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Original Research

Soil Acidity Reclamation and Improving Yields of Tomato by the Integrated Application of Lime and Vermicompost in Bedele District, South Western Ethiopia

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Abstract

This study was carried out to delve into the ameliorating capacity of amendments on soil acidity and growth yields of tomatoes. This study was set up using a fully randomized approach by two factorial experiments of 0, 2.5, 5, and 7.5 tha^{-1} vermicompost and 0, 4, 6, and 8 tha^{-1} of lime with two replications. The findings indicated that the integration of lime and vermicompost performed well in amending soil acidity and improving selected yields of tomatoes. Soil pH significantly increased from pH (4.99) to pH (5.53) and increased soil nutrient availabilities, phosphorus to 6.20 mg kg^{-1}, organic matter to 5.30%, and total nitrogen to 0.20% by the use of vermicompost and lime together. In addition, the highest plant height (6.84 cm) and maximum dry weight per plant (0.092 g plant^{-1}) were obtained under-treated soil. Therefore, the soil fertility was unlocked, the acidity of the soil was amended, and the growth yields of tomatoes improved by the application of vermicompost and lime treatments. From this finding, further field experiments are recommended to analyze the effects of amendments at smallholder farmers' levels at different locations with different ecologies.

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INTRODUCTION

Acidic soils have lower concentrations of essential nutrients due to leaching and fixing, and they are characterized by the toxicity of aluminum ($Al3^{+}$), iron (Fe^{2+}), and manganese (Mn^{2+}) ions, which causes a reduction in crop productivity (Rajasekharan et al., 2014). The sole vermicompost or lime and their integrations ameliorated soil acidity problems (Abdissa et al., 2018). Organic fertilizer application has been improving soil properties and crop growth by providing plant-essential nutrients (Zha et al., 2024). Vermicompost provides good plant development due to good water-holding capacity and aeration, high nutrient availability, and forming conducive environments for microbial activity (Pathma & Sakthivel, 2012). During the process of vermicompost preparation by using earthworms from the raw materials, essential nutrients are released in their available forms by plant roots (Goutam et al., 2011).

The application of vermicompost as compared to mineral fertilizers has positive effects on soil nutrient availability and early and later stages of the plant life cycle (Ansari & Sukhraj, 2010). This vermicompost is found to have positive results on the physical, chemical, and biological properties of the soil and the productivity of crops (García et al., 2024).

The tomato (*Lycopersicon esculentum* M.) is an element of the Solanaceae family and is a common vegetable crop that has been used in the world and can be either in the form of fresh or in multiple processed forms. Tomato has become the most profitable crop that provides higher income to smallholder farmers compared to other vegetable crops (Lemma, 2003). In many parts of the country, tomatoes are produced throughout the year by both rainfed and irrigated means for their fruit consumption by smallholder farmers (MoA, 2013).

The above findings confirmed that organic fertilizers integrated with lime have significant beneficial effects on soil acidity amelioration, essential nutrient availability, and growth yields of plants. Nevertheless, very few experimental researches indicated their ability to amend soil acidity problems, either solely or in combination, and explore unlocking the capacity of soil fertility and improving tomato yields by the application of vermicompost and lime. Hence, this study's objective was to amend the acidity of the soil, unlock its fertility, and improve the yields of tomatoes by the application of lime and vermicompost.

MATERIALS AND METHODS

Overview of the research location

The study was undertaken in the district of Bedele (Figure 1). It lies in the coordinates of longitude 36°21'E and latitude 8°27'N. It has an altitude of 2012–2162 masl. The study district gets 1898 mm of average annual rainfall and monthly mean maximum, mean, and lowest temperatures of 21, 19.2, and 17. 5 °C, respectively (NMA, 2022) (Figure 2).

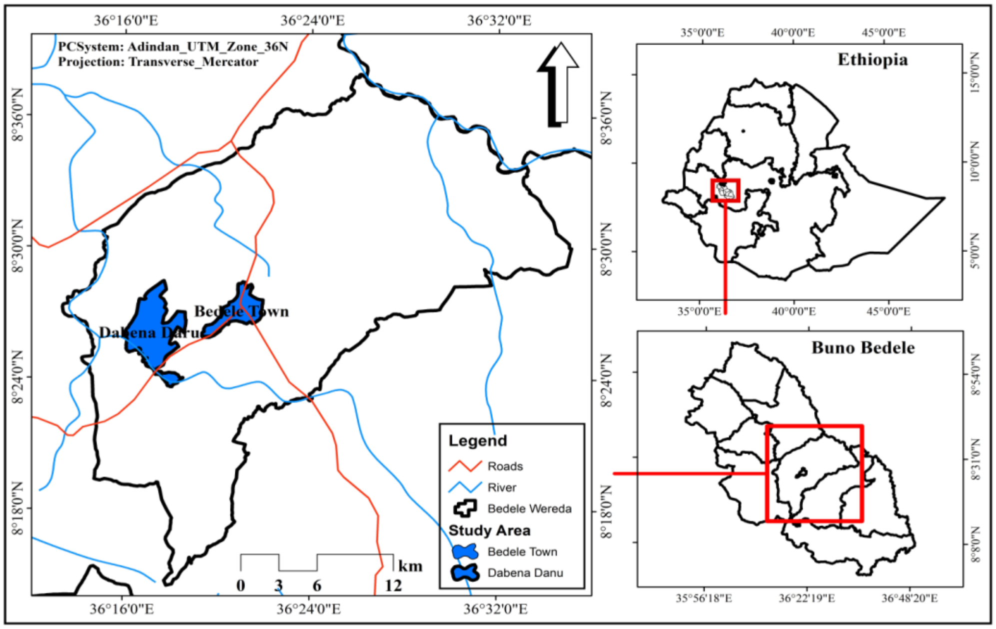

Figure 1. *The study area's location*

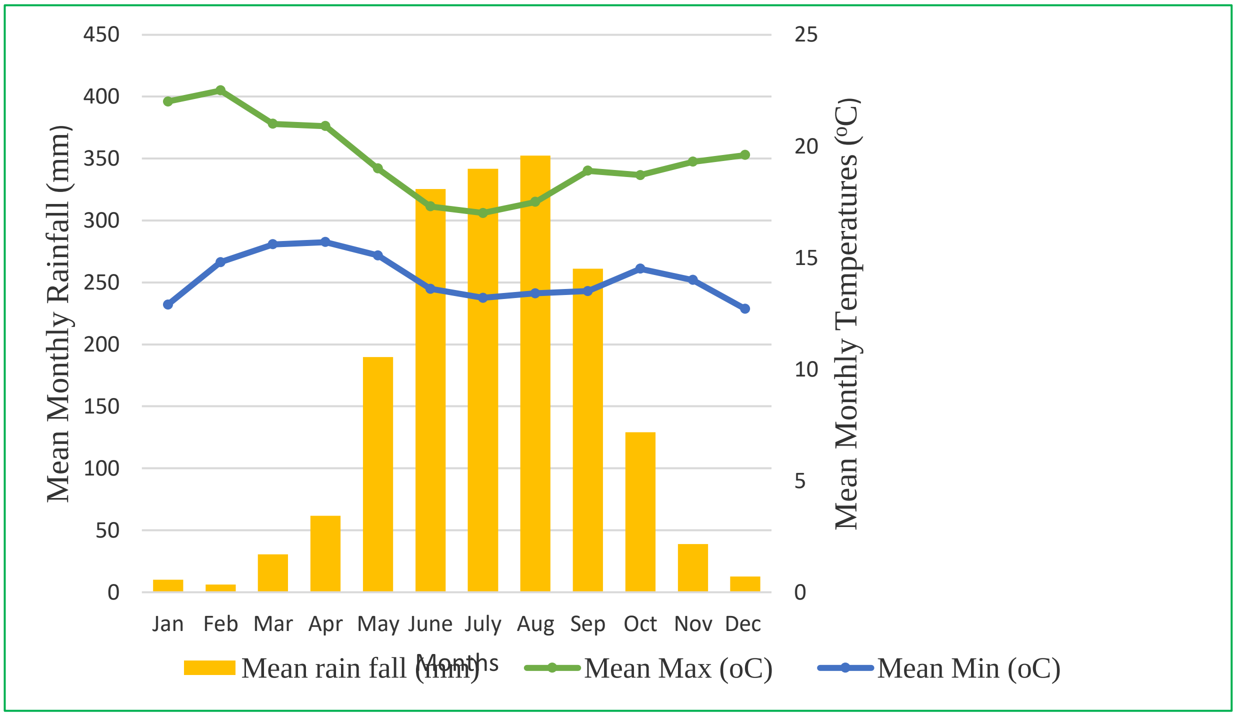

Figure 2. *Maximum & minimum temperature (^oC), and average monthly rainfall (mm), of the study site from the year 2013 to 2022*

Examination of the physicochemical characteristics of soil

Samples of undisturbed soil were gathered by core samplers and their bulk density (BD) was ascertained from this virgin soil as explained by Gupta (2000). The study site's average soil particle density (Pd) was 2.65 g cm^{-3} (Landon, 1991). From both BD and Pd, the soil total porosity (TP) was calculated as follows.

$$\text{Total porosity}(\%)=100-\left[\left(\frac{\text{BD}}{\text{Pd}}\right)*100\right].$$

The hydrometric approach was used to examine the soil textural class (Bouyoucos, 1951).

In a 1:2.5 soil: water suspension, the pH of the soil was measured with a glass pH meter (Kanwar & Chopra, 1976). The soil's exchangeable acidity was determined by saturating the samples of the soils with 1M potassium chloride suspension (Rowell, 1994). Exchangeable aluminum in soil was measured using 1M sodium fluoride from the same extractable acidity. The following formula was used to determine the soil's acid saturation (AS) based on its exchangeable acidity and effective cation exchange capacity (ECEC):

$$\text{AS}(\%)=\frac{\text{Exchangeable acidity}\left(\text{cmol}_c\text{kg}^{-1}\right)}{\text{ECEC}\left(\text{cmol}_c\text{kg}^{-1}\right)}\times 100$$

According to Pansu and Gautheyrou (2006), the ECEC was calculated by adding the exchangeable bases and acidity of the soil. Wet combustion was employed to determine the amount of organic carbon in the soil (Walkley & Black, 1934). The Kjeldahl digestion method of wet oxidation was used to measure the soil TN (Bremner & Mulvaney, 1982). The Bray II method was used to extract the soil, Ava. P

(Bray & Kurtz, 1945) and finally read using ultraviolet spectroscopy.

A 1M ammonium acetate solution with a pH of 7.0 was used to extract the soil exchangeable bases (Ca, Mg, Na, and K). Atomic absorption spectrophotometry (AAS) was used to evaluate the extract's exchangeable Mg and Ca, while a flame photometer was used to estimate its exchangeable K and Na (Chapman, 1965).

Analysis of vermicompost chemical compositions

The raw materials used for the preparation of vermicompost using earthworms (Eisenia fetida) were home residues, crop straws, weeds, sheep manures, and cow dung. The vermicompost chemical compositions were evaluated from air-dried, crushed, and sieved samples using a 2 mm sieve (Pisa & Wuta, 2013). The pH and electrical conductivity of vermicompost were determined using a 1:10 vermicompost: water suspension (Ndegwa & Thompson, 2001). The total OC of vermicompost was determined by the wet digestion and rapid titration method (Walkley & Black, 1934).

The total N content of the vermicompost was determined by the wet-oxidation procedure of the Kjeldahl method (Bremner & Mulvaney, 1982). Total exchangeable Ca, Mg, K, and Na were extracted by wet digestion using a mixture of concentrated sulphuric acid, selenium powder, lithium sulfate, and hydrogen peroxide (Okalebo et al., 2002). Total exchangeable Ca and Mg were determined from the wet-digested samples by AAS, while total exchangeable K and Na were estimated by flame photometers. Total P of vermicompost was extracted using a concentrated sulphuric acid, selenium powder, salicylic acid, and hydrogen peroxide mixture and finally read by using ultraviolet spectroscopy (Okalebo et al., 2002).

The acid saturation method was used to evaluate lime requirements for ameliorating the soil acidity of the study area for tomato production. Lime requirement determination using the acid saturation method was conducted from the relationship of permissible acid saturation percentage of crops exchangeable acidity and ECEC (Manson & Katusic, 1997).

$$\mathrm{LR}\left(\mathrm{kg\ ha}^{-1}\right) = \mathrm{LRF}\left[\mathrm{Ex.\ acidity} - \left(\mathrm{ECEC} * \mathrm{PAS}\right)\right]$$

Where, LR = Lime requirement; LRF is the lime requirement factor in kg lime ha^{-1} to lower the exchangeable acidity by 1cmol = 3000 kg lime/ha/cmole (Farina & Chanon, 1991) for most Ethiopian soils; Ex. acidity is exchangeable acidity (Al^{3+} + H^{+}); PAS is permissible acid saturation; and ECEC is effective cation exchange capacity (Ex. acidity + Exchangeable bases).

Greenhouse experiment

The experimental field of Mattu University Bedele College of Agriculture and Forestry served as the controlled environment for the research. Two replications were used to collect soil samples from the study site. After being prepared for analysis in the preparation room, the soil samples were examined. An auger was used to collect samples of the disturbed soil from the study area for the greenhouse experiment, and then four (4) kg of soil were taken to each plastic pot and treated at different rates of treatment. Water was added to the experimental pots every three days to bring the soil moisture close to its field capacity.

A completely randomized research design was used for the greenhouse experiment, and two replications with the following treatments were used. The units of VC and lime amounts were converted into hectares based on the plow depth (20 cm) and the average bulk density

(1.34 gcm^{-3}) of the soil. The experimental crop was harvested four months later at Mattu University Bedele College of Agriculture and Forestry. Lime rates of 0, 4, 6, and 8 tha^{-1} (corresponding with 0, 0.23, 0.46, and 0.69 g/4 kg soil, respectively), according to LR tests to address desired soil pH, and four rates (0, 2.5, 5, and 7.5 tha^{-1}) of VC were applied to all pots except the control pots. 32 pots were used for the greenhouse experiment

Post-harvest soil and test crop data collection

After harvest, soil samples were taken from each experimental pot and processed for analysis in order to assess the effects of lime and vermicompost on tomato growth yields as well as soil pH, exchangeable acidity, and ava. P, OM, TN, soil exchangeable bases, and ECEC. The tomato variety as a test crop for this research was Melkashola. The plant data collected from each experimental pot were plant height (cm), number of leaves per plant, dry weight (g $plant^{-1}$), and seedling girth (cm).

Data analysis and statistical procedures

Statistical analysis of variance (GLM procedure) was under taken using SAS software 9.4 (SAS, 2013). The relationship between means of treatments under incubation experiment was indicated by LSD test. Correlation analysis between soil parameters was done.

RESULTS AND DISCUSSION

The study site pre-sowing soil properties

Clay is the textural class of pre-sowing soil (Table 1). The bulk density of the soil in the research area was 1.34 g/cm³, which was below the BD essential threshold of 1.6 g/cm³ for crop growth (Table 1).

Table 1

Selected soil parameters before sowing

Parameters of soil	Units	Result of soil analysis
Clay	%	46.0
Sand	%	42.0
Silt	%	12.0
Class of texture	-	Sandy Clay
Bulk density	$g\ cm^{-3}$	1.34
Particle density	$g\ cm^{-3}$	2.65
Total porosity	%	49.43
pH (H_2O)	-	4.91
Exchangeable acidity	$cmol_c\ kg^{-1}$	1.04
Exchangeable aluminium	$cmol_c\ kg^{-1}$	0.83
Percentage of AS	%	6.94
Soil OM	%	4.31
TN	%	0.18
Available P	$mgkg^{-1}$	5.71
Exch. Ca	$cmol_c\ kg^{-1}$	4.51

Tabe.1 Continues.

Exch. Mg	$cmol_c\ kg^{-1}$	3.61
Exch. K	$cmol_c\ kg^{-1}$	1.72
Exch. Na	$cmol_c\ kg^{-1}$	4.11
Soil ECEC	$cmol_c\ kg^{-1}$	14.99

AS = acid saturation, ECEC = effective cation exchange capacity, Exch. Ca = exchangeable calcium, Exch. K = exchangeable potassium, Exch. Na = exchangeable sodium, Exch. Mg = exchangeable magnesium, OM = organic matter, TN = total nitrogen

The soil's total porosity was relatively high because of its low BD, and it is optimum for production. According to Jones (2003), the soil had a strong acidic content, with a relatively high exchangeable acidity. The soil's acid saturation level was 6.94%. The soil's TN (0.18) and OM (4.31%) levels fell into the intermediate and high ranges, respectively (Tekalign et al., 1991), while the available P (5.71 $mgkg^{-1}$) content was in the low range (Tekalign et al., 1991). Similarly, the mean soil exchangeable Ca (4.51 $cmol_ckg^{-1}$) was moderate, whereas exchangeable Mg (3.61 $cmol_ckg^{-1}$) was within the range of high (FAO, 2006). The soil ECEC (14.99 $cmol_ckg^{-1}$) of the study site was relatively low. The slow action of the clay minerals in the study site's soils could be the cause of this. Hence, pre-sowing soil tests made it abundantly evident that the research site's soils lacked vital nutrients because of the acidity issue. This leads to the development of unlocking activities of essential nutrients for such types of soil to enhance crop productivity on a sustainable basis.

Chemical composition analysis of vermicompost

The vermicompost chemical analysis indicated that it contains high amounts of plant nutrients (Table 2). The pH of vermicompost was 8.07, and its total OC, available P, and CEC were 9.04%, 5.30 g kg^{-1}, and 39.3 cmol kg^{-1}, respectively (Table 2).

Table 2

Vermicompost chemical compositions

Vermicompost parameters	Units	Value of chemical compositions
pH (H_2O)	-	8.07
EC	dSm^{-1}	1.84
TOC	%	9.04
TN	%	0.95
TP	gkg^{-1}	5.3
Total calcium	$cmol_c\ kg^{-1}$	36.3
Total magnesium	$cmol_c\ kg^{-1}$	19.8
Total potassium	$cmol_c\ kg^{-1}$	27.7
Total sodium	$cmol_c\ kg^{-1}$	14.2
Cation exchange capacity	$cmol_ckg^{-1}$	39.3

Keynote: EC = Electrical Conductivity, TOC = Total Organic Carbon, TP = Total Phosphorus, TN = Total Nitrogen

Therefore, it is obvious that vermicompost can ameliorate soil acidity and improve crop productivity. This is supported by the findings of Nada et al. (2011) and Bekele et al. (2018), who reported that vermicompost does have a high pH to ameliorate acidity.

Post-harvested selected soil parameters

Exchangeable acidity and pH of soil

Both pH and exchangeable acidity were considerably ($P < 0.05$) affected by the combined application of vermicompost and lime, according to the ANOVA result (Table 3). The pH of the sol increased from 4.99 to 5.53, and exchangeable acidity reduced from 0.26 to 0.16 cmol$_c$kg^{-1} by the application of the highest rates of vermicompost (7.5 tha^{-1}) (Table 3). The decrement of exchangeable acidity and increment of soil pH using vermicompost might be due to its capacity to amend soil acidity. This is consistent with Wang et al (2024), who found that the pH of the soil can be raised by applying vermicompost alone.

Table 3

Soil pH and exchangeable acidity after being treated with vermicompost and lime

Treatment	Rate	pH	Exch. Acidity (cmol$_c$kg^{-1})
Control (tha^{-1})	0	4.99^{g}	0.26^{a}
	4	5.04^{g}	0.22^{ab}
	6	5.10^{fg}	0.20^{abc}
Lime (tha^{-1})	8	5.60^{cde}	0.10^{b-f}
	2.5	5.07^{fg}	0.22^{ab}
	5	5.25^{f}	0.18^{a-d}
VC (tha^{-1})	7.5	5.53^{de}	0.16^{a-e}
VC 1 (tha^{-1})/lime1 (tha^{-1})	2.5/4	5.15^{fg}	0.18^{a-d}
VC1 (tha^{-1})/lime2 (tha^{-1})	2.5/6	5.62^{cde}	0.08^{c-f}
VC1(tha^{-1})/lime3 (tha^{-1})	2.5/8	5.77^{abc}	0.07^{def}
VC2 (tha^{-1})/lime1 (tha^{-1})	5/4	5.5^{e}	0.13^{b-f}
VC2 (tha^{-1})/lime2 (tha^{-1})	5/6	5.69^{a-e}	0.05^{ef}
VC 2 (tha^{-1})/lime3 (tha^{-1})	5/8	5.70^{a-d}	0.04^{ef}
VC3 (tha^{-1})/lime1(tha^{-1})	7.5/4	5.63^{b-e}	0.08^{c-f}
VC3 (tha^{-1})/ lime2(tha^{-1})	7.5/6	5.82^{ab}	0.02^{f}
VC3 (tha^{-1})/ lime 3(tha^{-1})	7.5/8	5.88^{a}	0.01^{f}
SE (±)		0.03	0.02
CV (5%)		0.87	5.37

**VC = Vermicompost; SE = Standard error; CV = Coefficient of variation; lime1 = 4 tha^{-1}; lime 2=6 tha^{-1}; lime 3= 8 tha^{-1}; VC1 = 2.5 tha^{-1}; VC2 = 5 tha^{-1}; VC3 = 7.5 tha^{-1}*

The combined treatment of lime and vermicompost raised the pH of the soil from extremely acidic (4.99) to moderately acidic (5.88) status and dramatically reduced exchangeable acidity from 0.26 to 0.01 cmolckg^{-1} (Table 3). This amount of change might be due to the synergetic effects of both reclamatory treatments. This finding is in agreement with Negese et al. (2021), who stated that under the combined application of vermicompost and lime, soil pH increased from strongly acidic to moderately acidic, and exchangeable acidity decreased.

Soil available P, OM, and TN of post-harvested soil

The ANOVA result indicated that the application of integrated VC and lime significantly ($P \leq 0.05$) affected available P (Table 4). The highest available P (6.28 mg kg^{-1}) was gained under the integrated use of both lime (8 tha^{-1}) and VC (7.5 tha^{-1}) rates. This might be due to the soil acidity reclamation capacity of both vermicompost and lime, which in turn unlock available P under fixation by aluminum. In harmony with this finding, Negese et al. (2021) investigated that the combined application of lime and vermicompost significantly increased soil P availability.

Table 4

Post-harvested soil Ava P, OM and TN

Treatment	Rate	Ava P in BrayII (mg kg^{-1})	OM (%)	TN (%)
Control (tha^{-1})	0	5.66^{g}	4.27^{de}	0.06^{g}
	4	5.79^{fg}	4.17^{e}	0.07^{g}
	6	5.93^{def}	4.28^{de}	0.07^{g}
Lime (tha^{-1})	8	5.93^{def}	4.28^{de}	0.08^{fg}
	2.5	5.69^{g}	4.33^{de}	0.10^{defg}
	5	5.75^{g}	4.49^{cde}	0.13^{bcde}
VC (tha^{-1})	7.5	5.90^{def}	4.80^{cd}	0.14^{bcd}
VC1 (tha^{-1}) + lime1 (tha^{-1})	2.5 + 4	5.80^{efg}	4.38^{de}	0.08^{fg}
VC1 (tha^{-1}) + lime2 (tha^{-1})	2.5 + 6	5.91^{def}	4.44^{cde}	0.09^{efg}
VC1 (tha^{-1}) + lime3 (tha^{-1})	2.5 + 8	6.00^{cd}	4.47^{cde}	0.09^{efg}
VC2 (tha^{-1})+ lime1 (tha^{-1})	5 + 4	5.98^{cd}	4.65^{cd}	0.12^{cdef}
VC2 (tha^{-1}) + lime2 (tha^{-1})	5 + 6	6.10^{bc}	5.07^{ab}	0.13^{bcde}
VC 2 (tha^{-1}) + lime3 (tha^{-1})	5 + 8	6.15^{ab}	5.17^{ab}	0.16^{abc}
VC3 (tha^{-1}) + lime1 (tha^{-1})	7.5 + 4	6.10^{bc}	5.21^{a}	0.17^{ab}
VC3 (tha^{-1}) + lime2 (tha^{-1})	7.5 + 6	6.20^{ab}	5.24^{a}	0.20^{a}
VC3 (tha^{-1}) + lime3 (tha^{-1})	7.5 + 8	6.28^{a}	5.30^{a}	0.20^{a}
SE (±)		0.03	0.07	0.01
CV (5%)		1.59	2.08	9.99

**Ava. P =Available phosphorous, CV= Coefficient of variation, VC= Vermicompost, OM= Organic matter, SE = Standard error, TN = Total nitrogen.*

In comparison to the control pots, the post-harvested soil organic matter content was higher in the soil treated with VC and lime. When lime (8 tha^{-1}) and vermicompost (7.5 tha^{-1}) were applied together, the maximum OM (5.30%) concentration was achieved (Table 4). This might be due to soil acidity decrement by the treatments, which consecutively made the environments conducive for soil microbial activity, which in turn increases soil OM. In agreement with this result, Amba et al. (2011) point out that lime and organic manure application increased soil OC. The application of VC together with lime significantly ($P \leq 0.05$) increased the total N of the treated soil (Table 4). This might be due to the increment of OM, which consecutively increased the soil total N. The combined application of VC (7.5 t ha^{-1}) and lime (6 and 8 t ha^{-1}) produced the greatest (0.20 mg kg^{-1}) soil total N (Table 4). This is supported by the findings of Negese et al. (2021), who reported that the total N of the soil increased slightly by the combined application of lime and VC.

Effective cation exchange capacity and soil exchangeable bases The ANOVA disclosed that the highest (13.90 cmol$_c$kg^{-1}) and lowest (10.99 cmol$_c$kg^{-1}) soil exchangeable Ca were recorded under the application of VC (7.5 tha^{-1}) with lime (8 tha^{-1}) and untreated pots, respectively (Table 5). This may be due to the discharge of exchangeable Ca from the dissolution of lime and decomposition of VC that can replace acidic cations on the exchange site. This is in agreement with the previous works of Adeleye et al. (2010), who reported that exchangeable Ca increased by integrated application of organic fertilizers and lime.

Table 5

Post-harvested soil exchangeable bases and ECEC

Treatments	Rates	Exch.Ca	Exch. Mg	Exch. K	Exch. Na	ECEC
		cmolc kg^{-1}				
Control	0	10.99^{g}	5.79^{f}	0.70^{cde}	4.22^{d}	21.97^{h}
	4	11.09^{g}	6.05^{ef}	0.69^{cde}	4.18^{d}	22.22^{h}
	6	12.00^{f}	6.86^{de}	0.72^{cde}	4.14^{d}	23.91^{g}
Lime (tha^{-1})	8	12.29^{ef}	7.10^{cd}	0.73^{b-e}	4.22^{d}	24.42^{efg}
	2.5	11.05^{g}	5.99^{f}	0.67^{de}	4.24^{d}	22.15^{h}
	5	12.04^{f}	7.05^{cd}	0.77^{a-d}	4.36^{cd}	24.40^{efg}
VC (tha^{-1})	7.5	12.68^{cde}	7.39^{bcd}	0.79^{a-d}	4.44^{bcd}	25.46^{d}
VC$_1$ (tha^{-1})/lime$_1$ (tha^{-1})	2.5/4	12.17^{ef}	7.04^{cd}	0.62^{a}	4.19^{d}	24.19^{fg}
VC$_1$ (tha^{-1})/lime$_2$ (tha^{-1})	2.5/6	12.50^{def}	7.66^{a-d}	0.72^{cde}	4.40^{bcd}	25.35^{de}
VC 1 (tha^{-1})/lime3 (tha^{-1})	2.5/8	13.04^{bc}	8.05^{ab}	0.89^{a}	4.87^{a}	26.91^{bc}
VC2 (tha^{-1}) /lime1 (tha^{-1})	5/4	12.46^{def}	7.62^{a-d}	0.66^{de}	4.35^{cd}	25.20^{def}
VC 2 (tha^{-1})/lime2 (tha^{-1})	5/6	13.08^{bc}	8.04^{ab}	0.82^{abc}	4.88^{a}	26.86^{bc}
VC 2 (tha^{-1})/ lime3 (tha^{-1})	5/8	13.72^{a}	8.05^{ab}	0.87^{ab}	4.72^{abc}	27.38^{ab}
VC 3 (tha^{-1})/lime1 (tha^{-1})	7.5/4	12.99^{bcd}	7.77^{abc}	0.78^{a-d}	4.47^{a-d}	26.08^{cd}
VC3 (tha^{-1})/lime2 (tha^{-1})	7.5/6	13.43^{ab}	8.22^{ab}	0.87^{ab}	4.68^{abc}	27.20^{ab}
VC 3 (tha^{-1})/lime3 (tha^{-1})	7.5/8	13.90^{a}	8.38^{a}	0.91^{a}	4.80^{ab}	27.99^{a}
SE (±)		0.10	0.15	0.03	0.07	0.18
CV (5%)		1.10	2.91	4.81	2.33	1.03

**CV = Coefficient of variation, ECEC = Effective cation exchange capacity, Exch. Ca = Exchangeable calcium, Exch. Mg = Exchangeable magnesium, Exch. K = Exchangeable potassium, Exch. Na = Exchangeable sodium, SE = Standard error, VC = Vermicompost*

The combined application of an 8 tha^{-1} lime rate and a 7.5 tha^{-1} VC rate resulted in the maximum (8.38 cmolckg^{-1}) soil exchangeable magnesium, according to the ANOVA result (Table 5). This increment of soil exchangeable Mg under the combined application of lime and VC may be due to the release of Mg from VC decomposition and the reduction of Al^{3+} and H^{+} content in soil exchange sites. This finding corresponds to Nasrin et al. (2019), who reported that available Mg significantly increased by the application of vermicompost.

The exchangeable K (0.91 cmol$_c$kg^{-1}) and Na (4.80 cmol$_c$kg^{-1}) were obtained by the application of the maximum rates of both VC and lime (Table 5). The release of nutrients from VC may be the cause of this increase in exchangeable Na and K caused by the application of both lime and VC. This is supported by the report of Adeniyan et al. (2011), who indicated that when organic fertilizers and lime were applied, soil exchangeable bases increased. Applying both treatments resulted in a significant ($p < 0.05$) increase in soil ECEC (Table 5). This could be because vermicompost and lime were applied, which increased the pH of the soil and raised its exchangeable bases. Increased negative charges on the soil exchange site's surfaces are the cause of the pH rise. This finding is supported by Wang et al. (2024), who investigated that cation exchange capacity has undergone significant change with the application of vermicompost and steel slag amendments.

The effects of lime and VC on the growth yield of tomato

Tomato growth yields were considerably ($P < 0.05$) affected by the combined application of VC and lime (Table 6).

Table 6

Tomato growth yields by application of lime and VC

Treatment	Rate	PH (cm)	SG (cm)	NL	DW (g plant^{-1})
Control (tha^{-1})	0	4.68^{d}	0.380^{d}	4.01^{c}	0.034^{c}
	4	4.73^{d}	0.375^{d}	4.00^{c}	0.070^{ab}
	6	5.37^{c}	0.510^{c}	5.00^{b}	0.057^{bc}
Lime (tha^{-1})	8	5.74^{bc}	0.580^{bc}	5.00^{b}	0.055^{bc}
	2.5	5.98^{b}	0.665^{b}	6.00^{a}	0.068^{ab}
	5	6.46^{a}	0.670^{b}	6.00^{a}	0.062^{abc}
VC (tha^{-1})	7.5	6.74^{a}	0.795^{a}	6.00^{a}	0.071^{ab}
VC1 (tha^{-1})/lime1 (tha^{-1})	2.5/4	6.56^{a}	0.770^{a}	5.50^{bc}	0.080^{ab}
VC1 (tha^{-1})/lime2 (tha^{-1})	2.5/6	6.57^{a}	0.785^{a}	5.50^{bc}	0.079^{ab}
VC1 (tha^{-1})/lime3 (tha^{-1})	2.5/8	6.58^{a}	0.790^{a}	5.50^{bc}	0.066^{abc}
VC2 (tha^{-1})/lime1 (tha^{-1})	5/4	6.55^{a}	0.770^{a}	6.00^{a}	0.079^{ab}
VC2 (tha^{-1})/lime2 (tha^{-1})	5/6	6.77^{a}	0.795^{a}	6.00^{a}	0.084^{ab}
VC 2 (tha^{-1})/lime3 (tha^{-1})	5/8	6.83^{a}	0.805^{a}	6.50^{ab}	0.087^{ab}
VC3 (tha^{-1})/lime1 (tha^{-1})	7.5/4	6.73^{a}	0.810^{a}	5.50^{bc}	0.079^{ab}
VC3 (tha^{-1})/lime2 (tha^{-1})	7.5/6	6.83^{a}	0.815^{a}	5.50^{bc}	0.082^{ab}
VC3 (tha^{-1})/lime3 (tha^{-1})	7.5/8	6.84^{a}	0.835^{a}	6.50^{ab}	0.092^{a}
SE (±)		0.08	0.02	0.48	0.01
CV (5%)		1.78	3.37	12.38	11.68

CV = Coefficient of variation, DW= Dry weight, NL = number of leaves, PH = plant height, SE = Standard error, SG = seedling girth, VC = Vermicompost

It was observed that tomatoes (*Lycopersicum esculentum*) showed unequivocal differences in the plant height grown for 120 days under controlled and treated soils by different rates of VC and lime. Under controlled soil, the plant height recorded was 4.68 cm, whereas that of plants grown under the united application of high rates of VC (7.5 tha^{-1}) and lime (8 tha^{-1}) was 6.84 cm (Table 6).

Therefore, the highest (6.84 cm) plant height was noted under the integrated application of VC (7.5 tha^{-1}) and lime (8 tha^{-1}). This might be due to the increment of essential nutrient availability for the crop. This is inconsistent with Kedir and Bikiltu (2022), who stated that vermicompost application resulted in the highest tomato height.

The combined application of VC and lime had a significant ($P < 0.05$) impact on seedling girth, according to the ANOVA result (Table 6). The maximum seedling girth **(**0.835 cm) was recorded under the integrated application of both VC (7.5 tha^{-1}) and lime (8 tha^{-1}), whereas the minimum seedling (0.375 cm) was under 4 tha^{-1} of lime application (Table 6). The maximum seedling girth is obtained at the maximum rates of the treatments due to the acidity of the soil reclamation and fertility increment.

The ANOVA result indicated the mean number of leaves per plant was found to be different under controlled and amended soils. The maximum number of leaves was obtained by combining the maximum rates of lime (8 tha^{-1}) and VC (7.5 tha^{-1}). This might be due to the high impact of VC on vegetative stages of plant growth.

The statistical result indicated that under control, the dry weight per plant was considerably ($P < 0.05$) different from the results obtained under different applications of VC and lime, individually and in combined applications (Table 6). The maximum dry weight per plant (0.092 $gplant^{-1}$) was obtained at the maximum VC rates (7.5 tha^{-1}) and lime (8 tha^{-1}), whereas the minimum dry weight per plant (0.034 $gplant^{-1}$) was recorded under control.

CONCLUSION

Amalgamated nutrient management, especially the use of vermicompost and lime, has been getting attention. By the application of these treatments, soil acidity was ameliorated, soil fertility was unlocked, and ultimately improved tomato growth yields. These findings indicated that by the application of lime and vermicompost, the growth parameters of tomatoes significantly increased. From this research, it is possible to infer that the combined application of treatments, treated soil acidity, and unlocked soil fertility consequently increased tomato growth yield. Therefore, integrated application of lime and vermicompost is recommended for soil acidity reclamation, unlocking soil fertility and enhancing tomato growth yields.

CRediT authorship contribution statement

Abdissa Bekele: Conceptualization, Writing – original draft, Investigation, Data curation Methodology, Visualization, Writing - Review & Editing **Mekonnen Begna:** Validation, Resources, Software, Formal analysis**,** Supervision.

Declaration of competing interest

The authors declare that there is no conflict of interest.

Data availability

Data will be made available on request.

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