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Integrated Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties and Bread Wheat Production in Gechi District, Western OROMIA

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Abstract: Information on soil fertility status and crop response to different soil fertility management is very important to come up with sustainable crop production plan. A study was conducted in Gechi District on farmers' fields to find out the combined effects of vermi-compost (organic fertilizer) and NPS (inorganic fertilizer) rates on soil chemical properties and bread wheat production. The treatments consisted of three levels of vermi-compost (0, 1.5 and 3 t ha^{-1}) and three levels of NPS fertilizer (0, 100 and 200 kg ha^{-1}). The experiment was laid out in RCBD design in factorial combination with three replications., laboratory analysis results of composite soil samples collected before sowing showed deficiency in soil chemical properties. However, analysis of variance of post-harvest composite soil samples collected from each plot indicated significant differences in soil pH, available P, OC, TN and CEC while, soil exchangeable acidity showed positive improvement as compared to the initial one. The analysis of variance among the treatments showed significant differences ($P \leq 0.05$) on almost all the bread wheat characters tested. The highest and lowest bread wheat grain yield (5722.2 kg ha^{-1}) and (750.0 kg ha^{-1} were obtained from the treatment combination of 3 t ha^{-1} vermi-compost with 200 kg ha^{-1} NPS and 92 kg ha^{-1} N, and control plot, respectively. Therefore, the present study revealed that combined fertilization of vermi-compost and NPS fertilizer enhanced bread wheat productivity and soil fertility status in the study area but indicated that bread wheat productivity in the study sites was reduced due to high demand for external nutrient inputs. Hence combined fertilization of 3 t ha^{-1} vermi-compost with 200 kg ha^{-1} NPS and 92 kg ha^{-1} N could improve crop productivity and soil chemical properties, and is recommended for the study area (Gechi District) and similar agro-ecology. The result also showed that the soils of the study sites had poor chemical fertility and integrated soil fertility management practices can improve the current situation.

Keywords: Cation Exchange Capacity, Soil Organic Carbon, Soil pH, Total Nitrogen, Vermi-Compost

1. Introduction

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including wheat. [1] Indicates that soil fertility is a major overriding constraint that affects all aspects of crop production. As is the case in other regions in Africa, Ethiopian farmers use inadequate nutrient inputs, inappropriate quality and inefficient combinations of fertilizers, which in the end prove to be lack of soil fertility restoring inputs and unbalanced nutrient use [2]. The low nutrient levels in the soil are caused by crop removal of nutrients from the soil, little or no fertilizer application, and total removal of crop residues from the farmland and burning. Due to increasing population pressure and a shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion [3, 4]. Moreover, the shortage of land for the production of food crops has eliminated the practice of fallowing and crop rotation.. Furthermore, the shortage of grasslands (grazing areas) has forced the farmers to remove crop residues for animal feed, which has led to a decrease in soil organic matter and a depletion of soil nutrients.

Soil fertility and functioning must be restored to provide sustainable farming systems. As an alternative, solutions for increasing soil organic matter have been proposed [5, 6], which advocate regular soil amendments with organic amendments. Long-term fertilization had a significant effect on soil organic Carbon, total nitrogen content, total phosphorus and pH. The highest values of soil organic Carbon, total Nitrogen content and total Phosphorus were recorded in soils amended with organic manure [7, 8]. Organic matter is an imperative indicator of soil fertility [9] by improving soil structure, nutrient exchange and maintaining soil physical conditions [10, 11]. It also reduces the level of carbon dioxide in the atmosphere that contributes positively to climate change [12]. For the sustainable development of agriculture [13], Vermicompost is the latest organic fertilizer to supplement chemical fertilizers. It is a material that is characterized by high porosity, aeration, drainage, water holding capacity and microbial activity [14]. It increases soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants [15]. It can improve physical, chemical and biological processes of the soil which have their bearings on the plant's growth. [16]. Use of organic fertilizers improves soil structure, nutrient exchange, and maintains soil health and has raised interest in organic farming [17]. Other studies indicated that organic fertilizer typically mineralized within only a few cropping seasons to obtain a sustainable and stable increase in yield [18].

On the other hand, inorganic fertilizers overcome soil fertility problems and are responsible for increasing a large part of the world's food production [19]. Application of commercial fertilizers has resulted in an increment of crop yield of 30 to 50% [20, 21]. Crop yields in the developed world are high and agricultural soils have high fertility status due to intensive use of fertilizers [22]. This implies that using chemical fertilizer plays a significant role in increasing food production to meet the demand of the growing world population. Similarly, vermicompost is increasingly being considered in agriculture as a promising alternative to chemical fertilizers. However, the effects of vermicompost either alone or integrated with chemical fertilizers, on the crop productivity are not yet fully understood.

Integrated plant nutrients management can lessen this problem and can be suitable for any farming system and socio-economic conditions [23]. Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and to balance nutrient supply in order to boost up the crop yield per unit area [24-26]. However, in the study area there is no information on the combined use of vermi-compost and chemical fertilizer for bread wheat production. Therefore, the objective of the study was to find out the effects of vermi-compost and NPS (inorganic fertilizer) rates on some soil chemical properties, bread wheat yield and yield components in Gechi District.

2. Materials and Methods

2.1. Description of the Study Areas

The study was conducted on three farmers' fields in Gechi District of Buno Bedele zone in the 2019 main cropping season, Gechi District is located at 08°24'40.0" to 08°25'12.0"N and 036°25'61.0" to 036°33'20.0"E with an altitude ranging from 1013 to 2390 m.a.s.l. The 18 years of weather information at the nearby study area (Ethiopian Meteorology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with an average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil types in southwest and western Ethiopia in general and the study area in particular, are Nitisols according to the [27] soil classification system. Its vernacular name is "*Biyyee Diimaa*" meaning red soil. The soil is deep; relatively highly weathered on average, well drained, clay in texture, and strongly to moderately acidic in reaction. Nitisols are highly weathered soils that are found in the west and southwest of Ethiopia [28].

2.2. Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth were collected from each experimental site before sowing and intensive soil samples were collected from each experimental plot after harvest to analyze soil pH (H_2O), exchangeable acidity, available P (Olsen), (OC%), (TN%), and CEC. The collected soil samples were prepared and analyzed following standard laboratory procedures at the soil analysis laboratory of Bedele Agricultural Research Center.

2.3. Treatments, Experimental Design and Procedures

The treatments consisted of three levels of vermi-compost (0, 1.5 and 3 t ha^{-1}) and three levels of NPS fertilizer (0, 100 and 200 kg ha^{-1}) were arranged in a randomized complete block design (RCBD) in a factorial combination with three replications. There were a total of nine treatments. The gross plot size was $12m^2$ (3m x 4m). The Liban bread wheat variety, which outperforms other improved bread wheat varieties in the study areas in terms of yield, was used as a test crop with a seed rate of 150 $kgha^{-1}$ The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times and treated with lime for soil pH less than 5.5, and the amount of lime needed per hectare was calculated based on the formula LR = Ex. Acidity *1.5*10 Kun ha^{-1}. Full dose of vermi-compost and phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top-dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices for disease and insect pest control were done.

Finally, days to 50% heading, biomass and grain yield data were collected. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

3. Results and Discussion

3.1. Effects of Vermi-Compost and NPS Fertilizer Rates on Soil Chemical Properties After Bread Wheat Harvest

Post-harvest soil pH, exchangeable acidity, available P, OC, TN and CEC are presented in (Table 1). The results indicate that there was no significant ($P < 0.05$) difference in soil pH and exchangeable acidity among the different treatments. The treatments were statistically similar. However, the greatest positive pH (5.10) changes from an initial pH of 4.88 were recorded at the treatment combination of 3.0 tha^{-1} vermi-compost and no NPS fertilizer. The lowest negative pH changes from the initial soil pH were recorded with the control treatment which gave pH values of 4.85**.** Whereas exchangeable acidity decreased (improved) from 1.05 to 0.47 at 1.5 tha^{-1} vermi-compost and 100$kgha^{-1}$ NPS fertilizer. The status of soil pH and exchangeable acidity were improved in this study which indicated that the addition of lime to the experimental sites and Vermi-compost treatments were effective in increasing soil pH. It is realized that soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrients.

The results also indicate that there were significant ($P < 0.05$) difference in soil available P, OC, TN, and CEC. The status of soil available P after harvest was greatly enhanced as compared to initial P before sowing (Table 1). This indicated that Vermi-compost enhanced phosphorous concentration and uptake in soil, increasing the solubilization of phosphorous either by microorganism activation with excretion of organic acids like citric, glutamic, tartaric, succinic, lactic, oxalic, malic and fumaric [29]. Every year, plants absorb only about 20–30% of the P in applied fertilizers [30]. In general a small proportion of applied P is immediately taken up by the plants and the remaining P accumulates in the soil, which is potentially available for uptake by crops in subsequent years. Vermi-compost increases soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants [15]. Soil Cation Exchange Capacity (CEC) and crop yield are increased by vermi-compost [31]. Cation exchange capacity is highly correlated with organic carbon (OC) content of the soil, which is in turn, is affected by different soil management practices such as intensive cultivation, fertilization, and changes in land use [32]. Cation exchange capacity increases with increasing soil OM [33]. It is strongly affected by the nature and amount of mineral and organic colloids present in the soil. Thus, CEC measurements are commonly made as part of the overall assessment of the potential fertility of a soil, and possible response to fertilizer application [34] In conclusion the available nutrient status of soil was greatly enhanced by the application of vermi-compost as an organic source [35].

Table 1. *Effects of vermi-compost and NPS fertilizer rates on soil chemical properties after bread wheat harvest.*

Treatments		**Soil properties**					
		pH	**Ex. Acidity**	**P_{av}**	**OC**	**TN**	**CEC**
V. Com (tha^{-1})	**NPS ($kgha^{-1}$)**	**(H_2O)**	**(cmol(+) per kg soil)**	**(ppm)**	**%**	**%**	**(cmol(+) per kg soil)**
0	0	4.85^{b}	0.60^{a}	0.67^{b}	3.20^{d}	0.30^{b}	10.10^{c}
1.5	0	4.90^{ab}	0.60^{a}	0.53^{b}	3.53^{d}	0.30^{b}	12.36^{abc}
3	0	5.10^{a}	0.57^{a}	0.90^{ab}	4.16^{bc}	0.36^{a}	12.96^{abc}
0	100	5.00^{ab}	0.57^{a}	1.03^{ab}	3.56^{d}	0.30^{b}	11.96^{abc}
1.5	100	5.00^{ab}	0.47^{a}	1.07^{ab}	4.13^{bc}	0.40^{a}	11.76^{bc}
3	100	5.00^{ab}	0.50^{a}	1.17^{ab}	4.56^{ab}	0.40^{a}	14.00^{ab}
0	200	4.87^{b}	0.53^{a}	1.10^{ab}	4.10^{c}	0.36^{a}	13.76^{ab}
1.5	200	4.87^{b}	0.53^{a}	1.50^{a}	4.50^{abc}	0.40^{a}	13.80^{ab}
3	200	4.87^{b}	0.60^{a}	0.73^{b}	4.86^{a}	0.40^{a}	14.93^{a}
Mean		4.94	0.55	0.97	4.07	0.35	12.85
CV (%)		2.61	30.63	43.46	6.19	7.80	13.74
LSD		0.22	ns	0.72	0.43	0.04	3.05
Initial (before sowing)		4.88	1.05	0.92	3.91	0.29	11.98

Where the meanings in each column preceded by the same letters do not differ significantly (P 0.05), V.com stands for vermicompost. CV = Coefficient of Variation, LSD = Least Significant Difference, Pav. = Available Phosphorus, OC = Organic Carbon, TN = Total Nitrogen, ppm = Part per million, Ex.Acidity = Exchangeable acidity, CEC = Cation Exchange Capacity, Ca = Calcium, t = ton,

3.2. Mean Days to Heading of Bread Wheat (Liban) in Relation to Vermi-Compost and NPS Fertilizer Rates

The analysis of variance indicated that days to heading were significantly ($P<0.05$) affected due to the application of NPS, vermi-compost and their interactions (Table 2). Increasing the levels of vermicompost lengthened the days to wheat heading. The growth and productivity of plants can be significantly influenced by vermi-compost [36]. Concerning the interaction effect of NPS and vermi-compost, the highest days to heading of 67.4 days was obtained with the unfertilized treatment, whereas the lowest (60.0 days) was obtained from 200 kg NPS ha^{-1} without vermi-compost application (Table 2).

Table 2. *Mean days to heading of bread wheat (Liban) under the effect of vermi-compost and NPS fertilizer rates.*

NPS (kg ha^{-1})	VC (t ha^{-1})			Mean
	0	1.5	3	
	Days to heading (days)			
0	67.4^{b}	67.0^{b}	69.0^{a}	67.8^{a}
100	62.1^{d}	64.6^{c}	64.8^{c}	63.9^{b}
200	60.0^{e}	64.6^{c}	65.1^{c}	63.3^{b}
Mean	63.2^{c}	65.4^{b}	66.3^{a}	
CV (%)	2.3			
LSD for NPS	0.8			
LSD for VC	0.8			
LSD for NPS * VC	1.4			

Whereas meaning followed by the same letters are not significantly different ($P \leq 0.05$), VC = vermi-compost, t = ton, ha = hectare, NPS = (nitrogen, phosphorus, sulfur), kg = kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences.

3.3. Effects of Vermi-Compost and NPS Fertilizer Rates on Bread Wheat Mean Biomass Yield

The effect of NPS fertilization on bread wheat biomass yield was significant. However, application of vermi-compost rates did not show significant effect on bread wheat biomass yield (Table 3) Biomass yield was increased with NPS rates where the maximum biomass yield (14,416.7 kg ha^{-1}) was obtained from the application of the highest NPS rate (200 kg NPS ha^{-1}) and the minimum (8,148.1 kg ha^{-1}) was from an unfertilized one (Table 3). Moreover, the interaction effect of these factors also revealed that the combinations of (200 kg NPS ha^{-1}) and (1.5 t ha^{-1}) vermi-compost gave significantly higher biomass yield of bread wheat (Table 3) This indicated that, vermi-compost plays a major role in improving growth and yield of different field crops, vegetables, flowers and fruits [37].

Table 3. *Mean biomass yield of bread wheat under the effect of vermi-compost and NPS fertilizer rates.*

NPS (kg ha^{-1})	VC (t ha^{-1})			Mean
	0	1.5	3	
	Biomass yield (kg ha^{-1})			
0	6889.0^{d}	7667.0^{cd}	9889.0^{bc}	8148.1^{b}
100	12358.0^{ab}	12278.0^{ab}	14194.0^{a}	12943.5^{a}
200	14222.0^{a}	14944.0^{a}	14083.0^{a}	14416.7^{a}
Mean	11156.5^{a}	11629.6^{a}	12722.2^{a}	-
CV (%)	24.9			
LSD for NPS	1601.2			
LSD for VC	1601.2			
LSD for NPS * VC	2773.4			

Whereas meaning followed by the same letters are not significantly different ($P \leq 0.05$), VC =vermi-compost, t=ton, ha=hectare, NPS= (nitrogen, phosphorus, sulfur), kg=kilogram, DH = days to headings, CV= Coefficient of variation, LSD= Least significant differences.

3.4. Mean Grain Yield of Bread Wheat Under the Effect of Vermi-Compost and NPS Fertilizer Rates

Table 4 presents the means of bread wheat grain yield as influenced by different rates of NPS and vermi-compost application. The analysis of variance indicated significant ($P<0.05$) grain yield differences due to the application of NPS, vermi-compost and their interactions. For the sustainable development of agriculture [13], Vermicompost is the latest organic fertilizer to supplement chemical fertilizers. Increasing NPS and vermicompost levels resulted in a linear and consistent increase in yield. Increasing the vermi-compost rate from 1.5 to 3 tha^{-1} increased grain yield by 20 to 35% compared to the control treatment (Table 4). Concerning the interaction effect of NPS and vermi-compost, the highest grain yield of 5722.2 kg ha^{-1} was obtained with the combination of 200 kg NPS ha^{-1} and 3 t ha^{-1} vermi-compost, whereas the lowest (750.0kg ha^{-1}) was obtained with the unfertilized treatment (Table 4). The highest yield for the interaction effect could be due to vermi-compost promoting better root growth, nutrient absorption and improving nutrient status of soil, both macro-nutrients and micro-nutrients [38]. The growth and nutrient status of crops have revealed a positive effect on plant nutrition, photosynthesis, chlorophyll content and nutrient content of different plant components namely roots, shoots and fruits [39]. In conclusion vermicompost is the latest organic fertilizer to supplementing chemical fertilizers for the sustainable development of agriculture.

Table 4. *Mean grain yield of bread wheat under the effect of vermi-compost and NPS fertilizer rates.*

NPS (kg ha^{-1})	VC (t ha^{-1})			Mean
	0	1.5	3	
	Grain yield (kg ha^{-1})			
0	750.0^{g}	1055.6^{g}	1527.8^{f}	1111.1^{c}
100	2722.2^{e}	3361.1^{d}	3694.4^{d}	3259.3^{b}
200	4611.1^{c}	5277.8^{b}	5722.2^{a}	5203.7^{a}
Mean	2694.4^{c}	3231.5^{b}	3648.1^{a}	
CV (%)	13.2			
LSD for NPS	228.9			
LSD for VC	228.9			
LSD for NPS * VC	396.5			

Whereas meanings followed by the same letters are not significantly different (P 0.05), VC = vermi-compost, t = ton, ha = hectare, NPS = (nitrogen, phosphorus, sulfur), kg = kilogram, DH = days to headings, LSD = least significant differences, CV = coefficient of variation.

4. Conclusions and Recommendations

The manner in which soils are managed has a major impact on agricultural productivity and its sustainability. Moreover, the optimum productivity of any cropping system depends on an adequate supply of plant nutrients. Laboratory analysis results of soil samples collected before sowing showed a deficiency in soil chemical properties. However, post-harvest soil samples indicated that significant differences and positive improvement with soil fertility status tested. Moreover, application of lime to the experimental sites was effective in increasing soil pH, which showed that soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrients. The analysis of variance among the treatments showed significant differences in the bread wheat characters tested. The maximum mean grain yield (5722.2 kg ha^{-1}) was recorded for the combined fertilization of 3 t ha^{-1} vermi-compost and 200 kg ha^{-1} NPS fertilizer, whereas the lowest was recorded for nil-fertilized plot. Accordingly, all the studied effects of vermi-compost and NPS fertilizer rates enhanced soil fertility status and bread wheat productivity in the study area; which indicated that bread wheat productivity in the study sites, was reduced due to high demand for external nutrient inputs. Based on the data obtained from this study combined fertilization of 3 t ha^{-1} vermi-compost, 200 kg ha^{-1} NPS fertilizer and 92 kg N ha^{-1} enhances soil nutrient availability and bread wheat productivity, and is recommended for the end users in Gechi District and similar agro-ecology. To sustain and/or improve the current unbalanced fertilizer application and soil mining of the study sites, precautionary actions such as adopting sustainable soil fertility replenishment strategy, soil conservation practices, lime application and avoiding unbalanced fertilizers can help to rebuild the soil conditions to increase crop productivity. Further research has to be continued to recommend the rate, time and method of combined application of vermi-compost and NPS fertilizer for major crops grown in this region.

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