International Journal of Environmental Chemistry
2024, Vol. 8, No. 2, pp. 37-47
https://doi.org/10.11648/j.ijec.20240802.12

Research Article

Effects of Vermicompost and Blended NPSB Fertilizer on Major Physicochemical Properties of Soil and Economy of Maize Production at Bako, Central Ethiopia

Belay Teressa Ensermu[1, *], Yibekal Alemayehu[2]

[1]Bako Agricultural Research Center (BARC), Oromia, Ethiopia

[2]School of Plant Sciences, College of Agriculture and Environmental Sciences, Haramaya University, Dire Dawa, Ethiopia

Abstract

Integrated vermicompost and blended NPSB inorganic fertilizer are needed to improve the soil's fertility status, which can raise output and revenue. Thus, the purpose of the experiment was to ascertain how major physicochemical properties of the soil at Bako were affected by the application of blended NPSB fertilizer and vermicompost. Factorial combinations of four levels of vermicompost (0, 2, 4 and 6 tons ha^{-1}) and four levels of NPSB blended inorganic fertilizer (0, 50, 100 and 150 kg ha^{-1}) were laid out in Randomized Complete Block Design (RCBD) with three replications. The interaction of vermicompost and NPSB blended inorganic fertilizer had significant effects on ear diameter, grain yields, and harvest index and cob weight. The maximum grain yield (7503.7 kg ha^{-1}) was obtained from application of blended NPSB fertilizer at the rate of 100 kg NPSB ha^{-1} and 4 tons ha^{-1} vermicompost rate with a net profit of 104850 birr and 6143% MRR with values to cost ratio of 3.47 birr profit per unit investment for midland maize production at Bako. Therefore, it can be said that the application of 100 kg NPSB ha^{-1} and 4 t vermicompost ha^{-1} was shown to be superior in terms of both grain yield and economic advantage, and it is therefore tentatively advised for use. To come to a definitive decision, the experiment needs to be repeated across a number of years, as this study was only conducted during one season at one site.

Keywords

Maize, NPSB, Vermicompost, Yields

1. Introduction

Maize is one of the most important cereal crops in the world agricultural economy both as food for human and feed for animals. Major constraints to maize yield production in Ethiopia are the depletion of soil fertility, the absence of improved varieties, the inadequacy of chemical fertilizers, and the high costs of chemical fertilizers. The soil fertility depletion is one of the causal factors that threaten agricultural productivity and food security in Ethiopia like in many Sub-Saharan Africa (SSA) countries. Soil fertility status and variability are essential in understanding the potential of soils and their management interventions in agriculture [20]. In addition, for the last three decades, Ethiopian agriculture

[*]Corresponding author: ensermu.b@gmail.com (Belay Teressa Ensermu)

Received: 5 August 2024; **Accepted:** 5 September 2024; **Published:** 29 September 2024

depended solely on imported fertilizer products namely UREA and di-ammonium phosphate (DAP) which is source of N and P and although most Ethiopian soils lack other macro and micro-nutrients [14]. In recent years, blended fertilizers have been introduced to include sulfur (S), Zinc (Zn) and Boron (B) in addition to N and P fertilizers [12]. However, new blended fertilizer NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) which represents the old chemical fertilizer DAP, is a mixture of inorganic fertilizer is currently being used by the farmers in the study area based on the soil fertility map of the area [14] that was started to use without optimum rate of recommendation. The available evidences suggests that the addition of vermicompost plays a vital role in improving soil properties like increasing soil porosity, available water, organic matter, nutrients status, crop yields as well as lowering soil bulk density [2, 22].

The main importance of using organic fertilizer like vermicompost with the combination of inorganic fertilizer like blended NPSB fertilizer was boldly identified in increasing the production and productivity of the crops through boosting the soil nutrients available to plants and enhances soil structure and drainage. The fundamental challenge with sustainable agriculture is maintaining soil fertility and stabilizing crop production year after year in light of the grave scenario of soil degradation and diminishing crop yields. Recycling organic wastes is not only necessary for the environment, but in a nation like Ethiopia, it is also required economically [4]. However, adoption of vermicompost application along with inorganic fertilizers for improving soil fertility and maize production is poor in Bako area. Therefore, the research was initiated to determine the effect of vermicompost and blended NPSB fertilizer on major physicochemical properties of soil.

2. Materials and Methods

2.1. Descriptions of Experimental Site

The field experiment was conducted at Bako Agricultural Research Center, which is located in East Wollega Zone of the Oromia National Regional State, Central Ethiopia (Figure 1). The center is located at 258 km west of the capital, Addis Ababa, 8 km away from the nearest town, Bako and 4 km from highway road to Nekemte town. Bako Agricultural Research Center lies at 9°6' North latitude and 37°09' East longitude in the sub-humid agro-ecology and at altitude of 1650 meters above sea level (masl).

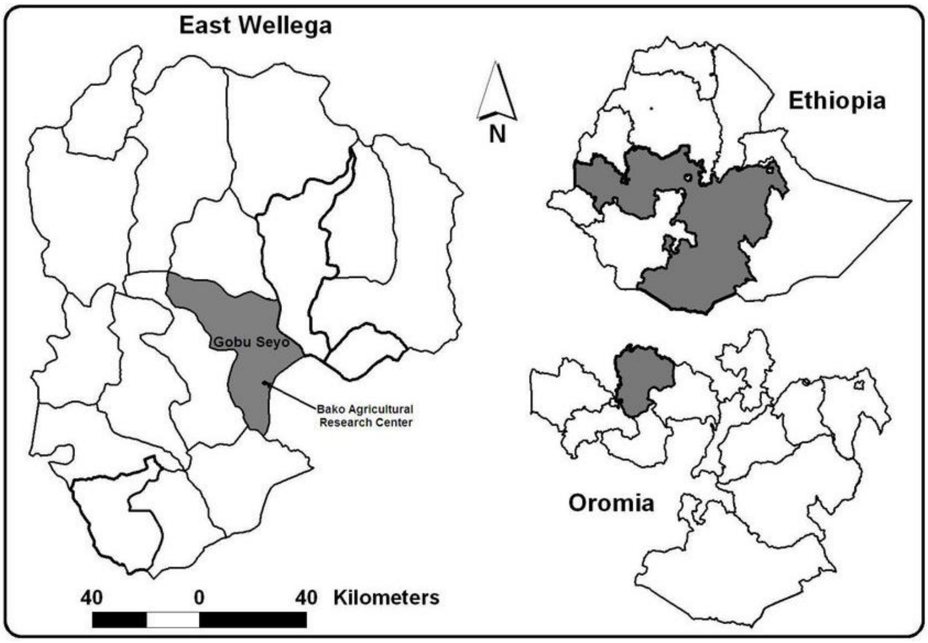

Figure 1. *Geographic map of the study area.*

The mean annual rainfall in the last sixty years from 1961 to 2021 is 1253.3 mm (BARC metrological station, unpublished data). The rainy season covers from April to October and maximum rain is received in the months of July and August. The mean annual minimum, maximum and average air temperature is 13.4, 28.1, and 20.8°C, respectively and relative humidity of 60.8%. According to USDA soil classification, the soil is Alfisols developed from basalt parent materials and is deeply weathered and slightly acidic in reaction [36].

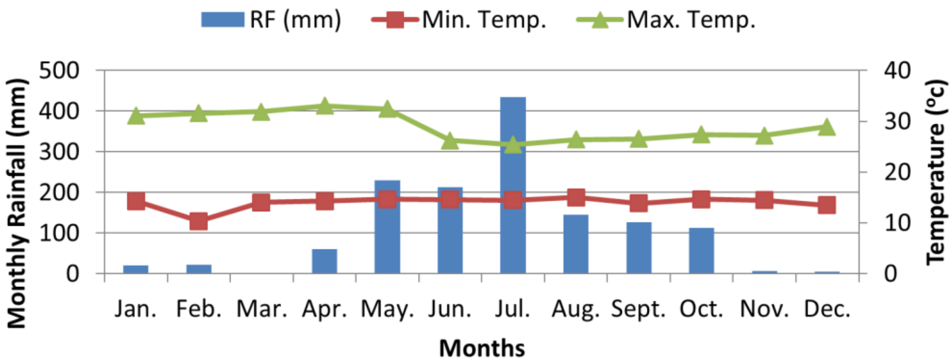

Figure 2. *Monthly Rainfall (mm), Minimum and Maximum temperature (℃) of Bako Agricultural Research Center (study area) during the 2021 cropping season.*

2.2. Experimental Material

Improved maize variety BH-546 was used as a test crop. The variety was selected based on yield performance, lodging resistance and farmers' preference in the study area. The seed material was collected from Bako Agricultural Research Center (BARC). Blended NPSB fertilizer containing (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) was applied in the row as per the treatment and mixed with soil just at the time of planting. Vermicompost prepared from soybean residue and farm yard manure at Bako Agricultural Research Center was used for this study.

Table 1. *Description of improved variety of maize: BH-546.*

Year of release	2013	Remark
Altitude	1000-2000 masl	
Maturity group/date	Intermediate/145 days	
Yield at farmers field	5500 to 7500 kg ha^{-1}	
Yield at research center	8500 to 9500 kg ha^{-1}	
Seed rate kg ha^{-1}	25 kg ha^{-1}	

Source: [23]

2.3. Treatments and Experimental Design

The treatments comprised of two factors specifically four levels of vermicompost (0, 2, 4 and 6 tons ha^{-1}) and four levels of blended NPSB fertilizer (0, 50, 100 and 150 kg ha^{-1}). The rate of vermicompost was settled based on the recommendation [35] that was 2.5 tons ha^{-1} and the NPSB blended fertilizer rate was be settled according to the recommendation of [33] that was 100 kg ha^{-1}. The treatment was arranged as 4 x 4 factorial combinations in Randomized Complete Block Design (RCBD) with three replications. The gross plot comprised of six rows of 3 m length (6 x 0.75 m x 3 m = 13.5) and one row each from both sides of the plot was left as a border row. Thus, the central four rows (4 × 0.75 m × 3 m = 9 m^2) were used for data collection as net plot. The distance between the blocks and plots were 1.5 m and 1.0 m respectively. The space between rows and plants were used 75 cm x 20 cm as recommended [6].

2.4. Soil Sampling and Laboratory Analysis

A representative soil sample was taken using auger from the whole experimental field in zigzag pattern from ten spots at the depth of 0-30 cm before planting. Finally composite sample was prepared for analysis to determine physicochemical properties of the soil of experimental site.

The collected soil samples were air dried; ground and sieved using a 2 mm mesh size sieve for analysis of physical properties of the soil like: soil texture, soil moisture content and bulk density. The bulk density soil sample was collected from four representative spots before the land preparation by using metal ring pressed into the soil.

Likewise, the analysis of soil chemical properties like: soil pH, organic carbon, total nitrogen (N), available phosphorous (P), available Sulphur (S), available boron (B), exchangeable bases and Cation exchange capacity (CEC) were determined by using standard laboratory procedures. After harvesting soil sample was collected to analyze selected physicochemical properties of the soil.

The soil physical properties analysis methods were described as below: The particle size distribution was determined by using hydrometer method using particles less than 2 mm diameter. The procedure measures percentage of sand (0.05-2 mm), silt (0.02-0.05 mm) and clay (<0.002 mm) fraction in soils [18, 24]. The moisture content of the soil was determined by gravimetric method [31] and bulk density of the soil was determined by dividing the dry weight of soil by its volume.

The chemical properties of the experimental soil were determined as the following: The pH of the soil was determined on 1: 2.5 (weight / volume) soils to water ratio using a pH meter [24]. The organic carbons were determined by Walkley and Black oxidation method [37]. Total nitrogen was analyzed by Kjeldhal method [11]. Available phosphorus was determined by the Olsen method [29]. Available Sulphur was determined by using turbid metric method. Available boron was determined by using hot water method [17]. Calcium and magnesium was determined by atomic absorption spectroscopy method [7]. Potassium and sodium was determined by flame photometer method [3]. Cation exchange capacity (CEC) was measured after saturating the soil with 1 N ammonium acetate (NH_4OAc) and displacing it with 1 N [8].

2.5. Experimental Procedures and Field Management

The experimental field was ploughed two times by tractor and followed by disc harrowing and leveling of the land was done manually. Finally the unit plots were prepared with spade and hoe for sowing.

In the unit plot, blended NPSB fertilizer and vermicompost was applied as per experimental specification. The whole amount of blended NPSB and vermicompost was applied at the time of planting. Nitrogen fertilizer in the form of UREA (46% N) was applied equally for all treatments three times, ¼ at planting, ¼ at knee height and $^{1}/_{2}$ at flowering stage, respectively, as recommended [35] at the rate of 200 kg ha^{-1} were used as a base for this trial. All other management practices were done as per the recommendations. To avoid the damage of Fall Army Worm (FAW) which were occurred in the study area, Selecron insecticide were applied at the rate of 1 L ha^{-1} immediately when the worm was seen on maize before causing damage.

2.6. Data Collected

2.6.1. Yield and Yield Component Parameters

Ear diameter (cm): The ear diameters were measured at the mid-way along ear length, as the average diameter of ten randomly taken ears from each experimental plot and then the mean value were determined.

Grain yield (kg ha^{-1}): The total grain yields from all the ears of each experimental unit were recorded. These were adjusted to 12.5% moisture level to estimate grain yield per hectare. Sensitive balance was used to weigh the grain yield while moisture tester was used to measure grain moisture content.

Harvest Index /HI (%): Harvest index were determined as the ratio of grain yield to the total above ground biomass. Harvest index were calculated as the following formula:

$$HI(\%) = \frac{\text{Grain Yield}}{\text{Biological Yield}} x100$$

2.6.2. Statistical Analysis

All data collected were subjected to two-way analysis of variance (ANOVA) using the SAS (9.2) computer software. The mean comparison among and within treatments were used by Duncan Multiple Range (DMR) test at LSD 5% probability level.

2.6.3. Partial Budget Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments of the rates of vermicompost and NPSB fertilizer that concerns to the seed cost. The partial budget analyses were done as described by [9] in which the value of market prices for inputs at planting and that of outputs at harvesting time. The average open market price for maize grain, vermicompost, NPSB and UREA fertilizer were 20 birr kg^{-1}, 5 birr kg^{-1}, 17.3 birr kg^{-1} and 16.25 birr kg^{-1} in 2021 cropping season respectively, while the maize improved seed price was 40 birr kg^{-1}. The analyses were performed to investigate the economic feasibility and profitability among the treatments.

3. Result and Discussion

3.1. Selected Physicochemical Properties of Soil Before Planting

The physicochemical properties of the soil of the study area at before planting are shown in Table 2. The soil contains 78% clay, 16% silt and 6% sand, which were categorized texturally in to clay soils according to the soil textural triangle [32]. The soil reaction of the experimental site was strongly acidic with a pH of 5.04 as described by [26] and [34]. Similar results were obtained by [16] who reported that in western part of Ethiopia, the soils tend to be acidic soil.

The amount of organic carbon content recorded was categorized as low 2.09% [19]. According [27] soils in Sub-Saharan Africa can nourish crops if the soil organic matter content is more than 3.4% based on the soil textural class that can hold the nutrients for plant growth and development. The optimum SOM also improves the buffering capacity of the agricultural soils based on the soil textural class and decomposed organic materials [25].

Therefore, the experimental soils qualify for medium in total N (0.18%) and low in organic carbon. The low organic carbon and medium in total nitrogen content of the study area indicates low fertility status of the soil. This result is similar with [21] who reported that low organic carbon and medium N content indicated low fertility status of the soil. This is also in line with the reports of [1] who indicate low in organic carbon and medium in total nitrogen showed low in soil fertility. This low in organic carbon in soil indicates that, there is a limit in soils ability to provide nutrients for sustainable crop production. The available phosphorus was found to be 5.04 (mg kg^{-1}) that was considered as medium [34] hence addition of phosphorus fertilizer to the soil of study site expected to increase grain yield. These results are in agreement with findings of [15, 13] who reported that cultivated land in Ethiopia regularly shows low available phosphorus to the crop. The available sulfur concentration of the study site was found to be 3.80 mg kg^{-1} soil. According to [28] it falls in the range of adequate. The laboratory analysis of available Boron of soil was not detected Table 2.

The available boron content of the study area was deficient in its availability which agrees with the finding of [14] that identified nutrient status as deficient at the study area. The status of exchangeable calcium in tested soils (3 cmol kg^{-1}) has been with in low ranges [19]. Low in exchangeable calcium in soil which causes inhibited in plant growth and also causes smaller and misshaped leaves that may reduce the photosynthesis activity for plat growth. Cation exchange capacity of soil before planting was medium in its content which is 16.40 cmol kg^{-1} Table 2. The percent of exchangeable potassium in study area had 0.45 cmol kg^{-1} found in medium according to [19] rating. The soils in the study area had medium K, indicating that these soils have adequate levels of K for crop production. The result disagrees with [36] who reported K deficiency in Dystric Nitosols of Bako area.

Table 2. *Selected Physicochemical Properties of Soil before planting maize crop.*

Soil before planting		
Physical properties	Clay%	78
	Silt%	16
	Sand%	6
	Soil texture	Clay
	%MC	35.68
	BD	1.26
Chemical properties	pH (1: 2.5)	5.04
	%OC	2.09
	%TN	0.18
	Avai. P (mg kg^{-1})	5.04
	Avai.S (mg kg^{-1})	3.80
	Avai.B (mg kg^{-1})	ND
	Ex. Ca (cmol kg^{-1})	3.00
	Ex.Mg (cmol kg^{-1})	4.75
	Ex.K (cmol kg^{-1})	0.45
	CEC (cmol kg^{-1})	16.4

ND- Not Detected, MC-Moisture Content, BD-Bulk Density, TN-Total Nitrogen, OC-Organic Carbon, Avai. P-Available Phosphorus, Avai. S-Available Sulphur, Avai. B-Available Boron, Ex. Ca-exchangeable calcium, Ex. Mg-exchangeable magnesium, Ex. K-exchangeable potassium, CEC-cation exchange capacity

3.2. Chemical Properties of Soil After Harvesting

The chemical properties of the soil of the study area after harvesting are shown in Table 3. The soil reaction of the experimental site after harvesting was moderately acidic with a mean pH of 5.28 as described by [26, 34].

The mean amount of organic carbon content recorded after harvesting was categorized as low 2.30% [19]. According [27] the soils in Sub-Saharan Africa can nourish crops if the soil organic matter content is more than 3.4% based on the soil textural class that can hold the nutrients for plant growth and development. The experimental soils qualify for medium in mean total N (0.20%) and low in organic carbon. The low organic carbon and medium in total nitrogen content of the study area indicates low fertility status of the soil. This result is similar with [21] who reported that low organic carbon and medium N content indicated low fertility status of the soil. This is also in line with the reports of [1] who indicate low in organic carbon and medium in total nitrogen showed low in soil fertility.

The mean available phosphorus after harvesting was found to be 5.60 (mg kg^{-1}) that was considered as medium [34] hence addition of phosphorus fertilizer to the soil of study site expected to increase grain yield. These results are in disagreement with findings of [15, 13] who reported that cultivated land in Ethiopia regularly shows low available phosphorus to the crop. The application of blended NPSB inorganic fertilizer and vermicompost organic fertilizer changes the availability of phosphorus in the study area soil. The ranges of available sulfur concentration of the study site were found to be 0.08-2.61 mg kg^{-1} soil. According to [28] it falls in the range of adequate. The laboratory analysis of available Boron after harvesting of crop was not detected (Table 3). This implies that the boron availability in the soil is deficient for crop production. This result was in agreement with the finding of [14] which clearly indicates the boron deficiency at western part of the country. The status of mean exchangeable calcium in tested soils (4.02 Cmol kg^{-1}) has been with in low ranges [19]. This result was increased from 3.0 to 4.02 Cmol kg^{-1} after the application of vermicompost and NPSB fertilizer.

The mean percent of exchangeable potassium after harvesting in the study area had changed from 0.45 to 1.20 Cmol kg^{-1} after the application of vermicompost and NPSB fertilizer which is found in medium range according to [19] rating. The soils in the study area had stable in potassium, indicating that these soils have adequate levels of potassium for crop production. The result disagrees with the finding of [36] who reported that the potassium deficiency in Dystric Nitisols of Bako area. The mean cation exchangeable capacity of soil after harvesting was medium in its content which is 19.40 cmol/kg (Table 3).

Table 3. Chemical properties of experimental soils after harvesting maize crop.

Trmt (VC t and NPSB kg)	pH (1: 2.5) H_2O	% OC	%TN	Avai.P (mg kg^{-1})	Avai.S (mg kg^{-1})	Avai.B (mg kg^{-1})	Ex. Ca (cmol kg^{-1})	Ex. Mg (cmol kg^{-1})	Ex. K (cmol kg^{-1})	CEC (cmol kg^{-1})
0vc+0NPSB	5.22	2.26	0.19	5.59	2.61	ND	3.00	3.50	0.99	14.98
0vc+50NPSB	5.15	1.33	0.11	5.65	0.35	ND	3.25	3.50	0.57	14.64
0vc+100NPSB	5.29	1.79	0.15	5.95	1.80	ND	3.75	5.00	0.89	19.28
0vc+150NPSB	5.30	2.18	0.19	5.75	1.92	ND	4.00	6.75	1.07	23.64
2vc+0NPSB	5.26	2.83	0.24	5.06	1.42	ND	3.75	7.75	1.72	25.44
2vc+50NPSB	5.27	2.34	0.20	5.59	2.53	ND	3.00	3.00	1.02	14.04
2vc+100NPSB	5.26	2.67	0.23	5.96	0.28	ND	4.00	2.25	1.43	15.36
2vc+150NPSB	5.27	2.30	0.20	6.07	0.11	ND	3.75	3.50	1.42	17.34
4vc+0NPSB	5.34	1.93	0.17	5.59	0.65	ND	5.75	4.25	0.87	21.74
4vc+50NPSB	5.22	2.57	0.22	7.97	0.68	ND	3.75	6.00	1.60	22.70
4vc+100NPSB	5.18	2.36	0.20	6.22	0.08	ND	4.00	2.38	0.74	14.23
4vc+150NPSB	5.34	2.20	0.19	5.79	0.96	ND	5.50	4.50	1.41	22.82
6vc+0NPSB	5.34	2.16	0.19	5.98	0.39	ND	4.25	2.75	0.98	15.96
6vc+50NPSB	5.31	2.65	0.23	5.93	1.37	ND	6.00	2.25	1.57	19.64
6vc+100NPSB	5.30	2.61	0.23	5.80	1.37	ND	3.50	6.63	1.32	22.89
6vc+150NPSB	5.37	2.57	0.22	6.89	0.91	ND	3.00	8.25	1.59	25.68

ND- Not detected, VC t- Vermicompost by ton, OC-Organic carbon, TN-Total Nitrogen, CEC-cation exchange capacity

Finally, the soil laboratory analysis showed that the application of vermicompost and NPSB fertilizer to the study area soil slightly increases the availability of total nitrogen from 0.18% to 0.2%, the availability of phosphorus from 5.04 mg kg^{-1} to 5.6 mg kg^{-1}, the soil pH from 5.04 to 5.28 and the percentage of organic carbon and cation exchange capacity from 2.09 to 2.3 and 16.4 to 19.4, respectively. This indicates that the application of vermicompost and blended NPSB inorganic fertilizer to the soil to some extent decreases the soil acidity and increases the fertility status of the soil. Though, if the application of vermicompost and NPSB inorganic fertilizer takes place continually, the fertility status of the soil will increase in sustainable. Increasing soil fertility, results in increasing the productivity and income of maize crop that was targeted in achieving the pillar of climate smart agriculture. This is because of vermicompost is a nutritionally rich organic fertilizer which releases nutrients into the soil and improves the quality of plants with improved of physical and biological properties of soil as well as successes the objectives of climate smart agriculture to overcome the major hazardous occurred by climate change on the environment as well as on the ecosystem generally to sustain agricultural production as well.

3.3. Yields and Yield Components

3.3.1. Ear Diameter

The analysis of variance showed that ear diameter was significantly ($P< 0.05$) influenced by the main effects of NPSB fertilizer, VC application rates and their interaction. Significantly higher mean ear diameter of maize was obtained from the interaction of VC with NPSB fertilizer application (Table 4). The data in Table 4 revealed that the thickest ear diameter was obtained when 4 tons VC ha^{-1} with 100 kg NPSB ha^{-1} fertilizer was associated (4.6) together and the thinnest mean of ear diameter was obtained from the interaction of 0 ton VC ha^{-1} with 0 kg NPSB ha^{-1} (3.2). The increased in ear diameter with increasing combined application of vermicompost and blended NPSB fertilizer may be attributed to the availability of adequate nutrients like nitrogen and phosphors which are essential for plant growth and photosynthesis. As ear diameter of maize is one component of grain yield, the application of organic fertilizer combined with inorganic fertilizer boosts the size of the cobs with a full of grain fillings that compares with unfertilized. Additionally, the combined use of organic and inorganic fertilizer is more valuable than the sole application use of fertilizers. This result was in agreement with the finding by [30] who reported that, the thickest ear diameter was obtained from fertilizer treated with compared to zero fertilizer on maize crops.

Table 4. Interaction effects of NPSB and VC on ear diameter of maize at Bako.

Ear diameter (cm)				
VC (ton ha^{-1})	NPSB fertilizer (Kg ha^{-1})			
	0	50	100	150
0	3.2c	4.2b	4.1b	4.06b
2	4.2b	4.3b	4.1b	4.2b
4	4.3b	4.2b	4.6a	4.1b
6	4.3b	4.3b	4.1b	4.3b
LSD (5%)	0.12			
CV (%)	3.56			

CV: Coefficient of variation, LSD: Least significant difference, NS: Non-significant. Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

3.3.2. Grain Yield

The analysis of variance showed that the main effects of VC and NPSB fertilizer application rates and interaction effects between VC and NPSB blended fertilizer rates was statistically significant on grain yield of maize. Significantly higher mean grain yield of maize was obtained from application of NPSB with VC and optimum rate of vermicompost (Table 5). The data in table 5 revealed that the highest grain yield was obtained from the interaction of 4 tons VC ha^{-1} with 100 kg NPSB ha^{-1} (7503.7) which is followed by the interaction of 2 tons VC ha^{-1} with 150 kg NPSB ha^{-1} (5255.6) and the lowest mean of grain yield is obtained from the interaction of 0 ton VC ha^{-1} with 0 kg NPSB ha^{-1} (3100.0). A considerable increase of 24.2% grain yield advantage was obtained from the optimum use of fertilizer and vermicompost over control. Generally, use of organic fertilizer combined with inorganic chemical fertilizer enhanced the productivity of maize crops when compared to non-fertilized one. Additionally, the higher grain yield at higher vermicompost and blended NPSB fertilizer application might be due to lower competitions for nutrients and positive effects of combined use of organic and inorganic fertilizer on plant growth that increases in grain yield. This result was in agreement with the finding by [33] who reported that, the highest grain yield was obtained from fertilizer and vermicompost treated with compare to zero fertilizer and vermicompost on maize crops. Likewise, the grain yield increases as the fertilizer rate increases to the optimum rate of fertilizer [10].

Table 5. Interaction effects of vermicompost and NPSB inorganic blended fertilizer on grain yield of maize.

Grain yield (Kg ha^{-1})				
VC (ton ha^{-1})	NPSB fertilizer (Kg ha^{-1})			
	0	50	100	150
0	3100^{d}	4051.9^{cbd}	3903.7^{cd}	4503.7^{cb}
2	4803.7^{cb}	4803.7^{cb}	4351.9^{cbd}	5255.6^{b}
4	4051.9^{cbd}	4503.7^{cb}	7503.7^{a}	4503.7^{cb}
6	3900^{cd}	4651.9^{cb}	4651.9^{cb}	3751.9^{cd}
LSD (5%)	0.49			
CV (%)	14.61			

CV: Coefficient of variation, LSD: Least significant difference. Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

3.3.3. Harvest Index

The analysis of variance showed that the main effects of VC and NPSB fertilizer application rates and interaction effects between VC and NPSB blended fertilizer rates was statistically significant on harvest index of maize. Significantly higher mean harvest index of maize was obtained from application of NPSB with Vermicompost rates (Table 6). The highest harvest index was obtained from the interaction of 4 tons VC ha^{-1} with 100 kg NPSB ha^{-1} (55.58) and the lowest mean of harvest index is obtained from interaction of 0 ton VC ha^{-1} with 0 kg NPSB ha^{-1} (34.30). The use of organic fertilizer combined with inorganic chemical fertilizer boosted the harvest index of maize crops when compared to unfertilized one. Furthermore, the increase in harvest index due to the combined application of vermicompost and NPSB fertilizer may be associated with a fundamental role of both vermicompost and blended NPSB fertilizer in many physiological and biochemical processes during growth and development period that enable the crop to allocate much dry matter into grain which has direct relationship to harvest index. This feature elicits that the application of integrated vermicompost and blended NPSB fertilizer has a significant compete for the growth and development of maize at their different growing durations. This result was in agreement with the finding [33] who reported that, the highest harvest index was obtained from NPSB blended fertilizer treated with compare to zero NPSB blended fertilizer on maize crops.

Table 6. Interaction effects of vermicompost and NPSB inorganic blended fertilizer on harvest index of maize.

Harvest index (%)				
VC (ton ha^{-1})	NPSB fertilizer (Kg ha^{-1})			
	0	50	100	150
0	34.30^{d}	37.94^{cbd}	37.93^{cbd}	37.92^{cbd}
2	38.06^{cbd}	44.01^{b}	34.47^{d}	41.72^{cbd}
4	36.25^{cd}	39.43^{cbd}	55.58^{a}	40.09^{cbd}
6	37.31^{cd}	38.48^{cbd}	39.61^{cbd}	35.64^{cd}
LSD (5%)	3.24			
CV (%)	9.87			

CV: Coefficient of variation, LSD: Least significant difference. Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

3.3.4. Cob Weight

Table 7. Interaction effects of vermicompost and NPSB inorganic blended fertilizer on cob weight of maize.

Cob weight (kg ha^{-1})				
VC (ton ha^{-1})	NPSB fertilizer (Kg ha^{-1})			
	0	50	100	150
0	3888.89^{d}	5000.0^{cbd}	4811.11^{cd}	5555.56^{cb}
2	5922.22^{cb}	5922.22^{cb}	5366.67^{cbd}	6477.78^{b}
4	5000.0^{cbd}	5555.56^{cb}	9255.56^{a}	5555.56^{cb}
6	4811.11^{cd}	5733.33^{cb}	5733.33^{cb}	4622.22^{cd}
LSD (5%)	0.61			
CV (%)	14.59			

CV: Coefficient of variation, LSD: Least significant difference. Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

The analysis of variance showed that the main effects of VC and NPSB fertilizer application rates and interaction effects between VC and NPSB blended fertilizer rates was statistically significant on cob weight of maize. The highest cob weight was obtained from interaction of 4 tons VC ha^{-1} with 100 kg NPSB ha^{-1} fertilizer (9255.56) and the lowest mean of cob weight is obtained from the interaction of 0 ton VC ha^{-1} with 0 kg NPSB ha^{-1} fertilizer (3888.89). The higher cob weight at higher vermicompost and blended NPSB fertilizer application might be due to lower competitions for nutrients and optimistic effects of combined use of vermicompost and blended NPSB inorganic fertilizer on plant growth that increases in cob weight, while at lower vermicompost and blended NPSB fertilizer application the cob weight was lower. This result was in agreement with the finding [30] who recorded the highest cob weight from maximum fertilizer application while the lowest was recorded from control. Similarly, the highest cob weight was recorded from maximum fertilizer application while the lowest cob weight was recorded from the control [5].

3.4. Partial Budget Analysis

Analysis of the net benefits, total variable costs, value to cost ratios and marginal rate of returns are presented in Table 8. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The study assessed the economic benefits of the treatments helps to develop recommendation from the agronomic data. This enhances selection of the right combination of resources by farmers in the study area. The partial budget analysis was done on the basis cost of NPSB, vermicompost and application cost of fertilizers.

The partial budget analysis showed that the combined application of 4 tons VC ha^{-1} with 100 kg NPSB ha^{-1} blended inorganic fertilizer produced the highest net return of 104850.00 birr ha^{-1} with high MRR value of 6143% (Table 8). On the other hand, the combined application of 6 tons VC ha^{-1} with 150 kg NPSB ha^{-1} blended inorganic fertilizer produced the lowest net benefit (26445.00 Birr ha^{-1}). This implies that farmers would be better of applying 4 tons vermicompost ha^{-1} to their maize in combination with application of 100 kg NPSB ha^{-1} as these increase maize yields and thus increase farmer’s income. This recommendation is also supported by [9] which stated that farmers should be willing to change from one practice to another if the marginal rate of return of that change is greater than the minimum acceptable rate of return.

It is interesting to note that the combined application of vermicompost with NPSB blended inorganic fertilizer application can benefits maize productivity in short-run and can improve soil health due to increase in soil organic matter.

***Table 8**. Partial budget analysis of the effects of blended NPSB and vermicompost on maize.*

VC (ton ha^{-1})	Fertilizer NPSB (kg ha^{-1})	GY (Kg ha^{-1})	10% Adjusted GY (kg ha^{-1})	Gross field benefit (ETB ha^{-1})	TVC (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Value to cost ratio	MRR (%)
0	0	3100	2790	55800	4250	51550	12.13	
0	50	4052	3647	72940	9365	63575	6.79	235
0	100	3904	3514	70280	10230	60050	5.87	D
0	150	4504	4054	81080	11095	69985	6.31	1149
2	0	4804	4324	86480	18500	67980	3.67	D
2	50	4804	4324	86480	19365	67115	3.47	D
2	100	4352	3917	78340	20230	58110	2.87	D
2	150	5256	4730	94600	21095	73505	3.48	D
4	0	4052	3647	72940	28500	44440	1.56	D
4	50	4504	4054	81080	29365	51715	1.76	D
4	100	7504	6754	135080	30230	104850	3.47	6143
4	150	4504	4054	81080	31095	49985	1.61	D
6	0	3900	3510	70200	38500	31700	0.82	D
6	50	4652	4187	83740	39365	44375	1.13	D
6	100	4652	4187	83740	40230	43510	1.08	D
6	150	3752	3377	67540	41095	26445	0.64	D

VC: Vermicompost, GY: Grain yield, TVC: Total variable cost, MRR: marginal rate of return, D: Dominated, 17.3 birr= cost of NPSB/kg, 5 birr= cost of vermicompost/kg, 100 kg of maize = 2000 Birr, 40 birr=cost of improved seed/kg

4. Summary and Conclusions

Low soil fertility is one of the major chemical constraints on soil that limits maize productivity in central Ethiopia. To increase the fertility status of the soil that can increase productivity and income, the use of integrated vermicompost and blended NPSB inorganic fertilizer is required. To increase the production and productivity of the maize crop, increasing the potential of the soil is mandatory. As the fertility of the soil was increased, the production per unit area will be increased through the application of organic and inorganic fertilizer which was used to meet the main climate smart agriculture objectives. Therefore, the experiment was conducted to determine the Effects of Vermicompost and Blended NPSB Fertilizer on Major Physicochemical Properties of Soil and economy of maize production.

The experiments were laid out in randomized complete block design (RCBD) in factorial arrangements of four levels of blended NPSB fertilizer (0, 50, 100 and 150 kg ha^{-1}) and four levels of vermicompost rates (0, 2, 4 and 6 tons ha^{-1}) with three replications.

Results showed that the slightly increments in availability of total nitrogen, available phosphorus and percent of organic carbon results in to some extent reducing the soil acidity and increases the soil fertility status. The combined application of organic fertilizer like vermicompost and inorganic fertilizer blended NPSB boosts the fertility status of the soil if their application is in a sustainable way.

The results revealed that ear diameter; grain yield, harvest index, cob weight and moisture content of maize were significantly influenced by the interaction effects of vermicompost with blended NPSB fertilizer rates. The highest ear diameter (4.6), grain yield (7503.7), harvest index (55.58), moisture content (16.0) and cob weight (9255.56) were significantly influenced by the interaction effect of vermicompost x blended NPSB inorganic fertilizer. The combined application of organic and inorganic fertilizer on soil positively affects the yield components of maize crop.

Determining the optimum rate of vermicompost and NPSB fertilizer has an ultimate significance to increase maize productivity across different agro-ecologies in western part of the country. The maximum grain yield (7503.7 kg ha^{-1}) was obtained from combined application of 100 kg NPSB ha^{-1} fertilizer and 4 tons VC ha^{-1} with a net profit of (104850 birr) and MRR (6143%) with values to cost ratio of 3.47 birr profit per unit investment for midland maize production at Bako, central Ethiopia.

From this study, it can be concluded that the combined application of 4 ton VC ha^{-1} with 100 kg NPSB ha^{-1} had resulted in higher grain yield and net benefit and is tentatively recommended for use. However, as this study was done for one season at one location, the experiment has to be repeated over locations and years under different soil types in the study area to reach at a conclusive recommendation and to determine the residual effect of vermicompost and NPSB fertilizer on the soil and on the crop.

Abbreviations

CEC	Cation Exchange Capacity
DAP	Di-ammonium Phosphate
NPSB	Nitrogen, Phosphorus, Sulphur and Boron
RCBD	Randomized Complete Block Design
SSA	Sub-Saharan Africa

Author Contributions

Belay Teressa Ensermu: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Writing – original draft

Yibekal Alemayehu: Methodology, Supervision, Validation, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Fields

Belay Teressa Ensermu: Agronomy, Seed Research, Soil Fertility improvement, Plant physiology, Soil and plant nutrition

Yibekal Alemayehu: Plant physiologist, Horticulturalist, Plant science, Agriculture and Environmental Science, Soil fertility improvement