Innovation
2025, Vol. 6, No. 1, pp. 1-7
https://doi.org/10.11648/j.innov.20250601.11

Research Article

Cost Effectiveness of Wheat Production Using Vermicompost and NPS Fertilizer at Mao Komo Districts, Western Ethiopia

Jemal Ebrahim*

Ethiopian Institute of Agricultural Research, Assosa Agricultural Research Centre, Assosa, Ethiopia

Abstract

Bread wheat is one of the most important cereal crops produced in Benishangul Gumuz region and in Mao-Komo districts. However, appropriate management practice that combines integrated application of organic and inorganic fertilizer is lacking in Mao-komo. A study was conducted to evaluate economic cost effectiveness of using vermicompost and NPS fertilizer for bread wheat production in the study area. The treatment consists of four levels of vermicompost (0, 5, 10 and 15 t ha^{-1}) and four levels of NPS fertilizer (0, 50, 100 and 150 kg ha^{-1}) were used in randomized complete block design in a factorial arrangement with three replications. Analysis of the result showed that combined application of 10 t ha^{-1} vermicompost & 100 kg ha^{-1} NPS produced grain yield of 3455 kg ha^{-1} with the highest net benefit value of 84221.56 Birr ha^{-1} and the highest marginal rate of return value of 909.24%. with the costs and prices increase by 5%, 10 % and 15% at 10 t vermicompost ha^{-1} & 100 kg ha^{-1} NPS fertilizers gave a higher marginal rate of return (861.18, 817.49 and 777.60 %) respectively. Therefore, if the farmers use by integrating 10 t ha^{-1} vermicompost and 100 kg ha^{-1} NPS, they can be more profitable in the study area.

Keywords

Vermicompost, Bread Wheat, Partial Budget, NPS Fertilizers

1. Introduction

Wheat (Triticum aestivum L.) is one of the most important cereal crops which ranks first among the world food crops, in terms of cultivated area (223.56 m ha) or production (689.95 mt) and with productivity of (3086 kg ha^{-1}) Wheat, with its root ramifying into the depth of human culture has an evolutionary history parallel with history of human civilization itself [10]. It is among the most important crops in the world for food and nutrition. In developing nations, where 1.2 billion people rely on wheat for survival, it serves as the main source of protein. [6].

Ethiopia is considered to be the greatest producer of wheat in Sub-Saharan Africa, and it is one of the main cereal crops grown in the country's highlands [2]. Even though wheat has been grown for a very long time and is important to Ethiopian agriculture, its average yield is still very low—it not often exceeds 2.4 t ha^{-1} [4]. Additionally, it is utilized by the food processing sectors to make regional bread, biscuits, macaroni, and pasta [11].

Due to low soil fertility and acidity issues, wheat production was estimated to cover 1.75 million hectares nationwide

*Corresponding author: Ebrajem35@gmail.com (Jemal Ebrahim)

Received: 7 December 2024; **Accepted:** 19 December 2024; **Published:** 7 January 2025

with an average production of 2764 kg ha^{-1} and 0.30 million ha in Benishangul Gumuz Regional State with an average production of 2414 kg ha^{-1}, below the national average [5].

The average amount of fertilizer used in Ethiopian wheat cultivation (115 kg ha^{-1}) was significantly less than the 250 kg ha^{-1} recommendation made by the Kulumsa Agricultural Research Center [8]. One of the primary causes of inorganic fertilizers for grain crops' inefficient use is their high cost. However, wheat producers in Ethiopia, particularly in Benishangul Gumuz, often do not utilize vermicompost fertilizer because farmers believe it is not cost-effective and the response of different cultivars to vermicompost has not been thoroughly demonstrated. By using a combination of chemical and organic fertilizers, production can be kept at its optimum and less chemical fertilizer is needed, which has a detrimental effect on the environment and production costs [13]. In contrast to conventional compost, vermicompost promoted better growth in brinjal and chili plants, particularly in terms of plant height and yield [14]. By combining locally accessible organic materials with mineral fertilizers, farmers may receive a return of US$7.57 for every US$1.0 investment through the use of 1:1 compost: mineral fertilizer. This suggests that malt barley would be highly profitable [9].

Vermicompost is occasionally used by farmers as organic fertilizer for wheat, and there is some evidence that combining organic fertilizer with NPS can increase yields [7]. So, the objective of this study was to evaluate economic cost effectiveness of using vermicompost and NPS fertilizer for bread wheat production in the study area.

2. Materials and Methods

2.1. Description of the Study Sites

The experiment was carried out during the 2020 cropping season in Mao-Komo areas of Western Ethiopia under rain-fed conditions from August 31 to December 29. At an elevation of 1820 meters above sea level, the Mao-Komo special district is located approximately 687 kilometers west of Addis Ababa and 125 kilometers southeast of Assosa town, which is located at latitude 9° 23′ 12.93″ N and longitude 34° 24′ 27.81″ E. The texture of soil was Silt Loam with a pH of 5.38 (which is strongly acidic) [12]. Ten years of average monthly relative humidity of about 70.8% and ten years of average annual total rainfall of 1299.31 mm.

2.2. Treatments and Experimental Design

Based on N equivalence, the treatments are 4x4 factorial combinations of four NPS rates (0, 50, 100, and 150 kg ha^{-1}) and four vermicompost rates (0, 5, 10, and 15 tons ha^{-1}). The rates were based on 100 kg ha^{-1} of NPS fertilizer and 10 tons ha^{-1} vermicompost (Based on N equivalency). The treatments were arranged in a randomized complete block design (RCBD) with three replications. The test crop was an improved bread wheat variety called "Shorima (ETBW 5483)" (UTQE96 /3/PYN/BAU//Milan), which has the potential to produce average yields of 5.41 t ha^{-1}. NPS fertilizers containing 19% Nitrogen, 38% P_2O_5 and 7% sulfur was used as inorganic fertilizer sources and vermicompost which contain pH of 7.36, total nitrogen content of 0.67%, available phosphorus content of 114.6 ppm, Organic carbon 7.772%, organic matter 13.39% and EC 0.39 mmhos/cm was used as organic fertilizer sources.

2.3. Data Collected

Data were collected on parameters like grain yield, and Straw yield (kg ha^{-1}). Data collected were subjected to analysis of variance (ANOVA) using SAS version 9.2 with computer software statistical package **(**SAS, 2000**)**. The treatments significant differences were separated by using LSD (Least Significant Difference) at 5% level of significance.

2.4. Partial Budget Analysis

The purpose of the partial budget was to compare the gains and losses of each treatment. The following methodology, as recommended by [3], was used to calculate it.

A partial budget was taken into consideration when analyzing the gross benefit (GB), net benefit (NB), total variable cost (TVC), and marginal rate of return (MRR).

Vermicompost cost = 1 Birr kg^{-1}; NPS fertilizer cost = 15 Birr kg^{-1}; Vermicmpost and NPS fertilizer application and transportation cost = 110 Birr t^{-1} and 2.2 Birr kg^{-1} respectively; The local selling price of straw yield is 2 Birr kg^{-1}, whereas the local selling price of wheat grain is 29 Birr kg^{-1}.

Gross field benefit (GFB) (ETB ha^{-1}): was calculated by multiplying the crop's adjusted yield by the field/farm gate price that farmers receive when they sell it.

$$GB = (YA \times PA) + (YB \times PB)$$

Where, GB = Gross benefit, TVC = Total variable cost, NB = Net benefit, MRR = Marginal rate of Return, YA = Grain yield, PA = Price per unit quintal, YB = Straw yield, PB = Price of straw per unit kg.

Total variable cost (TVC) (ETB ha^{-1}): It was the cost of NPS fertilizers, Vermicompost and labour cost involved in the application and transportation of the NPS fertilizer and vermicompost.

Net benefit (NB) (ETB ha^{-1}): It was calculated for each treatment by subtracting the gross field benefits (GFB) from the total variable costs (TVC) as follows: NB = GFB - TVC.

Marginal rate of return (MRR) (%): - It was calculated by dividing the change in total variable cost by the change in net benefit. To decide which treatments would produce the best return on farmers' investments, a marginal rate of grain yield analysis was performed on non-dominated treatments. In order to consider a treatment as worthwhile option to farmers, 100% marginal rate of return (MRR) is minimum acceptable rate of return [3].

MRR (%) = Change in NB (NBb − NBa) / Change in TVC (TCVb − TCVa) × 100

2.5. Sensitivity Analysis

was determined by redoing of a marginal analysis with alternative price incensement by 5%, 10% and 15% in order to determine the range over which a given treatment might be recommended.

3. Results and Discussion

The main effects of Vermicompost and NPS fertilizer were highly significant ($P < 0.01$) and their interaction effect was significant ($p < 0.05$) on grain yield. The combination of 10 t ha^{-1} vermicompost & 150 kg ha^{-1} NPS fertilizers produced the highest grain yield **(**3565.7 kg ha^{-1}) followed by the combinations of 10 t ha^{-1} vermicompost & 100 kg ha^{-1} NPS fertilizers produced grain yield of (3455 kg ha^{-1}) while the lowest grain yield (1983.3kg ha^{-1}) was recorded at 0 t ha^{-1} vermicompost and 0 kg ha^{-1} NPS fertilizers. In line with this result [17] reported that an average yields of three crops (wheat, maize, and rice) improved by 29% when organics plus chemical fertilizers were applied, compared to 8% when fertilizer was used alone.

The experimental site's poor soil fertility level may have contributed to the significant yield difference between treatments; however, when vermicompost was added to the soil along with NPS fertilizers, the soil became fertile and reached a level that enabled a higher yield. Similarly, [1] who reported that the mean grain yield of bread wheat was significantly increased by the application of both organic and inorganic fertilizers ($P<0.05$). In agreement with this [15] reported that in comparison to chemical fertilizers, vermicompost is more cost-effective. Its long-term benefits for the soil and increased yield benefit farmers as well as the national economy. Vermicompost can be used as a cost-effective and environmentally safe method to turn organic materials into fertilizer while guaranteeing higher crop yields [16]. In addition, the combination of 15 t ha^{-1} vermicompost & 150 kg ha^{-1} NPS produced the highest straw yield **(**4848.6 kg ha^{-1}) while the lowest straw yield (3166.7 kg ha^{-1}) was produced from 5 t ha^{-1} vermicompost & 0 kg ha^{-1} NPS fertilizers.

Table 1. *The interaction effects of vermicompost and NPS fertilizers on grain yield of bread wheat at Mao-komo in 2020 cropping season.*

Treatment	**NPS fertilizer kg ha^{-1}**			
Vermicompost t ha^{-1}	**0**	**50**	**100**	**150**
0	1983.3^{l}	2183.9^{kl}	2086.7^{l}	2534^{h-j}
5	2300^{j-l}	2631^{g-i}	2827^{e-h}	2926.3^{d-g}
10	2410.3^{i-k}	3132^{c-e}	3455^{ab}	3565.7^{a}
15	2733.3^{f-h}	3027.3^{c-f}	3235.3^{b-d}	3340.3^{a-c}
LSD (5%)	322.04			
CV (%)	6.96			

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; Means with a column followed by the same letter(s) are not significantly different at 5% level of significance.

3.1. Partial Budget Analysis of Vermicompost and NPS Fertilizer Application

Although the optimal combination of treatments produced the highest grain yield (3565.7 kg ha^{-1}), it might not be cost-effective for a final recommendation. The partial budget analysis showed that the application of 10 t ha^{-1} vermicompost and 100 kg ha^{-1} NPS fertilizers produced the most cost-effective treatment combination, which gave grain yields of 3455 kg ha^{-1} and adjusted grain yields of 3109.5 kg ha^{-1} with a net benefit value of 84221.56 Birr ha^{-1} and marginal rate of return (MRRs) of 909.24%, while the control treatment produced the lowest net benefit, 57834.09 Birr ha^{-1} (Table 2). A higher marginal rate of return (MRRs) of 909.24% was obtained at 10 t vermicompost ha^{-1} and 100 kg NPS fertilizers ha^{-1}, suggesting that these rates were the most cost-effective for the crop in this study. Similarly, [18] reported that cost production of a bag of organic fertilizer was one-fourth cheaper compared to an inorganic fertilizer price from an open market.

For farmers in the Mao-Komo district and other regions with comparable agro-ecological conditions, the application of 10 t ha^{-1} vermicompost and 100 kg ha^{-1} NPS fertilizers is therefore still economical.

Table 2. Partial budget analysis of the response of wheat to the application of vermicompost and NPS at Mao-komo districts in 2020.

Treatment	Wheat yield kg ha^{-1}				Income (ETB ha^{-1})					
vermicompost t ha^{-1}*NPS kg ha^{-1}	GY	STY	10% AGY	10% ASY	GY	SY	Gross field benefit (Birr ha^{-1})	TVC (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR (%)
0*0	1983.3	3372.2	1784.97	3034.98	51764.13	6069.96	57834.09	0	57834.09	
0*50	2183.9	3393.8	1965.51	3054.42	56999.79	6108.84	63108.63	860	62248.63	513.32
0*100	2086.7	3640	1878.03	3276	54462.87	6552	61014.87	1715	59299.87	D
0*150	2534	3299.1	2280.6	2969.19	66137.4	5938.38	72075.78	2570	69505.78	424.40
5*0	2300	3166.7	2070	2850.03	60030	5700.06	65730.06	5550	60180.06	D
5*50	2631	3602.3	2367.9	3242.07	68669.1	6484.14	75153.24	6410	68743.24	D
5*100	2827	3606.3	2544.3	3245.67	73784.7	6491.34	80276.04	7265	73011.04	74.66
5*150	2926.3	3682.6	2633.67	3314.34	76376.43	6628.68	83005.11	8120	74885.11	219.19
10*0	2410.3	3267.5	2169.27	2940.75	62908.83	5881.5	68790.33	11100	57690.33	D
10*50	3132	3701.3	2818.8	3331.17	81745.2	6662.34	88407.54	11960	76447.54	40.69
10*100	3455	3811.7	3109.5	3430.53	90175.5	6861.06	97036.56	12815	84221.56	909.24
10*150	3565.7	4201	3209.13	3780.9	93064.77	7561.8	100626.57	13670	86956.57	319.88
15*0	2733.3	3255.2	2459.97	2929.68	71339.13	5859.36	77198.49	16650	60548.49	D
15*50	3027.3	4006	2724.57	3605.4	79012.53	7210.8	86223.33	17510	68713.33	D
15*100	3235.3	4664.7	2911.77	4198.23	84441.33	8396.46	92837.79	18365	74472.79	D
15*150	3340.3	4848.6	3006.27	4363.74	87181.83	8727.48	95909.31	19220	76689.31	D

MRR (%) = Marginal Rate of Return; GY = Grain yield; SY= Straw yield; AGY= Adjusted grain yield; ASY=Adjusted Straw Yield, ETB=Ethiopian birr, Vermicompost cost = 1 Birr kg^{-1}; NPS cost = 15 Birr kg^{-1}; VC and NPS application and transportation= 110Birr t^{-1} and 2.2 Birr kg^{-1} respectively; wheat grain local selling price = 29 Birr kg^{-1}; Straw yield local selling price 2 Birr kg^{-1}; TVC = Total variable cost; VC= Vermicompost D= Dominated treatment.

3.2. Sensitivity Analysis

Sensitivity analysis is just a rerun of a marginal analysis with different costs to determine the range that particular treatments may be recommended for. Partial budget and marginal rate of return (MRRs) with the costs and prices increase by 5%, 10 % and 15% at 10 t ha^{-1} vermicompost & 100 kg ha^{-1} NPS fertilizers gave a value that was higher marginal rate of return (MRRs) value of 861.18, 817.49 and 777.60 % respectively, (Table 3 a, b and Table 4 c, d) indicating that 10 t vermicompost ha^{-1} & 100 kg NPS fertilizers ha^{-1} used in this study were the a consistence and higher marginal rate of return (MRRs) (Figure 1).

Table 3. a & b partial budget and MRRs with the original costs and prices (a) and at 5% costs and prices (b) increase.

Part Aa	T1	T2	T4	T7	T8	T10	T11	T12
Average Yield (kgha^{-1})	1983.3	2183.9	2534	2827	2926.3	3132	3455	3565.7
Adjusted Yield (kgha^{-1})	1784.97	1965.51	2280.6	2544.3	2633.67	2818.8	3109.5	3209.13
Average Straw Yield (kgha^{-1})	3372.2	3393.8	3299.1	3606.3	3682.6	3701.3	3811.7	4201
Adjusted Straw Yield(kgha^{-1})	3034.98	3054.42	2969.19	3245.67	3314.34	3331.17	3430.53	3780.9

Part Aa	**T1**	**T2**	**T4**	**T7**	**T8**	**T10**	**T11**	**T12**
Gross Field Benefit(Birr ha^{-1})	57834.09	63108.63	72075.78	80276.04	83005.11	88407.54	97036.56	100626.57
Fertilizer Cost(Birr ha-1)	0	750	2250	6500	7250	10750	11500	12250
Application Cost(Birr ha^{-1})	0	100	300	500	600	700	800	900
Transportation Cost(Birr ha^{-1})	0	10	20	265	270	510	515	520
Total Variable cost(Birr ha^{-1})	0	860	2570	7265	8120	11960	12815	13670
Net Benefit(Birr ha^{-1})	57834.09	62248.63	69505.78	73011.04	74885.11	76447.5	84221.56	86956.57
Marginal Rate of Return (%)		513.3186	424.3947	74.65942	219.1895	40.68828	909.242105	319.884
Part b of the table represents the partial budget and MRRs with the costs and prices increase by 5%								
Part Bb	T1	T2	T4	T7	T8	T10	T11	T12
Average Yield (kgha^{-1})	1983.3	2183.9	2534	2827	2926.3	3132	3455	3565.7
Adjusted Yield (kgha^{-1})	1784.97	1965.51	2280.6	2544.3	2633.67	2818.8	3109.5	3209.13
Average Straw Yield (kgha^{-1})	3372.2	3393.8	3299.1	3606.3	3682.6	3701.3	3811.7	4201
Adjusted Straw Yield(kgha^{-1})	3034.98	3054.42	2969.19	3245.67	3314.34	3331.17	3430.53	3780.9
Gross Field Benefit(Birr ha^{-1})	57834.09	63108.63	72075.78	80276.04	83005.11	88407.54	97036.56	100626.57
Fertilizer Cost(Birr ha-1)	0	787.5	2362.5	6825	7612.5	11287.5	12075	12862.5
Application Cost(Birr ha^{-1})	0	10.5	21	278.25	283.5	535.5	540.75	546
Transportation Cost(Birr ha^{-1})	0	105	315	525	630	735	840	945
Total Variable cost(Birr ha^{-1})	0	903	2698.5	7628.25	8526	12558	13455.75	14353.5
Net Benefit(Birr ha^{-1})	57834.09	62205.63	69377.28	72647.79	74479.11	75849.54	83580.81	86273.07
Marginal Rate of Return (%)		484.113	399.4236	66.34231	203.99	33.98884	861.182957	299.8897243

Table 4. *c and d the partial budget analysis with the cost and price incensement by 10% (c) and15% (d).*

Part Cc	**T1**	**T2**	**T4**	**T7**	**T8**	**T10**	**T11**	**T12**
Average Yield (kgha^{-1})	1983.3	2183.9	2534	2827	2926.3	3132	3455	3565.7
Adjusted Yield (kgha^{-1})	1784.97	1965.51	2280.6	2544.3	2633.67	2818.8	3109.5	3209.13
Average Straw Yield (kgha^{-1})	3372.2	3393.8	3299.1	3606.3	3682.6	3701.3	3811.7	4201
Adjusted Straw Yield(kgha^{-1})	3034.98	3054.42	2969.19	3245.67	3314.34	3331.17	3430.53	3780.9
Gross Field Benefit(Birr ha^{-1})	57834.09	63108.63	72075.78	80276.04	83005.11	88407.54	97036.56	100626.57
Fertilizer Cost(Birr ha-1)	0	825	2475	7150	7975	11825	12650	13475
Application Cost(Birr ha^{-1})	0	110	330	550	660	770	880	990
Transportation Cost(Birr ha^{-1})	0	11	22	291.5	297	561	566.5	572
Total Variable cost(Birr ha^{-1})	0	946	2827	7991.5	8932	13156	14096.5	15037
Net Benefit(Birr ha^{-1})	57834.09	62162.63	69248.78	72284.54	74073.11	75251.54	82940.06	85589.57
Marginal Rate of Return (%)		457.56	376.72	58.78	190.17	27.90	817.49	281.71
Part d of the table represents the partial budget and MRRs with the costs and prices increase by 15%								
Part Dd	T1	T2	T4	T7	T8	T10	T11	T12
Average Yield (kgha^{-1})	1983.3	2183.9	2534	2827	2926.3	3132	3455	3565.7

Part Cc	T1	T2	T4	T7	T8	T10	T11	T12
Adjusted Yield (kgha^{-1})	1784.97	1965.51	2280.6	2544.3	2633.67	2818.8	3109.5	3209.13
Average Straw Yield (kgha^{-1})	3372.2	3393.8	3299.1	3606.3	3682.6	3701.3	3811.7	4201
Adjusted Straw Yield (kgha^{-1})	3034.98	3054.42	2969.19	3245.67	3314.34	3331.17	3430.53	3780.9
Gross Field Benefit (Birr ha^{-1})	57834.09	63108.63	72075.78	80276.04	83005.11	88407.54	97036.56	100626.57
Fertilizer Cost (Birr ha-1)	0	862.5	2587.5	7475	8337.5	12362.5	13225	14087.5
Application Cost (Birr ha^{-1})	0	11.5	23	304.75	310.5	586.5	592.25	598
Transportation Cost (Birr ha^{-1})	0	115	345	575	690	805	920	1035
Total Variable cost (Birr ha^{-1})	0	989	2955.5	8354.75	9338	13754	14737.25	15720.5
Net Benefit (Birr ha^{-1})	57834.09	62119.63	69120.28	71921.29	73667.11	74653.54	82299.31	84906.07
Marginal Rate of Return (%)		433.3205	355.9954	51.87776	177.5561	22.33764	777.601831	265.1167048

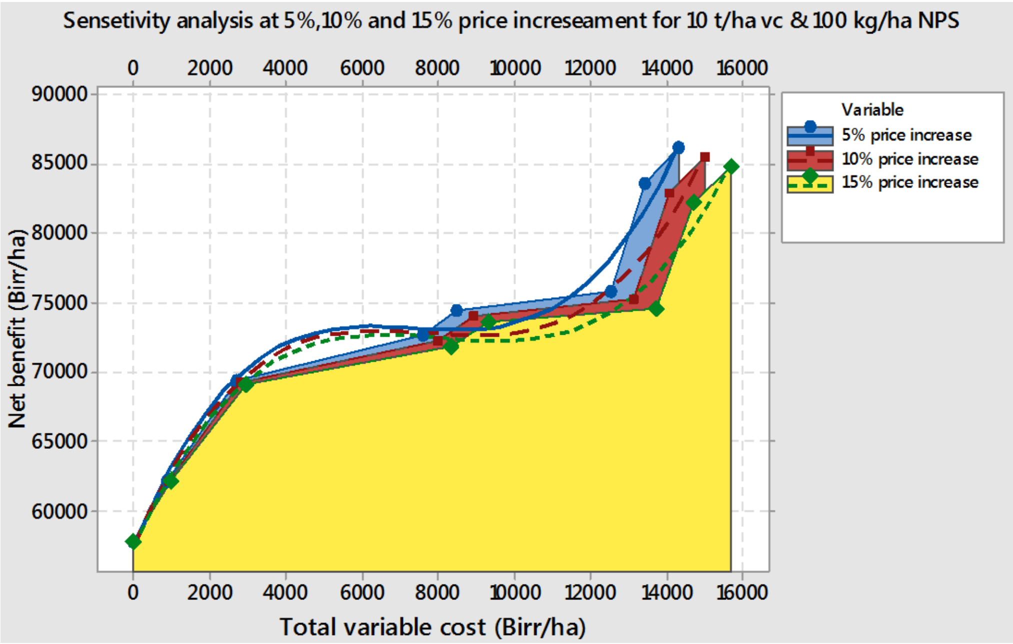

Figure 1. Sensitivity analysis graph for 10 t ha^{-1} vermicompost & 100 NPS fertilizers kg ha^{-1} at 5%, 10% and 15% price incensement at Mao-komo districts in 2020.

4. Summary and Conclusion

It can be summarized that integrated application of 10 t ha^{-1} vermicompost and 100 kg ha^{-1} NPS fertilizer, increase wheat grain yield and economical. The partial budget analysis indicated that the best economical treatment combination was recorded from the application of 10 t ha^{-1} vermicompost and 100 kg ha^{-1} NPS fertilizers that gave the grain yield of 3455 kg ha^{-1} and adjusted grain yield of 3109.5 kg ha^{-1} with the net benefit value of 84221.56 Birr ha^{-1} and marginal rate of return (MRRs) 909.24%. Sensitivity analysis also showed that partial budget and marginal rate of return (MRRs) with the costs and prices increase by 5%, 10 % and 15% at 10 t ha^{-1} vermicompost & 100 kg ha^{-1} NPS fertilizers gave a higher marginal rate of return (MRRs) value of 861.18, 817.49 and 777.60% respectively, indicating that using 10 t ha^{-1} vermicompost & 100 kg NPS fertilizers ha^{-1} in this study area were a consistence economical and higher marginal rate of return (MRRs).

Therefore, it can be concluded that application of 10 t ha^{-1} vermicompost & 100 kg NPS fertilizers economically feasible, cost effective and practically easy and can be tentatively recommended for farmers for production of wheat in the study area.

Abbreviations

VC	Vermicompost
pH	Potential of Hydrogen
BMI	Body Mass Index
GY	Grain Yield
AGY	Adjusted Grain Yield
MRR	Marginal Rate of Return
NB	Net Benefit
STY	Straw Yield
ETB	Ethiopian Birr
TVC	Total Variable Cost

Author Contributions

Jemal Ebrahim is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Almaz Admasu and Tadesse K. 2018. Response of organic and inorganic fertilizers on growth and yield of wheat at Kulumsa in Arsi highlands of Ethiopia. *Open Access Journal of Agricultural Research, 3 (6): 2474-8846*.

[2] Belete, F., Dechassa, N., Molla, A. and Tana, T., 2018. Effect of nitrogen fertilizer rates on grain yield and nitrogen uptake and use efficiency of bread wheat (Triticum aestivum L.) varieties on the Vertisols of central highlands of Ethiopia. *Agriculture & Food Security*, *7*(1), pp. 1-12. https://doi.org/10.1186/s40066-018-0231-z

[3] CIMMYT, 1988. *From agronomic data to farmer recommendations: an economics training manual*. No., 27.

[4] CSA (Central Statistic Agency). Agricultural sample suvey report on area and production of major crops for the period 2013/2014 cropping season. Vol I. Statistical Bulletin 532, Addis Ababa; 2014.

[5] CSA (Central Statistical Agency), 2019. Agricultural sample survey 2018/2019. *Volume I report on area and production of major crops*. Addis Ababa, Ethiopia.

[6] CIMMYT (Centro International de Mejoramiento de Maiz y Trigo/ International Maize and Wheat Improvement Center), 2011. Wheat Global alliance for improving food security and the livelihoods of the resource poor in the developing world. Proposal submitted by CIMMYT and ICARDA to the CGIAR Consortium Board. August 30, 20.

[7] Deshmukh, S. S., Chaudhari, V. S., Narkhede, S. D., Jadhav, R. N. and Attarde, S. B., 2011. Effect of three different composts on the growth rate of wheat (Triticum aestivum). http://www.hindagrihorticulturalsociety.co.in/

[8] KARC (Kulumsa Agricultural Research Center). 2014. Progress report of Land and Water Research Process of KARC for the year 2014. Kulumsa, Ethiopia.

[9] Kassu Tadesse, Mekonnen Asrat and Almaz Admasu. 2018. Malting barley response to integrated organic and mineral nutrient sources in Nitisol. *International Journal of Recycling of Organic Waste in Agriculture*, *7*(2), pp. 125-134. https://doi.org/10.1007/s40093-018-0198-

[10] Kumar, P. R. and Varaiya, P., 2015. *Stochastic systems: Estimation, identification, and adaptive control*. Society for industrial and applied mathematics.

[11] Molla, H., Gashaw, M., & Wassie, H. (2018). Response of bread wheat to integrated application of vermicompost and NPK fertilizers. *African Journal of Agricultural Research*, *13*(1), 14-20. https:// doi.org/10.5897/ajar2017.12720

[12] Murphy, G. I., 1968. Pattern in life history and the environment. The American Naturalist, 102(927), pp. 391-403. https://doi.org/10.1086/282553

[13] Shata, S. M., Mahmoud, A. and Siam, S., 2007. Improving calcareous soil productivity by integrated effect of intercropping and fertilizer. *Research Journal of Agriculture and Biological Sciences*, *3*(6), pp. 733-739.

[14] Katiyar, R. B., Sundaramurthy, S., Sharma, A. K., Arisutha, S., Pratap-Singh, A., Mishra, S., Ayub, R., Jeon, B. H. and Khan, M. A., 2023. Vermicompost: An Eco-Friendly and Cost-Effective Alternative for Sustainable Agriculture. *Sustainability*, *15*(20), p. 14701. https://doi.org/10.3390/su152014701

[15] Kayabaşı, E. T. and Yılmaz, O., 2021. The importance of vermicompost in agricultural production and economy. *Eurasian Journal of Agricultural Research*, *5*(2), pp. 146-159. https://dergipark.org.tr/en/pub/ejar

[16] Jjagwe, J., Chelimo, K., Karungi, J., Komakech, A. J. and Lederer, J., 2020. Comparative performance of organic fertilizers in maize (Zea mays L.) growth, yield, and economic results. *Agronomy*, *10*(1), p. 69. https://doi.org/10.3390/agronomy10010069

[17] Wei, W., Yan, Y., Cao, J., Christie, P., Zhang, F. and Fan, M., 2016. Effects of combined application of organic amendments and fertilizers on crop yield and soil organic matter: An integrated analysis of long-term experiments. *Agriculture, Ecosystems & Environment*, *225*, pp. 86-92. https://doi.org/10.1016/j.agee.2016.04.004

[18] Deba, F. A., Isma'il, S., Sahal, M. R. and Okpanachi, I. Y., 2019. Evaluation of economic importance of locally produced manure over inorganic fertilizer for maize production: vegetative performance and cost implication. *American Journal of Molecular Biology*, *9*(2), pp. 64-74. https://doi.org/10.4236/ajmb.2019.92006

Research Field

Jemal Ebrahim: Plant Science, Agronomy and physiology, Horticultural crops