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Effect of Integrated Application of Vermicompost and Inorganic Fertilizer on Yield and Yield Components of Bread Wheat in Shashemene District of West Arsi Zone, Ethiopia

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Abstract: Integrated soil fertility management (ISFM) is the combined application of inorganic with organic fertilizer for soil fertility and improving crop yield. A study was conducted in West Arsi Zone, Shashemene District on six farmers' field to determine the combined effects of vermi compost as organic fertilizer and NPS as inorganic fertilizer on grain yield of bread wheat and soil chemical properties. There were eight treatments that were replicated over farmers 'field. The analysis of variance showed highly significant differences (P≤ 0.05) between the treatments in wheat grain yield, plant height, and spike length. The highest grain yield (5130kg/ha) was obtained from T3 where 50% RNP combined with 8t/ha vermicompost followed by T7 (1275.53kg/ha) and T2 (1212.24kg/ha). The lowest grain yield was obtained from control (1944kg/ha). Composite soil samples were collected before compost application and after harvesting to evaluate the residual effect of compost on soil chemical properties. Accordingly, major soil nutrients after crop harvesting were increased at the treatments treated with maximum level of vermicompost. The partial budget analysis was done to recommend economically optimum rate of vermi compost integrated with chemical fertilizer. Accordingly, the highest net benefit (148,678.25 ETB ha-1) was recorded from treatment two where 4ton/ha vermicompost plus 50% recommended NP were applied. Therefore, 50%recommended NP plus half recommended vermi compost (4ton/ha) was economically feasible and recommended for scaling up of ISFM for bread wheat production in the district.

Keywords: Soil Fertility, Integrated Application, Organic and Inorganic Fertilizer, Vermicompost

1. Introduction

Bread wheat is grown primarily as a cereal crop in Ethiopia and it has been cultivated for a long period of time in the country. Although traditionally grown in the highlands, Wheat can be grown under a wide variety of agro climatic conditions, including elevations from zero to 2800 meters above sea level (m.a.s.l), under a similarly wide variety of moisture, temperature, and soil conditions [27]. However, wheat production and productivity are highly affected by different biotic and abiotic factors. The increased in price of chemical fertilizer and issues associated with their limited availability are becoming huge challenges to farmers. On the other hand, Continuous application of inorganic fertilizers leads to deterioration of soil chemical and physical properties and in general the total soil health [15]. It can also lead reduced production and productivity over the years [15]. However, Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients including micro-nutrients as well as improving soil physical, chemical, and biological properties thereby provide a better environment for root development by improving the soil structure [4]. The ISFM paradigm acknowledges the need for integration of both organic (compost) and mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them [28]. According to Getachew et al., the use of compost double the grain yield of cereal crops as compared to application of the chemical fertilizer alone [8].

Considering the environmental pollution related to excess use of chemical fertilizer, and its cost needs of an alternative approach based on biological origin, which is safe for use and less expensive to generate adequate plant nutrient through implementation of integrated soil fertility management (ISFM). Fully or partially replacements of chemical fertilizer in the soil through application of vermicomost have both environmental and Economic benefit in maintaining crop production more sustainable [12]. On the other hand, although nitrogen and phosphorous fertilizer rates were recommended for the production of bread wheat in Shashemene district, integrated application rate of organic sources with inorganic fertilizer were not identified. Therefore, this project is designed to evaluate the effect of vermicomost as organic source of fertilizer and its combination with chemical fertilizer on yield and yield components of Wheat.

Therefore, this experiment was required with the objectives of evaluating the effects of different levels of vermi compost and its combination with mineral fertilizer on the bread wheat yield and yield components.

2. Objective

1) To evaluate the effect of vermi compost integrated with chemical fertilizer on yield and yield components of bread wheat.
2) To determine the best combined rate of vermi compost and inorganic fertilizer for bread wheat production in the study area.
3) To evaluate the residual effect of integrated application of organic and inorganic fertilizer on soil physiochemical properties.

3. Materials and Methods

3.1. Description of the Study Area

The activity was conducted in Shashemene districts at Bute PA. It is located 250 km from Addis Ababa and 90km from Ziway/Batu. An altitude ranges from 1800-2200 m.a.s.l. The rainfall pattern of the district is characterized by bimodal distribution with small rainy season belg (March-June) and main rainy seasons Meher (July-November). The mean annual rainfall is 1200mm and means annual average temperature of 20^{o}c. As far as soil type is concerned, the dominant soil unit of the Shashemene district is Eutric andosol. Texturally, the soils of the area are classified as sandy loam. Wheat, potato, maize, and teff are the major crops produced in this district.

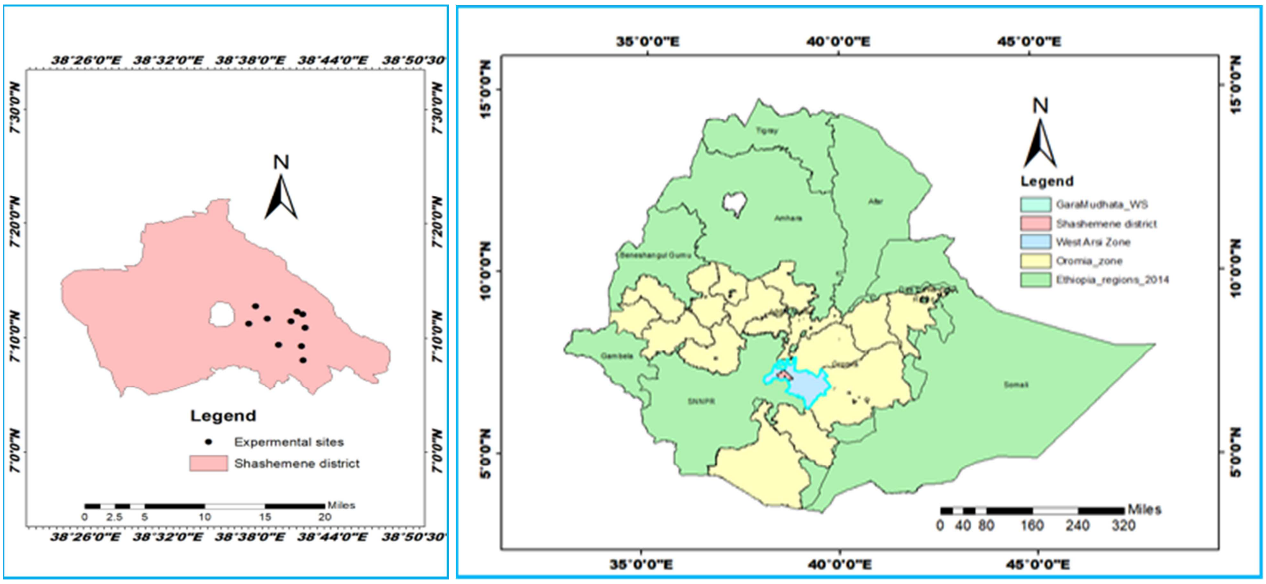


Figure 1. Location of study area.

3.2. Site Selection

Before site selection, briefing about the activity was made for agronomists and soil fertility experts at Agri. office of the district. Potentially wheat growing PA was purposively selected to conduct the activity. Accordingly, 'Bute filacha' PA was selected. One development agent (DA), who was working on soil fertility management in the selected PA, was assigned by the agricultural office of shashemene district. Nine model farmers were purposively selected based on their interest and experiences on conducting participatory research. The selected farmers were communicated and well informed about the activity.

3.3. Treatments and Experimental Design

The experiment consisted of eight treatments of sole and combinations of inorganic fertilizers (NPS and urea) and organic amendments (vermi compost). Details of the treatments have been shown in (Table 1). The treatments were replicated over farmers. Land preparation and Planting were done at all selected sites. Wheat variety called 'king bird' was used for the trial at the seed rate of 150kg/ha. It was preferred for its high yielding, disease resistant and early maturing character. Plot size was 3mx3m. Spacing between the rows were 30cm and 1m between plots.

Table 1. *Description of treatments.*

No.	Treatment combinations		
	Fertilizer/ha	**Vermi compost/ha**	**Description**
1	0	0	Control
2	50% recommended NP	4ton	50%RNP=50kg urea+80kg NPS
3	50% recommended NP	8ton	50%RNP=50kg urea+80kg NPS
4	100%RNP	0	100%RNP=100kg urea+160kg NPS
5	0	4ton	0
6	0	8ton	0
7	100%RNP	4ton	100kg urea+160kg NPS+4ton
8	100%RNP	8ton	100kg urea+160kg NPS+8ton

3.4. Data Collection and Management

3.4.1. Agronomic Data

Plant height and spike length were collected before harvesting. Grain yield, 000' seed weight, total biomass, and straw yield data were collected after harvesting.

3.4.2. Soil Data

Composite soil samples were collected before planting and from each plot after harvesting.

3.4.3. Data Management

Grain yield and yield component data were entered to the micro soft Excel. The data was subjected to analysis variance using R-software (ver.4.2.2). Difference among treatment mean was separated with LSD at 5% level of significance. The economic analysis was done using partial budget analysis model developed by CIMMYT (1998) to recommend the economically important combination of organic and inorganic fertilizer.

4. Result and Discussion

4.1. Grain Yield and Yield Components

The response of grain yield was significantly different ($p \leq 0.05$) between the treatments and negative control. However, it was identified that the response of grain yield by the treatments were not statistically significant. Maximum grain yield was obtained from the integrated application of recommended chemical fertilizer and vermi compost as compared with their sole application. The highest grain yield was obtained from treatment 3 (5130kg/ha) where 50%recommended NP was applied in combination with 8t/ha vermi compost followed by T7 (5012kg/ha) where 100%NP was applied in combination with 4t/ha vermi compost. The lowest grain yield was obtained from control (1944kg/ha) where no fertilizer and vermi compost was applied (table 2). Responses of spike length and plant height were also significantly different ($p \leq 0.05$). Similarly, treatment 3 and 7 showed greater spike L. and plant height indicating that spike length and plant height have positive correlations.

This is in agreement with findings of Ridvan et al., [20] who reported that application of vermicompost integrated with chemical fertilizer significantly increased wheat grain and straw yield. Other similar studies also reported that maize grain yield was increased in the first cropping season at the plots treated with compost and inorganic fertilizer [12, 29]. Increased grain yield could be due to vermicompost that can promote better root growth, nutrient absorption and improving both macro and micro nutrient status of the soil [13].

Table 2. *Response of grain yield and yield components to the treatments.*

No.	Treatments	Grain Yld kg/ha	Grain /timad	Sp L. (cm)	Pl. H. (cm)	TBM kg/ha	Straw Yld Kg/ha	000' grain weight (gm)
1	Control (no fertilizer)	1944.44^{d}	486.11d	5.66^{c}	60.83^{b}	5990.74^{b}	3768.52^{b}	36.55^{b}
2.	50% RNP+4 t/ha V.C	4847.95^{a}	1212.24a	7.33^{b}	78.13^{a}	11092.59^{a}	5550.92^{a}	41.65^{a}
3.	50% RNP+8 t/ha V.C	5130.49^{a}	1282.62a	7.91^{a}	78.16^{a}	11601.85^{a}	5738.42^{a}	40.61^{a}
4.	100% RNP	4790.22^{a}	1197.55a	7.66^{a}	77.00^{a}	10972.22^{a}	5497.68^{a}	40.74^{a}
5.	4 MT/ha V.C	4393.28^{b}	1098.30b	7.50^{b}	77.83^{a}	10768.52^{a}	5747.68^{a}	39.85^{a}
6.	8 MT/ha V.C	4800.35^{a}	1200.08a	7.61^{a}	77.16^{a}	11212.96^{a}	5726.85^{a}	41.25^{a}
7.	100%RNP+4 t/ha V.C	5012.14^{a}	1275.53a	7.70^{a}	80.83^{a}	10981.48^{a}	5969.34^{a}	42.05^{a}
8	100%RNP+8 t/ha V.C.	4008.39^{c}	1002.09c	7.50^{b}	77.50^{a}	11870.37^{a}	7861.98^{a}	39.53^{a}
LSD (0.05)		355.99	93.42	0.38	4.81	2534.50	2561.06	3.19
CV (%)		7.31	7.28	4.40	5.40	18.84	13.58	4.49

Yld=yield, SP L=spike length, pl.H=plant height, TBM=total biomass

4.2. Residual Effect of Vermicompost and Chemical Fertilizer Application on Soil Properties

The residual effect of applying vermicompost integrated with chemical fertilizer was evaluated after comparing soil chemical properties analyzed before treatment application and after crop harvest. Soil pH, soil organic matter, available phosphorous, total nitrogen, CEC, available Sulphur, available potassium and other micro nutrients were analyzed from the soil samples collected before planting and post-harvest.

4.2.1. Post-Harvest Soil pH

Soil pH is an excellent indicator of the suitability of a soil for plant growth. The report indicated that, soil pH levels that are too high or too low lead to a deficiency of many nutrients, decline in microbial activity, decrease in crop yields, and deterioration of soil health. For example, soil pH values below 5.5 and between 7.5 and 8.5 limit the availability of phosphate for plants. Soil pH is a characteristic that describes the relative acidity or alkalinity of the soil. Soils are considered acidic if pH < 5, very acidic if pH < 4 and neutral where soil pH is between 6.5-7.5. On the other hand, soils are considered alkaline if pH > 7.5, and very alkaline if pH > 8.

The soil laboratory report from the initial soil analysis indicated that, soil pH of the study area was 5.94 which were found to be slightly acidic. However, in post-harvest soil samples analysis, an average soil pH was increased to 6.4. Maximum soil pH (6.69) was observed at treatment 8 where 100%recommended NP and 8ton/ha vermi compost was applied (table 4). Post-harvest soil pH showed an increasing or positive trend as compared with their initial values at all experimental plots but it was still below the critical value (figure 3). This was attributed relatively high contents of exchangeable calcium and magnesium in vermicompost. It was identified that vermi compost contains 8792.90 mg/kg calcium and 2662.5mg/kg magnesium (table 3). The maximum pH of vermi compost was also found to be 7.9 which are above the critical level (7.5) indicating slightly alkaline (figure 2, table 3). The result is also strongly in agreement with previous study by R. Abafita [19] indicating that application of vermi compost improves the overall physio chemical properties, and at the same time decreases exchangeable acidity which can support a release of plant nutrients such as exchangeable calcium, magnesium and potassium in the acidic soils. In addition, vermicompost has a potential liming effect in acidic soils, due to the high molecular weight humic substance that reduce the interference of Al in the active uptake of P in root surfaces [10].

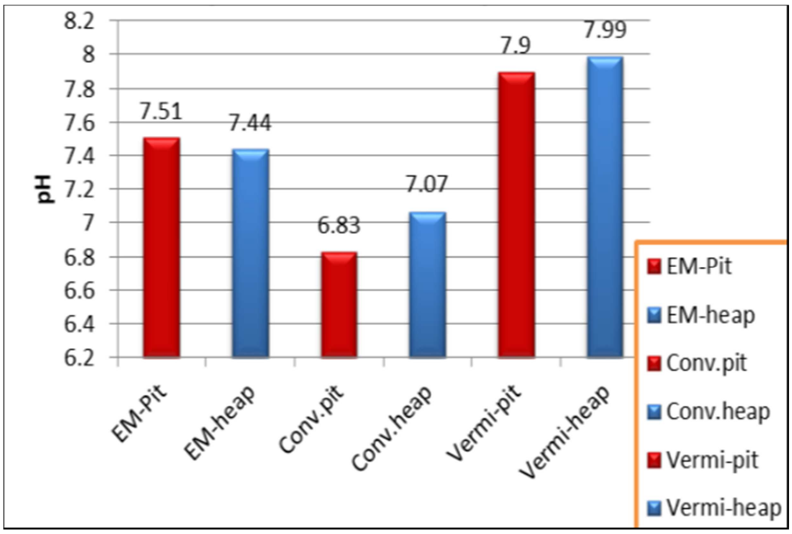


Figure 2. *pH values of different composting techniques.*

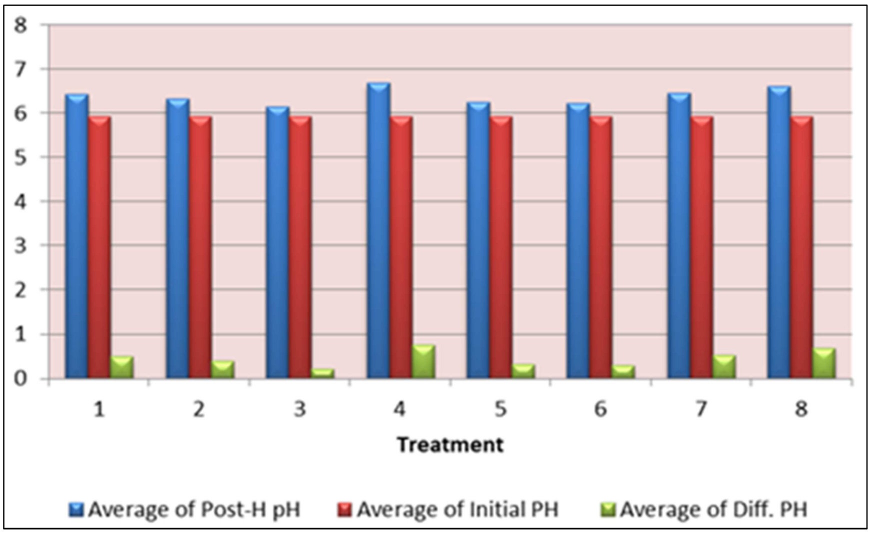


Figure 3. *Soil pH value after crop harvest.*

Table 3. *Nutrient contents of different composting techniques.*

Composting techniques	PH-H2O	Total N mg/kg	Avail. P mg/kg	Avail. K mg/kg	OC mg/kg	Sulfur mg/kg	Calcium Mg/kg	Magn. Mg/kg	C:N mg/kg	OM (%)
Pit - EM	7.51^{ab}	0.71^{c}	237.18^{cd}	7026.02^{c}	7.93^{c}	185.42^{c}	7512.30^{ab}	1159.7^{bc}	11.20^{a}	13.8^{c}
Heap - EM	7.44^{ab}	1.13^{bc}	437.82^{c}	9218.01^{bc}	13.50^{b}	261.5^{bc}	7806.40^{ab}	1271.2^{bc}	11.98^{a}	23.2^{b}
Pit only	6.83^{b}	0.71^{c}	143.39^{d}	4830.21^{c}	7.92^{c}	102.44^{c}	7081.5^{b}	774.9^{c}	11.22^{a}	13.7^{c}
Heap only	7.07^{b}	0.82^{c}	216.27^{cd}	6371.41^{c}	7.59^{c}	198.33^{c}	7765.80^{ab}	1060.6^{c}	9.31^{a}	13.1^{c}
Pit - Vermi	7.98^{a}	1.92^{ab}	807.98^{b}	15255.4^{ab}	16.43^{ab}	477.85^{b}	8490.20^{ab}	2362.6^{ab}	10.04^{a}	28.2^{ab}
Heap- Vermi	7.99^{a}	2.04^{a}	1090.82^{a}	21594.5^{a}	19.60^{a}	915.34^{a}	8792.90^{a}	2662.5^{a}	9.64^{a}	33.7^{a}
LSD (0.05)	0.72	0.64	270.55	6381.50	4.39	279.24	1479.50	1290.2	3.70	7.57
CV (%)	3.51	19.70	20.17	21.71	13.15	28.53	6.82	30.38	12.79	13.15
P-value	**	**	**	**	**	**	0.020	0.0016	0.18	**

EM= effective micro organisim

4.2.2. Post-Harvest Soil Organic Carbon Contents

Soil organic carbon (SOC) is the carbon that remains in the soil after partial decomposition of any material produced by living organisms. It was identified that the maximum soil organic carbon content (2.09%) was observed from post-harvest (PH) soil analysis collected from treatment 8 where 100%vermicompost and 100% recommended NP were applied (table 4). Generally, post-harvest soil analysis showed that, soil organic carbon and organic matter content of the soil was increasing at all experimental sites as compared with their initial status except control (treatment 1) and treatment four where soil organic matter and soil carbon pool showed a decreasing trend after crop harvest (figures 4&5).

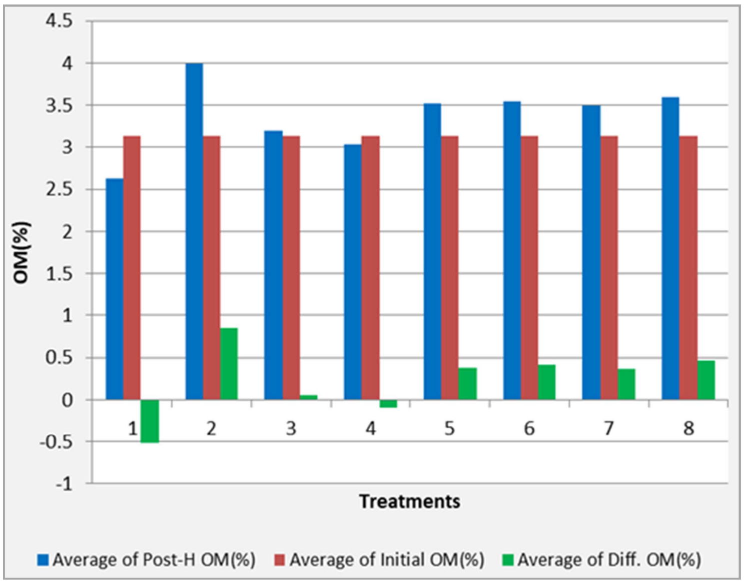


Figure 4. *Differences in soil organic matter (%).*

Figure 5. *Differences in soil organic carbon (%).*

Both soil organic matter and soil organic carbon significantly increased in a plot treated with vermicompost and combination of vermi compost and chemical fertilizers at different levels after the first crop harvest as compared with the plots treated only with inorganic fertilizer.

Therefore, when managed properly, soils can play an important role in climate change mitigation by storing carbon or decreasing greenhouse gas emissions to the atmosphere [26, 14]. It was identified that, a substantial amount of global CO_2 comes from soil through mineralization and soil respiration [17]. However, integrated application of organic and inorganic fertilizers increased soil organic matters that consequently improve soil carbon pool [6].

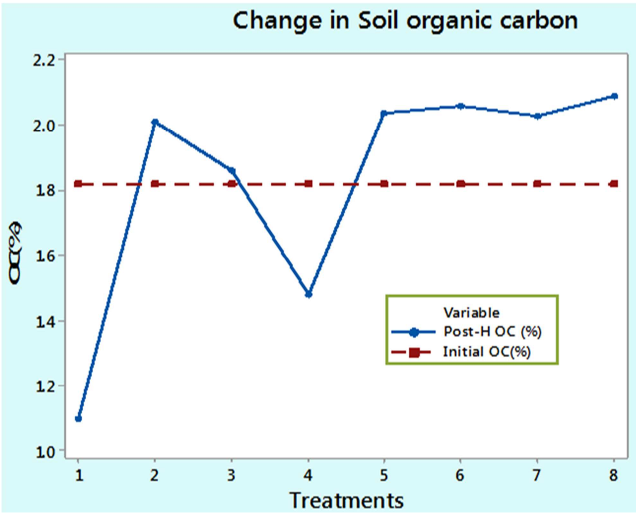


Figure 6. Change in soil carbon pool under each treatment.

4.2.3. Post-Harvest Total Nitrogen and Available Phosphorous

(i) Total nitrogen

Post-harvest soil analysis showed that total nitrogen was relatively high at the treatment six and eight were maximum amount of vermi compost (8ton/ha) were applied. This might be attributed to N released from compost through mineralization and N supplied to soil from the NPS fertilizer. As the amount of organic carbon increases in the soil through application of vermicompost fertilizer, total nitrogen also increases with strong positive correlation r=0.846 (figure 7). However, as compared with the initial level, total nitrogen showed a decreasing trend in post-harvest soil analysis at all treatments (figure 8).

Nitrogen is mainly excreted as ammonium released by the worm [25]. Increased availability of N in worm casts compared to non-ingested soil has been reported by several workers [9] reported that nitrogen from vermicompost was rapidly mineralized and almost entirely taken up by crops at the first cropping season. On the other hand, Earthworm excretion of nitrogenous compound in urine and mucus have low C:N ratio may provident particularly labile N source for soil microbes [16].

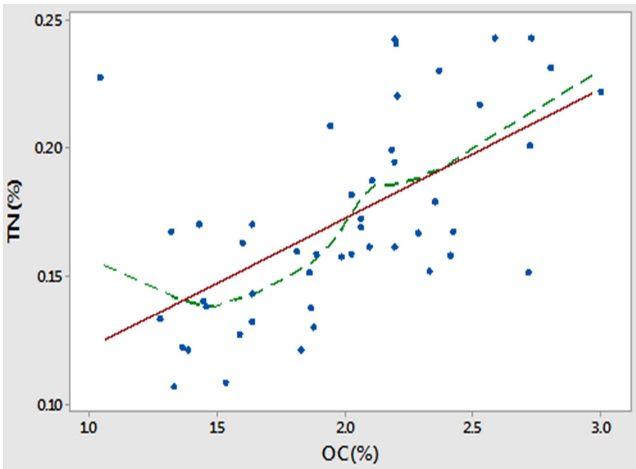
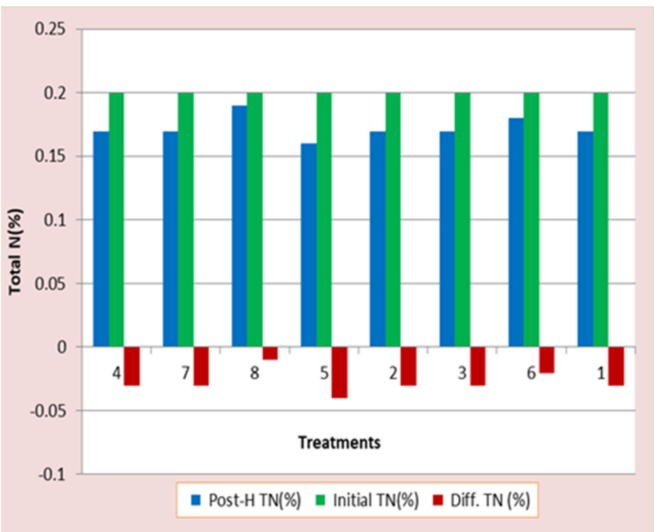
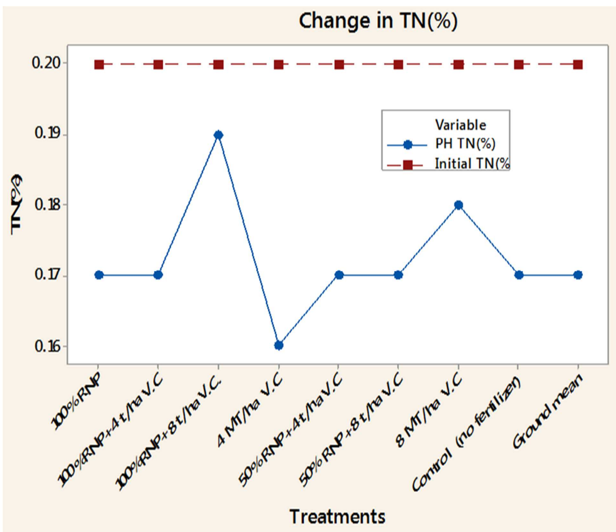


Figure 7. Matrix plot of organic carbon and total nitrogen.





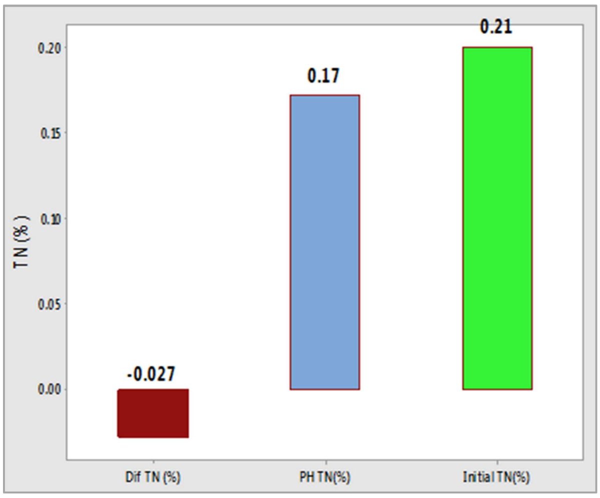


Figure 8. *Change in total nitrogen after crop harvesting.*

(ii) Available phosphorous

In the tropical soils P is the most commonly plant growth-limiting nutrient next to N. The amount of available p in soil after crop harvest significantly vary with the level of applied a vermicompost. The maximum available p (25mg/kg) was observed at the treatment where 8ton/ha vermi compost was applied which falls in medium to high range as per rating suggested by Ouédraogo et al. and Shara [18, 25]. Soil available p after crop harvesting was increasing at all treatments treated with different level of vermi compost but decreasing in treatment one and four where vermi compost was neglected (figure 9).

This finding is in agreement with previously conducted research by Inal et al. [11] and Habtamu et al. [9] who reported that increase in concentration of available p in soil after applying vermicompost and NPS fertilizer.

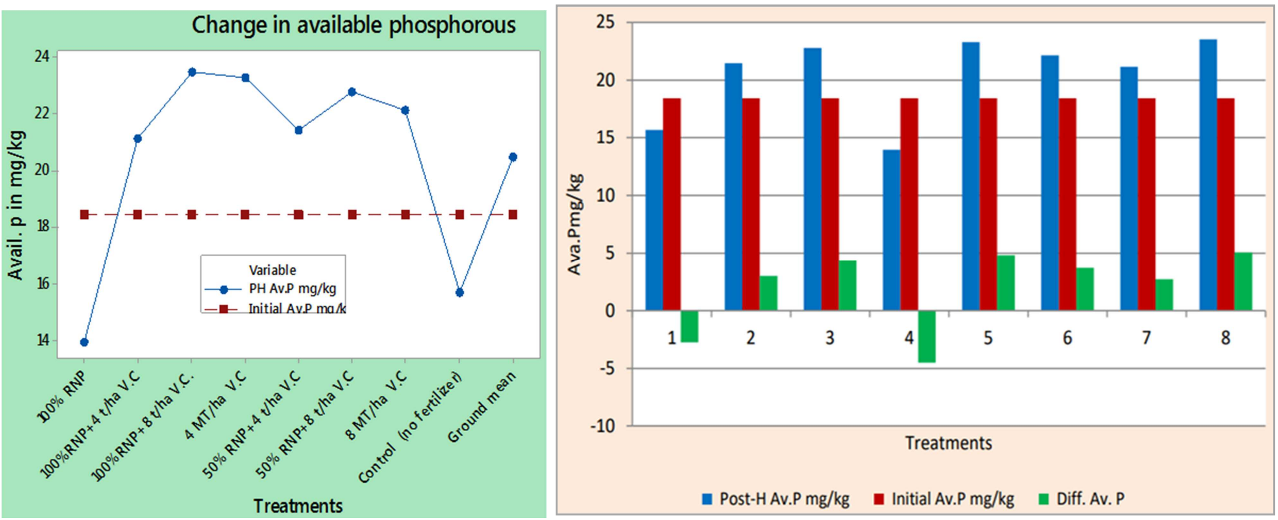


Figure 9. *Change in available phosphorous after crop harvesting.*

The result is strongly in agreement with the study by Getachew et al. [8] and Kasahun et al. [12] who reported that there was significant increase in available p and soil organic carbon after the first crop at the plots treated with compost as compared with of sole inorganic fertilizer. Other similar studies also reported that, compost application have strong positive effect on the physicochemical and biological properties of the soil which often leads to higher crop growth and yield [1, 7].

Table 4. *Differences in soil chemical properties between initial and post-harvest analysis (on farm).*

Treatments	Post-H pH	Initial PH	Diff. PH	Post-H Av.P mg/kg	Initial Av.P mg/kg	Diff. Av. P mg/kg	Post-H TN (%)	Initial TN (%)	Diff. TN (%)	Post-H OC (%)	Initial OC (%)	Diff. OC (%)
Control (no fertilizer)	6.44	5.94	0.50	15.70	18.44	-2.74	0.17	0.20	-0.03	1.10	1.82	-0.72
50% RNP+4 t/ha V.C	6.33	5.94	0.39	21.45	18.44	3.01	0.17	0.20	-0.03	2.01	1.82	0.19
50% RNP+8 t/ha V.C	6.15	5.94	0.21	22.78	18.44	4.34	0.17	0.20	-0.03	1.86	1.82	0.04

Treatments	Post-H pH	Initial PH	Diff. PH	Post-H Av.P mg/kg	Initial Av.P mg/kg	Diff. Av. P mg/kg	Post-H TN (%)	Initial TN (%)	Diff. TN (%)	Post-H OC (%)	Initial OC (%)	Diff. OC (%)
100% RNP	6.63	5.94	0.75	13.95	18.44	-4.49	0.17	0.20	-0.03	1.48	1.82	-0.34
4 MT/ha V.C	6.26	5.94	0.32	23.27	18.44	4.83	0.16	0.20	-0.04	2.04	1.82	0.22
8 MT/ha V.C	6.24	5.94	0.30	22.15	18.44	3.71	0.18	0.20	-0.02	2.06	1.82	0.24
100%RNP+4 t/ha V.C	6.47	5.94	0.53	21.15	18.44	2.71	0.17	0.20	-0.03	2.03	1.82	0.21
100%RNP+8 t/ha V.C.	6.69	5.94	0.69	23.51	18.44	5.07	0.19	0.20	-0.01	2.09	1.82	0.27
Ground mean	6.40	5.94	0.46	20.50	18.44	2.06	0.17	0.20	-0.03	1.83	1.82	0.01

***Table 4.** Continued.*

Treatments	Post-H CEC meq/100g	Initial CEC meq/100g	Diff. CEC meq/100g	Post-H Av.K mg/kg	Initial Av.K mg/kg	Diff. Av.K mg/kg	Post-H Sulfur mg/kg	Initial Sulfur mg/kg	Diff. Sulfur mg/kg	Post-H OM (%)	Initial OM (%)	Diff. OM (%)
Control (no fertilizer)	17.62	33.60	-15.99	299.13	347.56	-48.44	9.33	14.95	-5.63	2.62	3.14	-0.52
50% RNP+4 t/ha V.C	17.86	33.60	-15.75	273.75	347.56	-73.82	7.90	14.95	-7.05	3.99	3.14	0.85
50% RNP+8 t/ha V.C	18.57	33.60	-15.03	283.34	347.56	-64.22	8.38	14.95	-6.57	3.20	3.14	0.06
100% RNP	18.02	33.60	-15.58	257.61	347.56	-89.95	7.81	14.95	-7.14	3.04	3.14	-0.10
4 MT/ha V.C	17.40	33.60	-16.20	265.78	347.56	-81.79	8.75	14.95	-6.20	3.52	3.14	0.38
8 MT/ha V.C	17.43	33.60	-16.17	262.50	347.56	-85.06	8.25	14.95	-6.70	3.55	3.14	0.41
100%RNP+4 t/ha V.C	16.96	33.60	-16.64	274.96	347.56	-72.60	8.82	14.95	-6.13	3.50	3.14	0.36
100%RNP+8 t/ha V.C.	17.98	33.60	-15.62	323.68	347.56	-23.88	9.80	14.95	-5.15	3.60	3.14	0.46
Ground mean	17.73	33.60	-15.87	280.09	347.56	-67.47	8.63	14.95	-6.32	3.38	3.14	0.24

Post-H=post-harvest, Diff.=difference, Av.=available, OM= organic matter, OC= organic carbon, TN= total nitrogen

***Table 5.** Partial budget analysis using CIMMYT. 1988.*

Treatments	UREA in kg/ha	NPS in kg/ha	Grain Yield in Kg/ha	Price of wheat /kg	Price of Urea /kg	Price of NPS /kg	V. Compost Kg/ha	Price of V. Compost/kg	Total Variable cost /ha	Gross Income/ha	Net benefit/ha	MRR (%)
1	0	0	1944	35	40	40	0	4	0	68055.40	68,055.40	0.00
4	100	150	4090	35	40	40	0	4	10000	143157.70	133,157.70	651.02
5	0	0	4393	35	40	40	4000	4	16000	153764.80	137764.80	76.79
2	50	75	4848	35	40	40	4000	4	21000	169678.25	148,678.25	218.27
7	100	150	5012	35	40	40	4000	4	26000	175424.90	141,424.90	14.93
6	0	0	4800	35	40	40	8000	4	32000	168012.25	136,012.25	D
3	50	75	5130	35	40	40	8000	4	37000	179567.15	142,567.15	131.10
8	100	150	4008	35	40	40	8000	4	42000	140293.65	98,293.65	D

Maximum MRR (651%) was obtained from TR4 where only 100%RNP was applied, followed by TR 2 (218.27%) where 50%RNP+4ton/ha V.C was applied and TR3 where 50%RNP+8ton/ha V.C. However, for the treatments with MRR greater than minimum acceptable rate of return (100%), treatment having maximum NB will be recommended. Therefore, treatment 2 that gain the highest net benefit (148,678.25 ETB) is economically feasible and recommended for an extension in Shashemene district.

5. Conclusion and Recommendations

For sustainable land management, implementation of Integrated Soil fertility management (SFI) is very important. Organic fertilizers maintains soil health, improves soil nutrient and increase crop yield. Wheat grain yield was significantly higher at treatments were vermicompost was applied integrated with chmical fertilizer as compared with sole application of vermi compost and chemical fertilizer., implementation of ISFM significantly increased major soil nutrients except total total nitrogen which showed a decreasing trend due rapid mineralization of vermicompost and lower C: N ratio. In conclusion, It was identified that 8ton/ha vermicompost plus 50% recommended chemical fertilizer gave maximum grain yield but treatment 2 where 50% recommended chemical fertilizer plus 4ton/ha vermicompost economically gain maximum net benefit. Therefore, treatment 2 that gained the highest net benefit (148,678.25 ETB) is economically feasible and recommended for an extension in Shashemene district.

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