

Research Article

Integrated Effect of Vermicompost and NP Fertilizer on Soil Physico-Chemical Properties and Yield of Bread Wheat Under Limed Condition in Kofele District, Oromia, Ethiopia

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Abstract

Soil acidity is a major constraint to agricultural productivity throughout Ethiopia where high rainfall is common due to the deficiencies of nitrogen by leaching, phosphorus by fixation, and low soil organic matter. To cope with these production constraints, using lime and vermicompost was recommended. Vermicompost is one of the organic fertilizers with a low C: N ratio, high porosity and high water-holding capacity, in which most nutrients are present in forms that are readily available for plants. The use of lime in crop production is also believed to enhance soil health status through improving soil pH, base saturation and enhance P availability, which in turn improve crop performance. Therefore, the application of vermicompost and lime is recommended to cope with problem of soil acidity by raising acidic soil PH and to increase soil fertility. Kofele district is one of the Ethiopian highlands and specifically because of the severity of soil acidity problem. Therefore, this study was designed to determine integrated effect of vermicompost, lime and chemical fertilizer on yield and yield components of bread wheat and selected soil physico-chemical properties. Recommended NP fertilizers, 100%, 75%, 50%, and 25% N equivalent of vermicompost were used as treatments. The mean analysis of variance showed that, there were significant ($P < 0.05$) differences among treatments for plant height, spike length, grain yield, and biomass of wheat. The highest yield (4132 kg/ha) was recorded for the application of recommended rate of NP fertilizers followed by the application of 75% N + 25% N equivalent level of vermicompost + recommended rate of P fertilizer. Soil samples were collected before planting and after harvesting to evaluate the residual effect of vermicompost on soil properties. In general, the nutrient status of post-harvest soils was greatly enhanced as compared to the initial soil. Economic analysis was also done and the highest net income (152,888 ETB) was obtained from the application of the recommended fertilizer rate followed by the application of 75% N + 25% N equivalent level of VC + recommended rate of P fertilizer in which net income (150,872 ETB) was recorded. In conclusion, the integrated application of 75% N + 25% N equivalent level of VC + recommended rate of P fertilizer was improved yield of bread wheat and soil chemical properties and recommended in the study area in parallel to recommended rate of fertilizer.

Keywords

Soil Fertility, Lime Application, Soil Organic Carbon, Integrated Application, Vermicompost (VC) and Chemical Fertilizers

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1. Introduction

Wheat is globally one of the most important cereal crops in terms of area and production. Ethiopia is the largest wheat producer in sub-Saharan Africa covering an estimated area of 1.7 million ha with annual production of 4.6 million tons [4]. However, the current wheat production is inadequate to fill Ethiopia's needs due to low soil fertility and soil management practices. The major constraints to agricultural production in Ethiopian highlands could be the decline in soil organic matter, nutrient imbalance, and soil acidity problems [6].

Soil acidity is a major constraint to agricultural productivity throughout Ethiopia where high rainfall is common due to the deficiencies of nitrogen (N) by leaching, phosphorus (P) by fixation, and low soil organic matter. Hence, it requires a serious threat to crop production in most highlands and a major crop production constraint in the small-scale farmers of the country [9, 5].

To cope with these production constraints, using lime, vermicompost, biochar, and compost were recommended by several authors [7, 1, 5, 2]. Vermicompost is one of the stabilized organic fertilizers with a low C: N ratio, high porosity, and high water-holding capacity, in which most nutrients are present in forms that are readily available for plants. The use of lime in crop production is also believed to enhance soil health status through improving soil pH, base saturation, Ca, Mg and enhance P availability, which in turn improve crop performance. Therefore, the application of vermicompost and lime are recommended to cope with problem of soil acidity by raising acidic soil PH and to increase soil fertility [5, 1].

Vermicompost reduces production cost and it is an environmentally friendly method of agricultural inputs technology.

However, use of vermicompost alone has a slow but positive effect in releasing nutrients since they require microbial activity to decompose it. On other hand inorganic fertilizers are rapid for nutrient availability but expensive and are easily leached from the soil. Therefore, integrated application of organic and inorganic fertilizer under limed condition is economical and a viable solution to restore, increase yield of crops and improve productivity of the soil sustainably [1].

Kofele district is one of the Ethiopian highlands and specifically because of the severity of soil acidity problem; many crops give a very low productivity in the study area. Therefore, this study was designed with the following objectives to determine integrated effect of vermicompost and chemical fertilizer on yield and yield components of bread wheat and chemical fertilizer on selected soil physicochemical properties.

2. Materials and Methods

2.1. Descriptions of the Study Area

Kofele district which is located in West Arsi zone of Oromia Regional State in the central highlands of Ethiopia and far 280 km from Finfenne. Geographically the district is located between 6°50'55" to 7°9'40" North latitudes and 38°39'08" to 39°3'4" East longitudes with an altitude of 2620 m above sea level above sea level. The mean annual rainfall is 1036 mm and characterized by high altitude in the humid temperate climatic zones. The mean maximum and minimum temperatures of the District are 19.64 and 7.53°C, respectively.

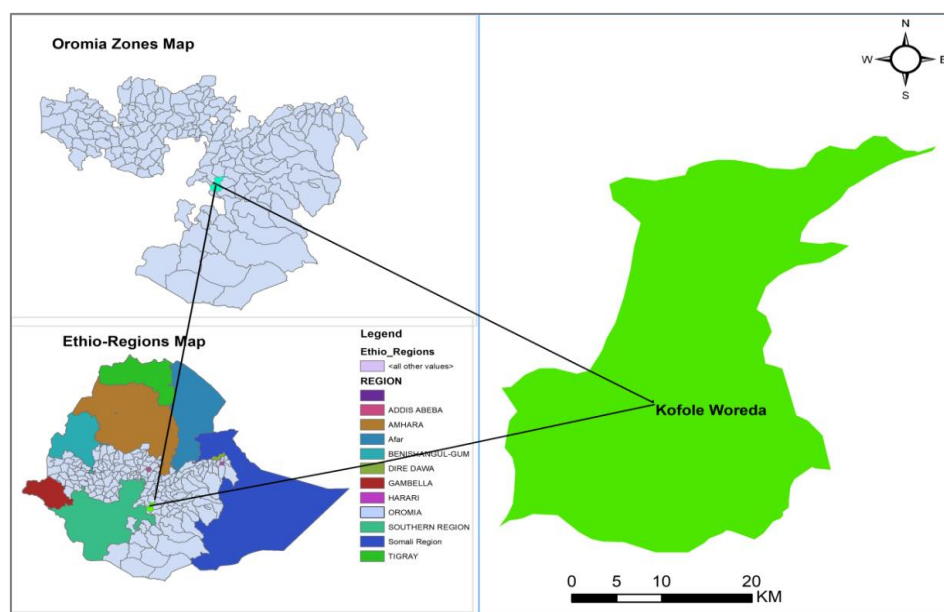


Figure 1. Maps of the study area.

2.2. Materials

Lime, vermicompost, inorganic fertilizers (NP and urea), 'Ogolcho' wheat variety, pesticide, and herbicide will be used for the experiment.

2.3. Soil Sampling and Analysis

Composite surface soil samples were collected across the district at 0-20 cm depth from each experimental site before sowing and after harvesting. The collected soil samples were prepared and analyzed for soil pH, EC, available P, available K, OC, TN, and CEC following standard procedures at Batu Soil Research Center.

2.4. Vermicompost Preparation and Analysis

Based on the availability of composting materials, vermicompost was prepared as a head-of-field experiment from animal manure and wheat straw as bedding materials. The vermicompost was prepared in shallow wood boxes with the dimensions of 0.4 m height, 0.6 m width, and 1 m length. The wheat straw was chopped and mixed with animal manure in 50:50 ratios and the mixtures were left with moisture for two weeks to degrade into smaller particles (partially digested) to make it palatable for the worms. Then; the earthworms were incorporated and at the maturity stage approximately one kg of the vermicompost was collected and taken to the laboratory for its nutrient analysis (pH, EC, Available P, Available K, OC, TN, and CEC).

3. Methods

3.1. Experimental Design and Treatments

The experiment was conducted on a Farmers' field in Kofele district for two consecutive years (2022 -2023). The experimental fields were prepared by using oxen plow and Ogolcho wheat variety was used as a test crop. The vermicompost was applied at five N equivalence levels: (0, 25%, 50%, and 75% and 100%. The field experiment was carried out using six treatments and the treatments were laid out in a randomized complete block design (RCBD) with two replications having a plot size 4 m x 5 m. Recommended P fertilizer ($P_c = 19$, $P_f = 3.30$ and 69 kg N ha^{-1}) and lime was applied to all treatments equally; however urea will be deduced based on the N equivalence of vermicompost. Using the result of exchangeable acidity, the lime requirement was calculated and applied uniformly to all treatments a month before planting. The amount of lime to be applied was calculated as: *Lime requirement (Q_t/ha) = Exchangeable acidity x*

1.5 x 10. The treatments were set based on the nitrogen equivalency of vermicompost and the recommended rate of inorganic fertilizers.

Treatments setup

T1 = Control (without fertilizer)

T2 = Recommended rate of chemical fertilizer

T3 = 25% N + 75% N equivalent level of VC + Recommended P fertilizer

T4 = 50% N + 50% N equivalent level of VC + Recommended P fertilizer

T5 = 75% N + 25% N equivalent level of VC + Recommended P fertilizer

T6 = 100% N equivalent level of VC + Recommended P fertilizer

3.2. Data Collection and Analysis

The agronomic and yield data such as plant height, spike length, number of seed per spike, biomass, and grain yield were collected. The data collected across the locations were properly managed using EXCEL computer software. All the collected data was subjected to the analysis of variance (ANOVA) as per the experimental design using GenStat, 2012 (15th edition) software.

4. Results and Discussion

4.1. Pre-Soil Chemical Properties

Composite soil samples were collected at 0-20 cm depth from each experimental site before planting and analyzed for soil physico-chemical properties (Table 1). Soil pH was measured by glass electrode of pH meter at 1:2.5 soils to water ratios and EC was by a conductivity meter. The pre-soil analysis result showed that, the soil pH was ranges from 5.04-5.38 which is in the range of strongly acidic to moderately acidic soil reaction range as per the soil pH rating [11]. The soil organic carbon was determined using the Walkley-Black wet oxidation procedure and the soil organic carbon content of the experimental site (2.4%) was in the moderate range. The total nitrogen content in the soils was determined using the Kjeldahl procedure. Furthermore, the total nitrogen of study area (0.23%) was rated as moderate in total nitrogen. The soil available phosphorus of experimental site was 9.62 ppm, which was in the midium range [10] for available soil phosphorus. Similarly, the cation exchange capacity (20.47 meq/100 gm soil) of the experimental site was determined by neutral ammonium acetate extraction and rated as moderate [8].

Table 1. The physico-chemical properties of pre-soil sample.

No.	Chemical Properties	Average Values
1	pH (1:2.5 soils to water)	5.11
2	Electrical Conductivity (dS/m)	0.16
3	Organic Carbon (%)	2.43
4	Total Nitrogen (%)	0.23
5	Available Phosphorus (ppm)	9.62
6	Available potassium (mgkg ⁻¹)	106.68
6	Exchangeable Acidity (meq/100 g soil)	0.34
7	Cation Exchange Capacity (meq/100 gm)	20.47

4.2. Chemical Properties of Vermicompost

Based on the availability of materials in the district, vermicompost was prepared from animal manure and wheat straw. The wheat straw was mixed with animal manure in 50:50 ratios and the mixtures were left with moisture for two

weeks to degrade into smaller particles (partially digested) to make it palatable for the worms. Then; the earthworms were incorporated and at the maturity stage approximately one kg of the vermicompost was collected and tested for its nutrient (pH, electro conductivity, available phosphorus, available potassium, organic carbon, total nitrogen, and cation exchange capacity).

Table 2. The physico-chemical properties of vermicompost.

No.	Chemical Properties	Average Values
1	pH (1:5 soils to water)	7.62
2	Electrical Conductivity (dS/m)	1.91
3	Organic Carbon (%)	2.15
4	Total Nitrogen (%)	1.32
5	Carbon to Nitrogen ratio	1.63
6	Available Phosphorus (ppm)	156.35
7	Cation Exchange Capacity (meq/100 gm)	64.45

4.3. The Effect of Vermicompost on Soil Chemical Properties

Composite samples of post-harvest soils were collected at 0-20 cm depth from each experimental site before planting and after harvesting. The collected soil samples were prepared and analyzed for soil pH, EC, available P, available K, OC, TN, and CEC following standard procedures at Batu Soil Research Center.

The residual effect of vermicompost was evaluated by

comparing the post-harvest soil chemical properties between the treatments and pre-soil results. The maximum amount of pH, Av. P, OC, TN, and CEC was recorded from the maximum application of vermicompost rate (100% N equivalent level of VC) as compared to the other treatments and pre-soil sample nutrient contents (Table 3). In general, as the application rate of vermicompost increased, the nutrient status of the post-harvest soils was also increased. Moreover, the nutrient status of the post-harvest soil was enhanced by the application of vermicompost as compared to the pre-soil sample (Table 3).

Table 3. Chemical Properties of post-harvest soil samples.

No	Treatments	pH	EC (dS/m)	Av. P (ppm)	OC (%)	TN (%)	Av. K (mg/kg)	CEC (meq/100 gm)
1	Control	5.55	0.18	10.43	2.45	0.22	107.2	20.55
2	Recommended fertilizer	5.59	0.19	13.81	2.54	0.25	121.5	21.69
3	75% N + 25% N equiv. level VC + Pc	5.62	0.17	14.19	2.89	0.29	132.3	22.64
4	50% N + 50% N equiv. level VC + Pc	5.68	0.16	14.76	3.10	0.31	138.8	23.09
5	25% N + 75% N equiv. level VC + Pc	5.72	0.17	15.51	3.12	0.32	147.0	23.29
6	100% N equiv. level of VC + Pc	5.89	0.17	15.78	3.17	0.35	163.7	25.11
	Pre soil sample	5.11	0.16	9.62	2.43	0.23	106.68	20.47

4.4. The Effect of Vermicompost on Yield and Yield Components of Maize

4.4.1. Plant Height, Spike Length and Seed per Spike of Wheat

The effect of vermicompost with inorganic fertilizer on yield and yield components of bread wheat was evaluated between the treatments. The mean analysis of variance showed that, Plant height, spike length and seed per spike were significantly ($p < 0.05$) influenced between the treatments by application of different rates of vermicompost. The maximum plant height (98.2 cm and 97.6 cm), spike length (8.7 cm and 8.5 cm) and seed per spike (48 and 47) were recorded from the recommended rate of NP fertilizers and 75% N + 25% N equivalent level of vermicompost + Pc respectively. While the lowest plant height (84.2 cm), spike length (6.8 cm) and seed per spike (32) was recorded from the control plot (Table 4). Moreover the interaction of lime, vermicompost and NP fertilizers showed significant ($p <$

0.05) response to plant height, spike length and seed per spike of bread wheat. Similar results were reported by [1, 9].

4.4.2. Grain Yield and Biomass of Bread Wheat

The mean analysis of variance showed that there were significant ($P < 0.05$) differences between treatments for grain yield and biomass of bread wheat (Table 4). The highest grain yield (4132 kg/ha and 4072 gk/ha) and biomass (14.69 t/ha and 14.27 t/ha) were recorded from the application of the recommended rate of fertilizer and 75% N + 25% N equivalence level of vermicompost + Pc respectively. This indicates the faster release of available nutrients from NP fertilizers had a significant contribution to better grain yield of maize as compared to the slow gradually release of nutrients from vermicompost. A similar result was reported by [12], who found the effect of vermicompost and NPS fertilizer on the yield of maize, in which the highest grain yield of maize (6,187 kg/ha⁻¹) was obtained from NP fertilizer application and followed by integrated application of NP fertilizer and vermicompost which was 5,193 kg/ha.

Table 4. Effect of vermicompost and inorganic fertilizer on the mean yield and yield components of bread wheat.

No	Treatments	PH (cm)	SL (cm)	S/spike	BM (t/ha)	GY (kg/ha)	HI (%)
1	Control	84.2 ^c	6.8 ^c	32 ^d	10.58 ^c	1910 ^c	24.6 ^{ab}
2	Recommended fertilizer	98.2 ^a	8.7 ^a	48 ^a	14.69 ^a	4132 ^a	28.2 ^b
3	25% N + 75% N equiv. level VC + Pc	94.4 ^b	7.7 ^{ba}	41 ^c	12.09 ^b	3702 ^b	29.2 ^a
4	50% N + 50% N equiv. level VC + Pc	96.3 ^{ba}	8.1 ^b	43 ^b	13.00 ^b	3816 ^b	31.0 ^a
5	75% N + 25% N equiv. level VC + Pc	97.6 ^a	8.5 ^b	47 ^a	14.27 ^a	4072 ^a	30.1 ^a
6	100% N equiv. level of VC + Pc	93.6 ^b	7.8 ^{ba}	42 ^{cb}	12.38 ^b	3638 ^b	28.4 ^b

No	Treatments	PH (cm)	SL (cm)	S/spike	BM (t/ha)	GY (kg/ha)	HI (%)
LSD (0.05)		2.95	0.85	1.9	0.95	228.1	4.5
CV (%)		1.2	4.1	1.7	2.9	2.5	6.1

5. Economic Analysis

To identify the treatments with an optimum return to the farmer's investment; partial budget analysis with dominance and marginal rate of return was carried out across the treatments. Based on average market price of bread wheat immediately after harvest, NPS, Urea and vermicompost collected from the local markets during the two consecutive years; a partial budget analysis was employed to investigate the economic feasibility of treatments. According to [3]; the MRR of major cereals ranges from the minimum recommended rate of 50% to 100% in most agricultural production and it is better when the MRR was > 100%. In this study, all treatment except control, all treatments shows feasible responses and their MRR were greater than the minimum marginal rate of return 100%. Moreover, the economic analysis showed that, the highest net of return (152,888 ETB) was obtained

from the application of recommended rate NP fertilizes and followed by 75% N + 25% N equiv. level of VC + Pc (150,872 ETB) with 487% and 2407% marginal rate of return respectively (Table 5). In conclusion, the application of the recommended rate of fertilizers, results in the highest grain yield (4132 kg ha⁻¹) and net of return (152,888 Birr ha⁻¹) as compared to the rest of treatments (Table 5). However, comparably the integrated application of 75% N from urea + 25% N equivalent level of vermicompost + recommended phosphorus fertilizer could be an alternative approach for integrated soil fertility management measure and wheat production instead of the sole application of inorganic fertilizers. Therefore, the integrated application of vermicompost 1.33 t/ha, and 75 kg of urea with the recommended phosphorus fertilizer could be the recommended in terms of economic return and productivity of bread wheat (Ogolcho variety) in the study area.

Table 5. Partial budget analysis for the effect of vermicompost and inorganic fertilizer on yield and yield components of bread wheat.

No	Treatments	TSP (kg/ha)	Urea (kg/ha)	VC (kg/ha)	AGY (kg/ha)	GNB (Birr ha ⁻¹)	TVC (Birr ha ⁻¹)	NR (Birr ha ⁻¹)	MRR (%)
1	Control	-	-	-	1719	77355	0	77,355	-
2	Recommended fertilizer	180	150	-	3719	167346	14458	152,888	487
3	25% N + 75% N equiv. level VC + Pc	180	38	5950	3332	149931	13217	136,714	527
4	50% N + 50% N equiv. level VC + Pc	180	75	3967	3434	154548	13630	140,918	1016
5	75% N + 25% N equiv. level VC + Pc	180	113	1983	3665	164916	14044	150,872	2407
6	100% N equiv. level of VC + Pc	180	-	7933	3274	147339	12803	134,536	447

Where, NPS cost = 49.16 Birr kg⁻¹, Urea cost = 37.47 Birr kg⁻¹ of N, bread wheat grain per ha = 45 Birr kg⁻¹, Vermicompost cost = 0.5 Birr kg⁻¹, TVC= total variable cost, NR= net of return, MRR (%) = marginal rate of return, Control = unfertilized.

6. Conclusions

Integrated application of vermicompost and recommended rate NP fertilizer enhanced the soil chemical properties as compared to the initial soil nutrient status. Also, the sole ap-

plication of recommended NP fertilizer and integrated use of vermicompost with NP fertilizer rate significantly affect the yield and yield components of bread wheat. The application of the recommended rate of NP fertilizer, results in the highest grain yield (4132 kg/ha) of bread wheat and a high net of return (152,888 Birr ha⁻¹) as compared to the rest treatments.

Comparably, the economic analysis also showed that the highest net income (150,872 ETB) was obtained from the application of 75% N + 25% N equivalent level of VC + recommended phosphorus fertilizer. Therefore, the integrated application of 75% N from urea + 25% N equivalent level of vermicompost + recommended phosphorus fertilizer could be an alternative approach for integrated soil fertility management measure and wheat production instead of the sole application of inorganic fertilizers.

7. Recommendations

The integrated application of 75% N from urea + 25% N equivalent level of VC + recommended phosphorus fertilizer enhanced both soil nutrients and grain yield and could be an alternative approach for bread wheat production and integrated soil fertility management measure instead of the sole application of inorganic fertilizers. Therefore, integrated application of at 25% N equivalent level of vermicompost, 75 kg of urea and recommended rate of phosphorus fertilizer was recommended in terms of soil fertility management, economic return and productivity of bread wheat (Ogolcho variety) in the study area.

Abbreviations

VC	Vermicompost
MRR	Marginal Rate of Return
ETB	Ethiopian Birr
Ca	Calcium
Mg	Magnesium
N	Nitrogen

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Author Contributions

Amante Lema: Data curation, Formal Analysis, Writing – original draft, Writing – review & editing

Tilahun Abera: Methodology, Software

Tilahun Firomsa: Conceptualization, Formal Analysis

Abdurahman Husien: Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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