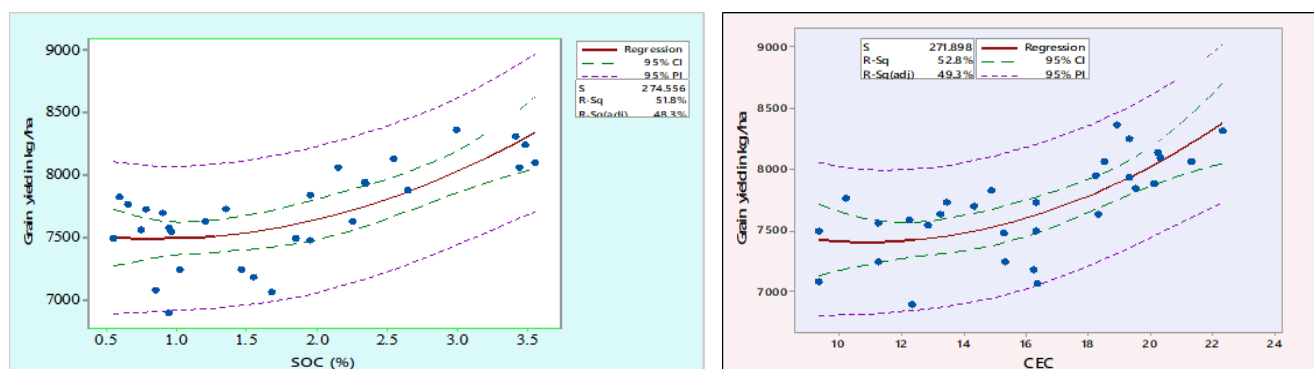


Figure 2. Relationship between Soil Organic Carbon and CEC.

The relationship among selected soil nutrient parameters like SOC, TN, CEC and available P were deployed using correlation matrix. Accordingly, the relationships between soil nutrient parameters were positive (Figure 3).

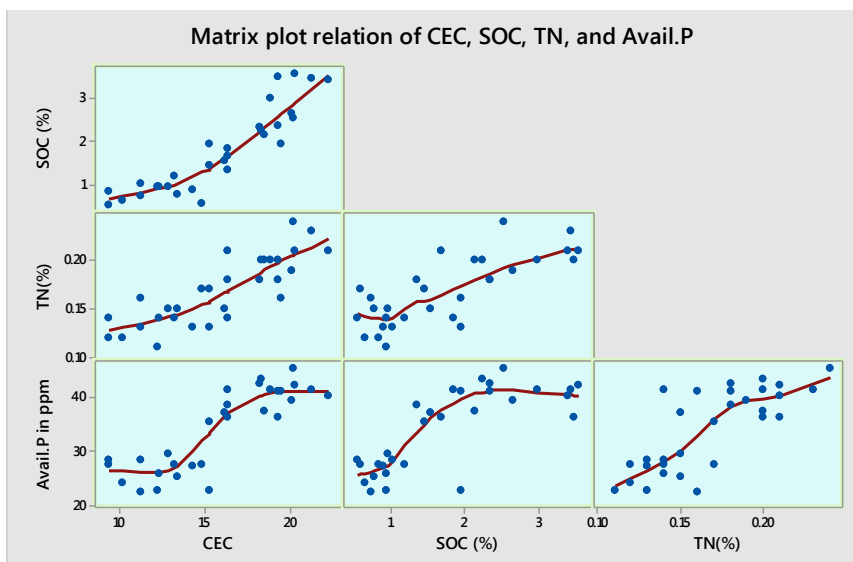


Figure 3. Relationship between CEC, SOC and Avail.P using matrix analysis.

3.6. Partial Budget Analysis for Integrated Soil Fertility Management

Partial budget analysis and marginal rate of return were carried out for the integrated use of vermin compost and NP fertilizers in maize production. As indicated in the (Table 3)

the economic analysis showed that the highest net income (232,943.0 ETB) was obtained from treatment 2 where recommended NP fertilizer rate plus 100% vermin compost were applied followed by application of 75%vermicompost plus 25% N and recommended phosphorus fertilizer in which net income (224,035.8 ETB) was recorded with 1354% and 2269% MRR respectively.

Table 3. Partial budget analysis.

Treatments	MGYkg/ha	Unit cost	NPS in kg	Unit cost	UREA kg	Unit cost	VC in kg	Unit cost	TVC	Gross inc	Net inc	MRR (%)
T1	7663.88	30	121	38	150	40	0.00	0.00	10598.0	229916	219318.4	-
T2	8205.55	30	121	38	0	40	3450.0	2.50	13223.0	246166	232943.5	1354
T3	7886.71	30	121	38	37.5	40	2587.0	2.50	12565.5	236601	224035.8	2269
T4	7369.44	30	121	38	75	40	1725.0	2.50	11910.5	221083	209172.7	433
T5	7252.77	30	121	38	112.5	40	862.50	2.50	11254.2	217583	206328.8	D

4. Conclusion and Recommendations

For sustainable land management, ISFM is very important. Soil analysis indicated that integrated application of vermin compost with chemical fertilizer improves soil nutrient and crop yield. Economically optimum maize grain yield was obtained from application of 100% vermin equivalent plus recommended P_2O_5 (46 kg/ha). Post-harvest soil sample analysis also indicated that major soil nutrients were significantly higher as compared with initial soil analysis. Therefore, implementation of ISFM beside improving maize grain yield, it has a positive residual effect on soil health.

In conclusion, the combined application of 100% vermin-equivalent for N and 46 kg P_2O_5 were economically feasible and is recommended for maize production and soil fertility improvement in the study area.

Abbreviations

AISA	Adequate Input Sustainable Agriculture
Ava.P	Available Phosphorus
CEC	Cation Exchange Capacity
CV	Coefficient of Variation
D	Dominance
ETB	Ethiopian Birr
Gross inc	Gross Income
ISFM	Integrated Soil Fertility Management
J/K	Jido Kombolcha
LSD	Least Significance Difference
MGY	Minimum Grain Yield
MRR	Marginal Rate of Return
Net inc	Net Income
OC	Organic Carbon
SOC	Soil Organic Carbon
TN	Total Nitrogen
TVC	Total Variable Cost
VC	Vermin Compost

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Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Aira, M., Monroy, F., & Dom ínguez, J. (2005). Ageing effects on nitrogen dynamics and enzyme activities in casts of *Aporrectodea caliginosa* (Lumbricidae). *Pedobiologia*, 49(5), 467-473.
- [2] Arancon et al. (2006). Effects of vermin composts on plant growth and marketable fruits of field-grown tomatoes, peppers and strawberries. *Bioresource Technology*, 96(4), 596-603.
- [3] Bekele, A., Kibret, K., Bedadi, B., Balemi, T., & Yli-Halla, M. (2018). Effects of lime, vermin compost and chemical P fertilizer on yield of maize in Ebantu District, Western highlands of Ethiopia. *African Journal of Agricultural Research*, 13(10), 477-489.
- [4] Dejene, K., Dereje, A., & Daniel, G. (2011). Synergistic effects of combined application of organic and inorganic fertilizers on the yield and yield components of tef (*Eragrostis tef* (Zucc.) Trotter) under terminal drought at Adiha, Northern Ethiopia. *Journal of the Drylands*, 3(1).

- [5] Dom ínguez, J., Aira, M., & G ámez-Brand ón, M. (2010). Vermicomposting: earthworms enhance the work of microbes. *Microbes at work: from wastes to resources*, 93-114.
- [6] Getachew, A. and Y. Chilot. 2009. Integrated Nutrient Management in Faba Bean and Wheat on Nitisols of central Ethiopian Highlands. Research Report No. 72. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, pp. 24.
- [7] Kasahun Kitila and Abay Chala, 2019. Evaluation of Compost Integrated with Chemical Fertilizer for better production of Maize in Shashemene District of West Arsi Zone, Oromia, AJAR, 2019; 4: 43.
- [8] Kitila, K., Chala, A., & Workineh, M. (2023). Evaluation of the Application rate of Organic integrated with Chemical Fertilizer on yield and yield components of Maize (Zia Maize) in Dugda District of East shewa Zone, Oromia. In *Regional Review Workshop on Completed Research Activities* (p. 11).
- [9] Lazcano, C., & Dom ínguez, J. (2011). The use of vermin compost in sustainable agriculture: impact on plant growth and soil fertility. *Soil nutrients*, 10(1-23), 187.
- [10] Lim, S. L., Wu, T. Y., Lim, P. N., & Shak, K. P. Y. (2015). The use of vermin compost in organic farming: overview, effects on soil and economics. *Journal of the Science of Food and Agriculture*, 95(6), 1143-1156.
- [11] Pedra F, Plaza C, Garcia-Gill JC, Polo, A. Effects of municipal waste compost and sewage sludge on proton binding behavior of humic acids from Portuguese sandy and clay loam soils. *Bio resource Technology*. 2008; 99: 2141-2147.
- [12] Raza, S. T., Zhu, B., Yao, Z., Wu, J., Chen, Z., Ali, Z., & Tang, J. L. (2023). Impacts of vermicompost application on crop yield, ammonia volatilization and greenhouse gases emission on upland in Southwest China. *Science of the Total Environment*, 860, 160479.
- [13] Satyanarayana, V., Prasad, P. V., Murthy, V. R. K., & And Boote, K. J. (2002). Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *Journal of Plant Nutrition*, 25(10), 2081-2090.
- [14] Singh, R. P., Singh, P., Araujo, A. S. F., Hakimi Ibrahim, M., & Sulaiman, O. (2011). Management of urban solid waste: Vermicomposting a sustainable option. *Resources, Conservation, and Recycling*, 55(7), 719-729.
- [15] Theunissen, J., Ndakidemi, P. A., & Laubscher, C. P. (2010). Potential of vermicompost produced from plant waste on the growth and nutrient status in vegetable production. *International Journal of the Physical Sciences*, 5(13), 1964-1973.
- [16] Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mokwunye, U., Ohiokpehai, O., Pypers, P., Tabo, R., Shepherd, K., Smaling, E. M. A., & Woomer, P. L. (2010). Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. *Outlook on Agriculture*, 39(1), 17-24.
- [17] Wakene, N., Kefyalew, N., Friesen, D.K., Ransom, J. and Abebe, Y., 2001. Determination of optimum farmyard manure and NP fertilizers for maize on farmers fields. pp. 387-393. In: Seventh Eastern and Southern Africa Regional Maize Conference.