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Effects Integrated Use of Lime, Vermi-Compost and Inorganic Fertilizer on Bread Wheat Production in Acid Soil of Toke Kutaye District, West Shewa Zone, Ethiopia

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Abstract

Acidic soils limit the productive potential of crops because of low availability of basic cations and excess of hydrogen and aluminium in exchangeable forms. In western shewa Zone, soil acidity is a well-known problem limiting crop productivity. Field experiments were conducted for two consecutive cropping seasons of 2020 and 2021 to evaluate the effects of lime, VC and chemical fertilizer on yield and yield components of wheat in Toke kutaye District, West shewa Zone of Ethiopia. The analysis of variance among the treatments showed significant differences ($P \leq 0.05$) on almost all the bread wheat characters tested except for plant height. The highest and lowest bread wheat grain yield (4035.7 kg ha-1) and (1440.5 kg ha-1) were obtained from the treatment combination of 4.6t ha-1 Vermi-compost with recommended lime and 150 kg ha^{-1} NPS, 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. Integrated use of lime with organic and chemical fertilizers is considered as a good approach for sustainable crop production under acidic soils. Vermicompost and chemical fertilizer when used with lime play a vital role in enhancing productivity of acidic soils. Hence combined fertilization of 2.3 t ha-1 Vermi-compost with half recommended lime based on exchangeable acidity of soil and 150 kg ha-1 NPS and 92 kg ha-1 N could improve crop productivity and it is recommended for the study area (Toke kutaye District) and similar agro-ecology.

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Vermi-compost, Lime and soil Acidity, nitrogen (N), phosphorus (P).

Introduction

Low soil fertility and nutrient availability due to acidity and low level of input use are also among the major crop production constraints in Ethiopia including wheat crop (Alemayehu *et al.*, 2011; Abreha *et al.*, 2013). Soil acidity with associated low nutrient availability is one of the major constraints to crop production on Ethiopian central highlands. It is a serious threat to crop production in most highlands of Ethiopia in general and in the South, South western and western part of the country in particular and also it is a major constraint to agricultural productivity throughout Africa where high rainfall is common due to the deficiencies of nitrogen (N) by leaching, phosphorus (P) by fixation, and low soil organic matter (OM) (Mesfin, 2007).

Different reports indicated that most cultivated lands of the Ethiopian highlands in general and western and south western parts in particular are prone to soil acidity due to removal of ample amount of nutrients by leaching, crop mining and runoff as compared with grazing and forest lands (IFPRI, 2015). Based on the problem that soil acidity causes on a larger area in Ethiopia, it needs due attention to be addressed by different coping mechanisms.

There are different materials of conventional and non-conventional sources to amend soil acidity and fertility. Productivity of crops in acid soils with Al toxicity and low soil availability of Phosphorus may be improved by use of lime, fertilizers with liming effects, and/or organic materials (Verde *et al.*, 2013). Lime is the most effective means of amending soil acidity (Anetor and Ezekiel, 2006).

Application of lime containing Ca and/or Mg compounds to acid soil increasesCa^{2+} and/or Mg^{2+} ions and reduces Al^{3+}, H+, Mn^{2+}, and Fe^{2+}ions in the soil solution. Hence, this leads to increased soil pH and available P due to reduction in P sorption (Kisinyo, 2011). Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients as well as improving soil physical, chemical, and biological properties (Mengesha and Mekonnen, 2012).

Vermicompost is a nutrient-rich, microbiologically-active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of organic matter. It contains most nutrients in plant-available forms such as nitrates, phosphates, and exchangeable calcium, soluble potassium and finely divided 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 (Arancon *et al.*, 2004). There is good evidence that VC application promotes growth of plants and positive effect on growth and productivity of cereals and legumes (Glenda *et al.*, 2009).

The combined application of inorganic and organic fertilizers is widely recognized as a way of improving productivity of the soil sustainably (Mahajan *et al.*, 2008). The pH of acidic soils increases following vermicompost applications, which may be due to calcium carbonates and organic acids in the manure that buffer soil acidity. However, in the study area there is no information on the combined use of Vermi-compost, lime and chemical fertilizer for bread wheat production. Therefore, the objective of the study was to find out the effects of vermicompost, lime and NPS (inorganic fertilizer) rates on bread wheat production in Toke kutaye District of west shewa zone.

Materials and Methods

Description of the Study Site

The study was carried out at Toke Kutaye Woreda by Ambo Agricultural Research Center, under the Ethiopian Institute of Agricultural Research (EIAR) during 2020 and 2021 main cropping season. Toke kutaye woreda is located in the West Shewa Zone of the Oromia of Ethiopia. Located 12km west of Ambo, this town has a latitude and longitude of 8°58′N 37°46′E, with an elevation of 2101 meters above sea level.

Determination of Lime Requirements

The amounts of lime applied was determined based on the exchangeable acidity, mass per 0.15m furrow slice and bulk density of the soil (Shoemaker *et al.*, 1961), considering the amount of lime needed to neutralize the acid content (Al + H) of the soil up to the permissible acid saturation level for wheat growth.

$$LR, \frac{CaCo3kg}{ha} = Cmol \frac{EA}{Kg} of\ soil * 0.15m * 10m^2 * BD\left(\frac{g}{cm^3}\right) * 1000 * crop\ factor \quad ....2000$$

Where: BD = bulk density, EA = exchangeable acidity (exch. H^+ + Al^{3+}), LR= lime requirements, 0.15m= plough depth/depth of lime incorporation. Crop factor = 1.5

2000 = to convert exchangeable acidity per kg of soil to per hectare

Experimental treatments, design and procedures

The treatments consisted of three factors lime, Vermi-compost and inorganic fertilizer levels arranged systematically in a randomized complete block design with three replications. The lime requirement (LR) of the soil for the plots was determined based on EA or acid saturation of the experimental soil. Calcium carbonate was used as the source of lime and the whole doses of lime of the respective plot treatment were broadcasted uniformly by hand and mixed in the top 15 cm soil layer, a month before sowing, to mix lime with soil properly. A land with average pH of 4.5 was selected for the study and land preparation took place well in advance before sowing wheat, as lime and VC need certain incubation period to bring change in physicochemical properties of the soil. The size of each plot was 3 x 4 m (12 m^2) and the spacing between replication and plots were 1.5 and 1 m, respectively. The experimental field was prepared following the conventional farmers' practices. The field was oxen ploughed three times before sowing.

The seed bed was prepared by ploughing and harrowing using oxen and then leveled manually. All agronomic practices such as hoeing and weeding, were undertaken uniformly to all plots by hand. The treatments of lime and VC were applied to the plots as per treatment in band according to the randomization set before sowing of wheat; and left for one months of incubation period for lime and VC. All the recommended cultural practices were used for the management of the experimental crop.

Agronomic data collection

Plant height was measured from the soil surface to the tassel base of randomly selected wheat plants. Total biomass yield of wheat was measured using graduated balance following complete sun-drying of sample plants taken from each net plot area. Initially, the grain yield was threshed, cleaned from straw and debris, and then weighed using a sensitive electrical balance. Grain yield was adjusted to 12.5% moisture content and converted to a hectare basis (kg ha^{-1}). Straw yield was quantified by subtracting grain yield from biomass yield.

Statistical analysis

To determine the effects of treatments on wheat yields, the collected crop data were subjected to analysis of variance (ANOVA) using a general linear model (GLM) procedure of Statistical Analysis System (SAS) software version 9.3 (SAS Institute, 2012). When the ANOVA revealed significant differences between treatments, mean separation was performed using LSD test at $p<0.05$

Results and Discussion

Effect of vermicompost, lime, and NPS fertilizer on growth, yield and yield components of bread wheat

There were significant differences among treatments for all parameters i.e., yield, above ground biomass, spike length, and number of seed per spike except for plant height, (Table1_6). In general, the results indicate that integrated use of lime, vermicompost, and chemical fertilizer can improve soil acidity and availability of nutrients.

Effect of vermicompost, lime, and NPS fertilizer on Grain yield of bread wheat

The effect of vermicompost, lime, and site-specific fertilizer rate rates significantly affected the grain yield of wheat crops. Accordingly, the highest grain yield (4035.7 kg ha-1) was recorded from Rec.VC +Rec. lime + Rec. SSFR (site-specific fertilizer rate) and followed by that (3653 kg ha-1) was recorded from Rec. SSFR (site-specific fertilizer rate) +50% Rec. lime +50% Rec. VC, while the lowest grain yield (1462.7 kg ha-1) was recorded from the control plot or treatment.

The sole application of Rec. lime and VC increased wheat yield by 14.39 and 33.1% respectively over the control treatment. The maximum grain yield is due to high plant height, spike length, seed numbers per spike, and above ground biomass. This showed that organic fertilizer might have been more advantageous than lime in maximizing productivity/managing soil acidity if properly used.

The combined use of vermicompost, lime, and inorganic fertilizers is more valuable than the sole use of in organic, organic fertilizers and lime. The highest grain yield with the combined application of vermicompost, lime, and chemical fertilizer might be attributed to the improving action of amendments on the soil's physicochemical properties and nutrient status in the soil, which enhances plant growth. Moreover, an increase in essential nutrients and organic matter due to the combined application of vermicompost, lime, and chemical fertilizer promotes microbial population, which ultimately enhances plant growth and production on a sustainable basis.

Liming alone did not increase yield and neither did VC when applied without liming and chemical fertilizer. But combined use of lime and VC almost increased the yield compared to the control even without chemical fertilizer. Dilshad *et al.*, (2010) reported that improvement in yield can be obtained if soil fertility is maintained through the combined use of organic and inorganic fertilizers.

Furthermore, high doses of VC increased grain yield since it improved soil physicochemical and microbial conditions and then facilitating wheat crop growth. Also, the effect of chemical fertilizer was much greater when integrated with lime and VC. This is in agreement with reports of Makinde and Ayoola (2010) who concluded that high and sustainable crop yields are only possible with integrated use of mineral fertilizers and OM.

Effect of vermicompost, lime, and NPS fertilizer on Number of seed per spike of bread wheat

The effect of vermicompost, lime, and site-specific fertilizer rate rates significantly affected the number of seed per spike of wheat (Table3). The positive response of wheat to applied lime, VC and SSFR might be due to the improvement of soil pH in response to lime and VC amendment, which enhanced growth and yield of the plant, as a result of increased availability of P that might have increased intensity of photosynthesis, flowering, seed formation and fruiting.

Table.1 Treatments and Description

Treatments	Lime kg/ha	VC kg/ha	NPS kg/ha	Urea kg/ha
50% Rec. lime + Rec. SSFR + 50 % Rec. Vc	1096.87	2300	150	200
Rec. lime + Rec. SSFR+Rec.VC.	2193.75	4600	150	200
Rec. VC + Rec. SSFR	0	4600	150	200
Rec. lime + 50 % SSFR + 50 % VC.	2193.75	2300	75	100
Rec. lime + Rec.SSFR	2193.75	0	150	200
Rec. SSFR.	0	0	150	200
50%Rec.lime + 50% Rec.VC+50%Rec.SSFR	1096.87	2300	75	100
50% (Rec. VC + Rec. SSFR)	0	2300	75	100
50%Rec. lime + 50%Rec. VC	1096.87	2300	0	0
Rec. lime + Rec. Vc	2193.75	4600	0	0
50% (Rec. lime + Rec. SSFR)	1096.87	0	75	100
Rec. lime based on EA	2193.75	0	0	0
Control	0	0	0	0
Rec.VC.	0	4600	0	0

Table.2 The combined effect of lime, VC and SSFR on grain yield of wheat under acid soil condition at Toke Kutaye during 2020-2021 main cropping season

Treatments	2020	2021	Mean
	Grain Yield kg/ha	Grain Yield kg/ha	Grain Yield kg/ha
50% Rec. lime + Rec. SSFR + 50 % Rec. Vc	3964.3a	3341.7b	3653.0ab
Rec. lime + Rec. SSFR+Rec.VC.	3828.6a	4242.9a	4035.7a
Rec. VC + Rec. SSFR	3690.5ab	2757.1bcd	3223.8bc
Rec. lime + 50 % SSFR + 50 % VC.	3452.4abc	2760.7bcd	3106.5cd
Rec. lime + Rec.SSFR	3071.4bcd	3041.7bc	3056.5cde
Rec. SSFR.	3042.9cd	2390.5cde	2716.7def
50%Rec.lime + 50% Rec.VC+50%Rec.SSFR	3039.7cd	3020.2bc	3028.0cde
50% (Rec. VC + Rec. SSFR)	2702.4de	2554.8cde	2628.6ef
50%Rec. lime + 50%Rec. VC	2702.4de	2104.8def	2403.6fg
Rec. lime + Rec. Vc	2226.2ef	2021.4efg	2123.8gh
50% (Rec. lime + Rec. SSFR)	1738.1fg	2406cde	2072gh
Rec. lime based on EA	1635.7fg	1540.5fg	1588.1i
Control	1535.7g	1345.2g	1440.5i
Rec.VC.	1457.1g	2034.5efg	1745.8hi
Mean	2720.23	2540	2630.18
$LSD_{0.05}$	647.1	692.6	448.47
CV%	11.01	12.62	11.7521

Where CV; is coefficient of variation, LSD; list significant different

Table.3 The combined effect of lime, VC and SSFR on seed per spike of wheat under acid soil condition at Toke Kutaye during 2020-2021 main cropping season

Treatments	2020	2021	Mean
	Seed NoSpike	Seed NoSpike	Seed NoSpike
Rec. lime + 50 % SSFR + 50 % VC.	46.6ab	49.8a	48.2a
Rec. lime + Rec. SSFR+Rec.VC.	51.1a	41.9abcd	46.700ab
Rec. lime + Rec. Vc	41.1abcd	44.5ab	42.800abc
Rec. SSFR.	42.70abc	42.7abc	42.70abc
50% Rec. lime + Rec. SSFR + 50 % Rec. Vc	39.4bcde	45.9ab	42.65abc
Rec. lime + Rec.SSFR	45.800ab	37.2abcd	41.50abc
Rec. VC + Rec. SSFR	44.7ab	35.2bcd	39.950abc
50%Rec.lime + 50% Rec.VC+50%Rec.SSFR	45.1ab	33.5bcd	39.30bc
50% (Rec. VC + Rec. SSFR)	36.2bcde	41.3abcd	38.75bc
Rec.VC	38.2bcde	37abcd	37.600cd
50% (Rec. lime + Rec. SSFR)	32.8cde	40.6abcd	36.7cd
50%Rec. lime + 50%Rec. VC	43.5abc	28.70d	36.1cd
Control	31.3de	29.2d	30.25
Rec. lime based on EA	28.8e	30.9cd	29.85
Mean	40.55	38.45	39.50
$LSD_{0.05}$	10.98	13.25	8.35
CV%	12.53	15.95	14.58

Where CV; is coefficient of variation, LSD; list significant different

Table.4 The combined effect of lime, VC and SSFR on above ground biomass of wheat under acid soil condition at Toke Kutaye during 2020-2021 main cropping season

Treatments	2020	2021	Mean
	Biomass ton/ha	Biomass ton/ha	Biomass ton/ha
50% Rec. lime + Rec. SSFR + 50 % Rec. Vc	10.09a	10.19a	10.14a
Rec. lime + Rec. VC + Rec. SSFR	9.71ab	4.93cd	7.32b
50% Rec. lime + Rec. SSFR + 50 % Rec. Vc	9.6ab	5.85abc	7.88ab
Rec. lime + Rec.SSFR	9.07abc	6.69abcd	7.78ab
Rec. lime + 50 % SSFR + 50 % VC.	8.5abc	6.45abcd	7.47b
50%Rec.lime + 50% Rec.VC+50%Rec.SSFR	7.73abcd	8.35abc	8.045ab
Rec. SSFR.	7.42abcd	5.26bcd	6.34bcd
50%Rec. lime + 50%Rec. VC	6.76bcde	6.90abcd	6.83bc
50% (Rec. VC + Rec. SSFR)	6.71bcde	4.97cd	5.84bcd
Rec. lime + Rec. Vc	5.92cdef	3.5d	4.7cd
50% (Rec. lime + Rec. SSFR)	4.59def	8.05abc	6.32bcd
Rec.VC.	4.11ef	7.45	5.78bcd
Rec. lime based on EA	4.11ef	9.26ab	6.7bc
Control	3.4f	4.5cd	3.95d
Mean	6.98	6.59	6.79
$LSD_{0.05}$	3.15	4.25	2.47
CV%	20.9	19.8	25

Where CV; is coefficient of variation, LSD; list significant different

Table.5 The combined effect of lime, VC and SSFR on plant height of wheat under acid soil condition at Toke Kutaye during 2020-2021 main cropping season

Treatments	2020	2021	Mean
	Plant height(cm)	Plant height(cm)	Plant height(cm)
Rec. lime + 50 % SSFR + 50 % VC.	65.5	84.8	75.15
Rec. lime + Rec. SSFR+Rec.VC.	66.9	83.5	75.2
Rec. lime + Rec. VC	60.5	74.1	67.3
Rec. SSFR.	62.2	87.2	69.85
50% Rec. lime + Rec. SSFR + 50 % Rec. VC	68.3	77.5	77.75
Rec. lime + Rec.SSFR	66.9	87.3	77.1
Rec. VC + Rec. SSFR	65.4	76.3	70.85
50%Rec.lime + 50% Rec.VC+50%Rec.SSFR	61.4	82.3	71.85
50% (Rec. VC + Rec. SSFR)	63.8	75.5	69.65
Rec.VC	55.7	77.2	66.45
50% (Rec. lime + Rec. SSFR)	56.90	78.4	67.65
50%Rec. lime + 50%Rec. VC	62.8	82.9	72.85
Control	61.1	77.8	69.45
Rec. lime based on EA	57.5	81.9	69.7
Mean	62.49	80.47	71.4
$LSD_{0.05}$	NS	NS	NS
CV%	6.43	7.7	7.18

Table.6 Mean spike length, Total tiller, and productive tiller of wheat under limed, vermicompost and site-specific blended fertilizer treated condition

	1st year		
Treatments	Spike Length(cm)	Total Tiller	Productive Tiller
Rec.SSFR+50%Rec.lime+50%Rec.VC	**6.4a**	3.13	3.13
Rec.lime+50%SSFR+50%VC	5.8abc	3.60	3.47
Rec.lime+Rec.SSFR+Rec.VC	6ab	4.07	3.93
Rec.lime+Rec.SSFR	5.2bcd	3.67	3.60
Rec.VC+Rec.SSFR	5.67abc	3.33	3.33
50%Rec.lime+50%Rec.SSFR	5.07cde	3.80	3.53
50%Rec.lime+50%Rec.VC	6ab	3.53	3.47
Rec.lime+Rec.VC	5.33bcd	3.93	3.87
50%Rec.lime+50%Rec.SSFR+50%Rec.VC	5.47bc	3.53	3.53
Rec.lime based On EA	5.03cde	3.40	3.33
Control	5.27bcd	3.33	3.27
Rec. SSFR	5.13cd	3.60	3.60
50%Rec.VC+50%Rec.SSFR	4.53de	3.40	3.40
Rec.VC	4.3e	3.60	3.33
Mean	5.37	3.56	3.48
CV (%)	9.13	16.78	18.23
LSD (0.05)	0.8236	NS	NS

Where CV; is coefficient of variation, LSD; list significant different

And also, this might be due to lime and VC enhanced vegetative growth, thereby, enabling the plant to bear higher number of seed than the untreated soil condition, and neutralizing soil acidity by lime and VC, which in turn increases availability of P for plant uptake, through reduction in its fixation on acid soils. Similar to this finding, Kisinyo *et al.,* (2016), reported that the application of lime, VC and P significantly increased number seed per plant.

Effect of vermicompost, lime, and NPS fertilizer on Biomass Yield of bread wheat

Combined application of vermicompost, lime and NPS fertilizer is significant affect biomass yield. The highest value (10.14-ton ha-1, 8.045-ton ha-1, 7.88-ton ha-1 and7.78-ton ha-1) was recorded from the plot treated by 100% (Rec. VC +Rec. lime +Rec. SSFR), 50% (Rec.lime + Rec.VC+Rec.SSFR), 50% Rec. lime + Rec. SSFR + 50 % Rec. VC and Rec. lime + Rec.SSFR respectively, while the lowest (3.95 t ha-1) in the control plot. This difference might be due to synergistic effects of lime, VC, and mineral fertilizer as well as high doses of mineral fertilizer and VC used for luxuriant vegetative growth of plants.

And also, this might be due to an improved ability of the plant to absorb P, when Al toxicity has been eliminated, and enhanced the vegetative growth of wheat, which resulted in increased dry biomass yield. From this study results wheat respond well to vermicompost fertilizer and lime application as a result of its well-developed root system which facilitates absorption of the required nutrients for effective dry matter production by the crop and reduction of exchangeable acidity in the soil. Temasgen *et al.,* (2017) reported that barley above ground biomass was reduced in control plots by 38.2% compared with amended plots.

The authors also reported that the highest dry biomass of barley was recorded on lime amended soil with 2.2 t ha^{-1} and 30 kg P ha^{-1}than separate application of lime and phosphorus. In agreement with this finding Kibunja *et al.,* (2010) reported that the total dry matter of wheat was highest from treatment combinations of inorganic and organic fertilizers than control, organic and chemical fertilizers alone.

These results are in line with that of Makinde and Ayoola (2010), who demonstrated that the application of OM as fertilizers provides growth regulating substances and improves physicochemical and microbial properties of soils.

Plant height

The results indicated that wheat's growth performed better in amended soil than unamended soil which could be as lime and compost may decompose and release nutrients slowly (Rheinheimer *et al.,* 2018). The greater increment of plant height of wheat from combined treatments could be related to reduced soil acidity and increased availability of nutrients that may enhance vegetative growth (Melese *et al.,* 2015). In addition, the application of Vermi-compost alone or combined with mineral fertilizers improved soil bulk density and water holding capacity, resulting in better roots growth and nutrients use efficiency (Agegnehu *et al.,* 2016).

Conclusion

Integrated nutrient management mainly use of vermicompost and mineral P fertilizers with lime has been getting attention because of its high ability to ameliorate soil acidity, improve soil fertility and eventually crop yield sustainably. The results of this study revealed that the combined application of different rates of vermicompost, lime, and inorganic fertilizer to soil significantly affected most parameters used for this investigation such as grain yield, seed per spike, spike length and above-ground biomass of wheat.

The combined use of vermicompost, lime, and NPS fertilizer by the rating of half of the recommended rate of both vermicompost, lime, and full NPS fertilizer increased wheat yield by 60.58% over the control treatment. The highest yield (4035.7 kg/ha) was 100% (lime, VC and SSFR) application, but at par with (3653 kg/ha) Rec.SSFR+50%Rec.lime+50%Rec.VC application. Both rates raised soil pH close to the optimum pH requirement of wheat, but drastically decreased the exchangeable Al3+ to a minimum level, which enhanced available P as a result of increased pH and decreased acidity level.

From this study, it is possible to deduce that integrated application of organic and mineral fertilizers with lime amended the acidic soils and improved its fertility which in turn increased crop yields. Hence, combination of Rec.SSFR+50%Rec.lime+50%Rec.VC application could serve as a reference to boost wheat production in the study area and in similar areas. So, the best option for soil acidity and fertility management is the integrated use of organic/vermicompost, lime, and inorganic fertilizers as soil amendments and nutrient sources than the strategy of using lime, organic or inorganic amendments alone.

However, to determine the application frequency, long-term effects of Vermi-compost and lime in combination on acidic soil properties and crop yield need to be investigated through further research.

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