International Journal of Plant & Soil Science

27(2): 1-18, 2019; Article no.IJPSS.44605
ISSN: 2320-7035

Soybean (*Glycine max* L.) Response to Lime and Vermicompost Amelioration of Acidic Nitisols of Assosa, North Western Ethiopia

Tigist Adisu[1*], Lemma Wogi[1] and Tesfaye Feyisa[1]

[1]*School of Natural Resources Management and Environmental Sciences, Haramaya University, Haramaya, Ethiopia.*

Authors' contributions

This work was carried out in collaboration among all authors. Author TA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author LW managed the analyses of the study and author TF managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2019/v27i230072
Editor(s):
(1) Dr. Marco Trevisan, Professor, Institute of Agricultural Chemistry and Environmental Research Centre BIOMASS, Faculty of Agriculture, Catholic University of the Sacred Heart, Italy.
Reviewers:
(1) Dr. N. Karmegam, Government Arts College, Salem, Tamilnadu, India.
(2) Zakaria Fouad Fawzy Hassan, Agriculture and Biological Research Division- National Research Centre, Egypt.
(3) Dr. Rebecca Yegon, University of Embu, Kenya.
Complete Peer review History: http://www.sdiarticle3.com/review-history/44605

Original Research Article

Received 04 August 2018
Accepted 22 October 2018
Published 28 March 2019

ABSTRACT

Acidic soils limit the production potential of crops because of low availability of basic cations and excess of hydrogen (H^+) and aluminium (Al^{3+}) in exchangeable forms. In the western part of the country such as Assosa and Wellega, soil acidity is a well-known problem limiting crop productivity. A field study was conducted to assess the effects of lime, vermicompost and their combinations on selected soil physico-chemical properties and responses of soybean grown on acidic Nitisols of Assosa area during 2016 and 2017 main cropping seasons. Soil samples were collected from the experimental site before planting and from plots after harvesting. The collected samples were analysed following the standard methods for soil physico-chemical analysis. The treatments were factorial combinations of four levels of lime (0, 1.62, 3.62 and 4.90 t ha^{-1}) and four levels of vermicompost (0, 1.50, 3.00 and 4.50 t ha^{-1}). The results revealed that soil pH increased from 5.31 – 5.86 pH while exchangeable acidity decreased from 5.46 - 2.85 cmol (+) kg^{-1} with levels of lime

**Corresponding author: E-mail: wowtigistadisu@gmail.com;*

and vermicompost (3.26 with 3 and 4.90 with 4.5) t ha^{-1} respectively, which resulted in improved soil physico-chemical properties. The combined application of lime and vermicompost also significantly improved the yield related parameters of soybean. The maximum grain yield (1.95t ha^{-1}) was obtained from the combined application of 4.90 ton lime and 3.00 ton vermicompost ha^{-1} followed by combined application of 3.26 ton lime with 3.00 ton vermicompost ha^{-1} with non-significant variation. Therefore, the combined application of 3.26 ton lime and 3.00 ton vermicompost ha^{-1} is a promising alternative amendment for amelioration of acidic Nitisols of Assosa (Amba-12 Kebele) and other similar agro-ecologies for the improvement of soybean production.

Keywords: Soybean yield; lime; vermicompost and soil acidity.

1. INTRODUCTION

Soybean (*Glycine max* L.) is one of grain legumes grown in tropical, subtropical and temperate climates. Globally, soybean production has increased by a factor of eight in the last half-century to reach its present level, about 100 million metric tons per year [1]. Due to the economic advantages, it has led many countries to start large scale production of this crop. Soybean is an important source of inexpensive and high-quality protein and oil. With an average protein content of 40% and oil content of 20%, it is second to groundnut in terms of oil content among food legume crops [2].

Soybean is one of the most important feed stuffs for livestock either in form of forage (as hay and silage) or soybean meal [3]. Because of its high quality protein content, soybean can also compensate for the expensive animal proteins to overcome malnutrition. Since its oil content is high (20% and above), soybean is also used for edible oil production in Ethiopia. Faffa Food Share Company, East African Flour Factory, and Health care food manufacturing private limited companies etc. are some of the companies use both local and imported soybeans for the preparation of enriched food products for children and adults [4].

According to Agricultural Sample Survey of CSA (Centeral Statics Agency) [5] there are 140,263.00 private peasant holdings that cultivate about 38,166.04 hectares of land and produced 812,418.33 quintals of soybean. The average production of soybean in the country is therefore, 2.13 t ha^{-1} while, that of Assosa area is by far below (1.3 t ha^{-1}) the national average due to soil acidity [5]. Grain legumes occupy about 14% of cultivated land in Ethiopia and their contribution to agricultural value addition is around 10%. Pulses are the fourth-largest export crop of Ethiopia after coffee, oilseeds and flowers, contributing 7% share in total export earnings [6].

Despite its growing demand in the international market, there is a chronic shortage of supply in Ethiopia. Several abiotic factors contributed to low productivity which includes poor soil fertility, acidity of the soil in high rain fall areas and low existence of effective indigenous rhizobia population in the area [7]. Soil acidity is one of the biotic factors that are globally known to reduce nodulation and yield of soybean. Since soils in the highlands of western Ethiopia where soybean is produced ranges from moderately to strongly acidic, it might significantly reduce the nodulation potential of the crop.

In Ethiopia, acidity-related soil fertility problems are the main production constraints, reducing the productivity of major crops grown in the country [8,6]. About 41% of the total land area of the country has an acidic reaction while, 33% of the soils in these areas have Al toxicity problem [9]. Soil nutrient depletion, erosion and leaching of basic cation are also very widespread crop production constraint in Western Ethiopia [10]. In the western part of the country such as Assosa and Wellega, soil acidity is a well-known problem limiting crop productivity. In these areas, 67% of soils have pH values less than 6 with the ranges varying from extremely acidic to moderately acidic [11].

Several agricultural practices have been recommended to overcome soil acidity problems for crop production worldwide. Among them, the most common and widely used practice is liming, which is the application of ground calcium and/or magnesium carbonates, hydroxides, and oxides aiming at increasing the soil pH and subsequently, modifying soil physical, chemical and biological properties [12]. Because of its great ameliorative effect on soil acidity, lime is commonly called the foundation of crop production or "workhorse" in acid soils [13].

Upon liming, numerous authors have reported decreases of Al^{3+} in the soil solution as well as from the exchange complex [14]. [15] reported that liming has improved soil structure, whereas [13] reported, significant increases in crop yield upon liming acidic soils. Liming does also have a significant effect on P uptake by plants [13], abundance and diversity of earthworms and organic matter decomposition and nutrient mineralization [16]. However, over liming may reduce crop yield by inducing P and micronutrient deficiencies [13].

Organic fertiliser application has been reported to improve crop growth by supplying plant nutrients as well as improving soil physical, chemical, and biological properties [17]. Vermicompost (VC) is one of the stabilised; finely divided organic fertilisers 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 [18]. Obtaining earthworms from vermiculture activity would be one-time cost in any vermiculture technology as the earthworms multiply rapidly creating huge population of worms which further promote and enhance the process [19]. When the organic material passes through the gut of the earthworm, it again increases the surface area of the material so that the microorganisms can break it down further. The undigested materials, or castings, are fertile and rich in nutrients [20]. They contain nutrients such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, and magnesium for plant growth [19]. There is an increasing interest in the potential use of VC as soil amendment [21] Application of VC showed marked improvements in the overall physical and biochemical properties, and at the same time, VC decreases exchangeable acidity which can support a release of plant nutrients in the acidic soils [22]. Current trends in agriculture are centered on reducing the use of inorganic fertilisers by bio-fertilisers such as VC [23]. There is good evidence that VC application promotes growth of plants and positive effect on growth and productivity of cereals and legumes [24]. When it is compared with conventional compost, VC promotes growth from 50 to 100% over conventional compost and from 30 to 40% over chemical fertilisers [19]. The combined application of inorganic and organic fertilisers is widely recognised as a way of improving productivity of the soil sustainably [25]. Several researchers [26,27,19], have demonstrated the beneficial effect of integrated nutrient management in mitigating the deficiency of several macro- and micronutrients.

The combined application of lime and organic materials could be an alternative for controlling soil acidity with reasonable cost for sustainable crop production in low input agriculture. Vermicompost and lime amendment have been reported to be suitable for humid tropical soils [28] to improve its physical and chemical properties. It has also been reported that combined applications of vermicompost and lime enhanced biological activity and soil organic carbon accumulation [29]. Furthermore, organic matter application to acidic soils improved availability of nitrogen, phosphorus and sulfur [30].

Application of lime and organic fertiliser at the same time produced highest nodule number; nodule volume and nodule dry weight per plants of all the combinations [31,32,33]. Nevertheless, some studies have compared separately the effects of lime and manure in ameliorating soil acidity [34]. Information is scarce regarding the use of ameliorating effects of combining vermicompost and lime on acidic nitisols of Assosa areas for crop production in general and soybean in particular. Therefore, the objectives of this study were: General objective:

- ❖ To evaluate the combined uses of vermicompost and lime as amendment for ameliorating acidic soil for crop production.

Specific objectives:

- ✓ To assess the combined effects of vermicompost and lime on selected soil physico-chemical properties.
- ✓ To investigate the response of soybean to the application of different combined rates of vermicompost and lime on acidic nitisols.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

The study was carried out at Assosa Agricultural Research Center (AsARC) in Amba-12 *Kebele*, one of the federal research centers of the

Ethiopian Institute of Agricultural Research (EIAR) in Benshangul Gumuz Regional State. AsARC is found at 680 km far from Addis Ababa to the North West direction. Geographically, it is located at 10^{0} 02' 47''N latitude and 34^{0} 34'27'' E longitude with an altitude of 1560 meters above sea level (Fig. 1). Agro-climatically, it has been characterised by hot to warm moist lowland plain with unimodal rainfall distribution pattern. The rainy season starts at the end of April and lasts at the end of October with maximum rainfall from June to October. The mean annual rainfall of the years (2016-2017) was 1407.8 mm. The mean annual minimum and maximum temperatures of the area for the same years were 18.12 and 30.9°C, respectively. The amount of rainfall observed during the growing year was showed (Fig. 1).

2.2 Soil Sampling and Vermicompost Characterisation

2.2.1 Soil sampling and analysis before planting

Seven disturbed sub-samples were collected from about 0.09 ha of land in the experimental site using a stainless steel soil augur at a depth of 0-15cm. a composite soil sample was prepared by thoroughly mixing these sub samples. The undisturbed soil samples were used to determine bulk density by core sampler weighing at field moisture content and then dried in an oven at 105°C and Porosity was determined using the following equation.

$$f = 1 - (pb/ps) \quad (1)$$

Where, f = total porosity, pb bulk density and Ps = particle density (2.65 g cm^{-3}), while, the disturbed composite soil samples was analysed for particle size distribution (soil texture) which was done by Bouyoucos hydrometer method as described by Bouyoucos (1962) that are among the physical soil parameters while, soil exchangeable acidity, exchangeable bases, soil pH, organic matter, total N, available phosphorus and cation exchange capacity (CEC) for soil chemical analysis were selected and all are determined following the standard procedures.

2.2.2 Vermicompost sampling and analysis

The known earth worm species (*Eisenia fetida*) using soybean (crop residues) and cow manure (wastes) were used for vermiculture preparation. The dried plant residues were chopped and then mixed with cow manure (in ratio of 7 parts of cow manure and 3 parts of waste, dry weight basis). The mixture allowed moisturising for two weeks and earthworms were added to the prepared bedding materials on the box. The moisture content was maintained at 60-70% by regular addition of water using water cans. After two months cast (vermicompost yield) were harvested and Five sub-samples were taken from the prepared cast to make one composite sample and then air dried, ground and sieve. Then, it was subjected to the analysis of pH, OC, N, P and total (Ca, Mg, and K) following standard procedures. The C:N ratio was estimated from OC and N contents of the vermicompost.

Table 1. Selected physico chemical properties before planting

Soil properties	Unit	Value
Sand	(%)	32.6
Silt	(%)	10.6
Clay	(%)	56.8
Textural Class		Clay
Bulk density	(gm cm^{-3})	1.36
Porosity	(%)	48.6
Ph(1:2.5) H2O		5.3
Ex. Acid	(cmol kg^{-1})	4.8
Ex.Al	(cmol kg^{-1})	3.8
OC	(%)	1.73
TN	(%)	0.2
av. P	(mg kg-1)	5.5
Ca	(cmol kg^{-1})	2.55
Mg	(cmol kg^{-1})	0.58
K	(cmol kg^{-1})	1
Na	(cmol kg^{-1})	0.21
CEC	(cmol kg^{-1})	10
ECEC	(cmol kg^{-1})	9.17
PBS	(%)	43.7
PAS	(%)	48

2.3 Lime Requirement Determination

The amounts of lime to be applied was determined based on the exchangeable acidity, mass per 0.15 m furrow slice and bulk density of the soil.

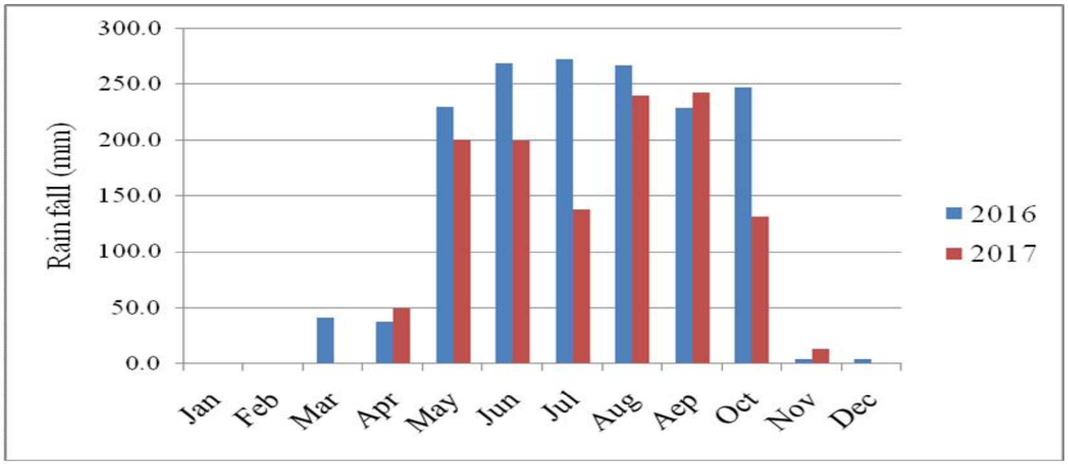

Fig. 1. Monthly total rain falls for 2016 and 2016 crop growing seasons and the 30 year average rainfall at Assosa and around the trial farm

Table 2. Chemical properties of vermicompost used for the study

Parameters	$pH_{(H2O)}$	OC (%)	TN (%)	C:N	TP ($mgkg^{-1}$)	Basic cations (cmol (+) kg^{-1})		
						Ca	Mg	K
VC	7.86	7.58	0.40	18.95:1	273.56	14.05	8.00	6.68

Key: VC: vermicompost

Table 3. Calculated lime quantity (t ha^{-1}) based on exchangeable acidity

% of lime rates	0	33.3	66.7	100
Lime t ha^{-1}	0	1.62	3.26	4.90

$$LR, CaCO_3\ (kg/ha) = \frac{cmolEA/kg\ of\ soil * 10^4\ m^2 * B.D.(Mg/m^3) * 1000}{2000} \quad (2)$$

Where: EA = 4.8cmol kg^{-1} of soil
B.D = 1.36 gm cm^{-3}

$$\frac{\frac{4.8cmol}{kgsoil} * 10{,}000m2 * 0.15m * \frac{1.36Mg}{m3} * 1000}{2000} = 4{,}896kg/ha$$

2.4 Experimental Design and Treatments

The experiment consisting of 16 treatments were conducted during the 2016 and 2017 cropping season (June to November) for two years. The treatments comprised of four levels (0, 1.50, 3.00 and 4.50 t ha^{-1}) of vermicompost and four levels of lime (0, 1.62, 3.26 and 4.90) t ha^{-1} based on the exchangeable acidity of the soil. The experiment was laid as Randomized Complete Block Design (RCBD) and replicated three times in 3 m by 2 m (6.0 m^2) plot size. Prior to planting the land was ploughed to a depth of 15 cm using oxen. Vermicompost and lime were uniformly surface broadcasted and then incorporated to the respective plots within 15 cm soil depth a month before planting.

2.5 Experimental Procedures

Bradyrhizobium japonicum strain was collected from Holeta Agricultural Research Center, Holeta, Ethiopia. Before planting, the soybean seeds were immersed in a luke warm water for few minutes and then 5g of *Bradyrhizobium japonicum* per 1kg of seed (recommended rate) was inoculated just before planting under shade to maintain the viability of cells and seeds were air dried for some time before sowing. Phosphorus fertiliser recommended P (46 kg P_2O_5 ha^{-1} from TSP) was applied at planting and the inoculated seeds were planted to the plots on July 13, 2016 and on the month in 2017. The seeds were sown in rows to maintain plant to plant distance of 5 cm and 60 cm between rows. The cropping was done by rain fall without any germination and seedling establishment problem.

The experimental field was weeded by hand five times during the growing period. Harvesting was done when the leaves of the soybean plants senescent and showed yellow collation of leaves and pods start to open.

2.6 Data Collection and Measurements

Yield and yield related parameters like, plant height, Nodulation and nodule data, Number of pods per plant Number of seeds per pod, Hundred seeds weight (g) and Grain yield of soybean (t ha^{-1}) were collected and soil chemical properties after harvest were collected.

2.7 Statistical Analysis

The data was subjected to analysis of variance (ANNOVA) by following the standard procedure [35] then analysed using Statistical Analysis System SAS software version 9.1. Significant mean of the treatments were delineated by Tukey's Test comparison at p< 0.01 or p < 0.05. Correlation analysis was carried between the parameters to determine the magnitude and degree of their relation.

3. RESULTS AND DISCUSSION

3.1 Ameliorative Effects of Lime and Vermicompost on Soil Chemical Properties

3.1.1 Soil pH and exchangeable acidity

Soil pH values were highly significant at both years of experiment (p < 0.01) after harvest of 2016 and 2017 cropping seasons (Table 4). In both seasons, combined analysis results showed that application of lime alone (main effect) recorded the highest value for soil pH water were 5.86 which increased by more than 10.35% over the control. *i.e* equivalent to change in the soil reaction from strongly acidic to moderately acidic. On the other side, the exchangeable acidity highly reduced due to the application of lime from 5.46 to 2.48 (cmol (+) kg^{-1} it was about more than 47.8% reduced the exchangeable acidity and the same on exchangeable Alummunium.

Main effect of vermicompost showed slightly significance on the analysis result and changed in soil pH from 5.56 (control) to 5.62 with level of 4.50 t ha^{-1}. Increase in soil pH over the control due to the application of vermicompost was also reported by [36]. Hence, vermicompost alone has also an effect on soil pH since; it can contribute basic cations that neutralise soil acidity through hydrolysis reaction. The increase was attributed to the displacement of Al^{3+} and H^{+} ions from soil sorption sites by Ca^{2+} content in lime. In addition, the OH^{-} ions and Mg^{2+} ions released through vermicompost decomposition may have also contribute to the complexation of Al^{3+} and H^{+} ions in the soil. Similar explanations were made by [37,38] who reported that application of lime combined with organic materials like manure increased soil pH.

3.1.2 Soil exchangeable bases (Ca, Mg and K)

Soil exchangeable bases (Ca, Mg and K) and CEC values were significant at both years of experiment (p < 0.01) after harvest of 2016 and 2017 cropping seasons. In both seasons, combined analysis results showed that main effect of lime recorded the highest value for soil ex. Ca was 6.15 which increased by more than 119.6% over the control (2.8. cmol (+) kg^{-1}). Even though, there were no interaction effect statistically at field condition Soybean also had good performance with combined application of lime and vermicompost at the rates 3.26 and 4.50 t ha^{-1}, respectively (Table 5). Probably, this higher ex. Ca^{2+}content from the combination of lime and vermicompost might be attributed to the release of Ca^{2+} ions in lime through its dissolution and mineralisation of the vermicompost. This agrees with [39] who reported increase of exchangeable Ca after application of manure alone and combined with lime. Similarly, [36] found significant increase in soil exchangeable Ca when lime applied to acidic soils with manure. Several authors reported that combined application of organic matter such as manure, compost and vermicompost with liming improved the soil chemical properties: pH, exchangeable Ca and microbial activity [38,3,40].

Main effect of vermicompost increased soil ex. Ca by 35% over the control plots (4.862.8. cmol (+) kg^{-1} with the application of 4.5 t ha^{-1}. However, ex. Ca content of soils from plots treated by 3.00 t ha^{-1} vermicompost was non significance difference with 4.5 t ha^{-1}. These result are clear in this study as it was found that soil exchangeable Ca was positively and significantly correlated to soil pH (R^2 = 0.802: p < 0.01). This indicates ex Ca is much more affected by soil pH. This is also in-line with the report of [41].

Main effect of lime on ex. Mg and K showed significance with the magnitude of 163 and 30.68% respectively over the control. In the current study, there was significant, positive relationship between soil pH and soil exchangeable Mg (R^2 = 0.846; p< 0.01), which shows the importance of soil pH improvement to enhance soil Mg availability (Table 5). According to [36], the availability of Mg in acid soils is reduced under low soil pH as the soil exchangeable sites are depleted of Mg, creating an imbalance of these nutrients. Therefore, its increase may be a result of improved soil conditions (acidity) due to improved organic matter and application of lime.

CEC showed significance difference on main effect of lime and vermicompost. Application of lime the rate of 4.5 t ha^{-1} increased 20.36% over the control. Whereas, vermicompost with the rate of 3 t ha^{-1} applied was increased more than 26.7% over the control. The correlation analysis of the results also indicated significant, positive relationship between soil pH and CEC of soil (R^2 = 0.645; p< 0.01). This clearly shows significant effect of soil pH on CEC. Therefore, any management option that can improve soil pH could increase CEC of soil and subsequently soil fertility.

Table 4. Effect of lime and vermicompost on soil pH and exchangeable acidity

Treatment	Soil PH(H_2O)	Ex. Acid (cmol(+) kg^{-1}	Ex. Al(cmol(+)kg^{-1}
Lime rate(t ha^{-1})			
0	5.31^b	5.46^a	2.76
1.62	5.40^b	4.13^b	2.08
3.26	5.72^b	3.6^c	1.36
4.9	5.86^a	2.85^d	1.02
Sig.	**	*	*
Vermicompost (t ha^{-1})			
0	5.56^{bc}	4.65	2.04
1.5	5.40^{bc}	4.07	1.84
3	5.71^a	3.88	1.69
4.5	5.62^{ab}	3.44	1.66
LSD (5%)	0.15	0.48	0.4
CV (%)	2.5	10.9	22
Sig.	*	Ns	Ns

Ex.acd: Exchangeable acidity and Al: Exchangeable Al, VC: vermicompost and LM: lime

Table 5. Effect of lime and vermicompost on soil exchangeable base and CEC

Treatment	Ca (cmol(+) kg^{-1}	Mg (cmol(+) kg^{-1}	K(cmol(+)kg^{-1}	CEC (cmol(+) kg^{-1}
Lime rate(t ha^{-1})				
0	2.8^c	1.46^d	0.88^b	13.26^b
1.62	4.68^b	2.68^c	1.1^a	10.97^c
3.26	5.54^a	3.25^b	1.14^a	15.48^a
4.9	6.15^a	3.85^a	1.15^a	15.96^a
Sig.	**	*	*	*
Vermicompost (t ha^{-1})				
0	4.86^a	2.87	1.07	12.23^d
1.5	3.91^b	2.44	0.95	14.35^b
3	5.2^a	3.17	1.18	15.50^a
4.5	5.21^a	2.76	1.07	13.55^c
LSD (5%)	0.6	0.44	0.152	5.4
CV (%)	15.9	18.7	17	0.63
Sig.	*	Ns	Ns	*

VC: Vermicompost and LM: Lime

3.1.3 Percent base saturation and percent acid saturation (PBS and ASP)

Combined or solo application of the amendments increased the percent base saturation with increase respective levels (Fig. 2). Application of lime alone caused an increase in PBS of the soil from the treated plots by 33 - 95%) over the control plot. The change in PBS (71.73) was recorded for soil from plots received with combined application of lime and vermicompost at the rates of 3.26 and 4.50 t ha^{-1}. The lowest PBS (37.31) and highest PAS (53.33) were recorded for soil from the control plot.

3.1.4 Soil organic carbon, total nitrogen and available phosphorus

Soil available phosphorus (Av.P) values were showed statically on main effect of both lime and vermicompost slightly significant on application of treatments but no interaction effect (Table 6). Application of lime alone slightly increased soil (Av.P) with increasing rates. The magnitude of increment was in the range 16 - 27% over the control respective of its level. Liming of acidic soils could increase soil pH, which enhances the release phosphate ions fixed by Al and Fe ions into the soil solution [40]. Similarly, [42] showed that deficiency of P could be corrected thought liming acid soil to increase the pH more than 6.

The increment of av. P on application of vermicompost 4.5 t ha-1 was about 18.9%. This might be due to mineralisation of vermicompost. It was suggested by [43], further decomposition of vermicompost could release organic substances that can form complex with ions of Fe and Al in soil solution consequently prevents phosphorus fixation. This gradually neutralises soil acidity and hence makes fixed phosphorus available in the soil solution [44]. This result agreement with [45] who reported increased soil av.P with application of goat manure. Therefore, application of vermicompost to acid soil could increase av.P contents of soil through releasing of P in it and also by increasing soil pH which reduces P fixation.

Table 6. Effect of lime and vermicompost on soil available P, total N and organic carbon

Treatment	Av. P mg Kg^{-1}	Total N (%)	%OC
Lime rate(t ha^{-1})			
0	5.56d	0.14c	1.67
1.62	6.46c	0.16b	1.57
3.26	6.78b	0.16b	1.71
4.9	7.07a	0.18a	1.76
Sig.	**	*	Ns
Vermicompost (t ha^{-1})			
0	6.23	0.15	1.69
1.5	6.11	0.16	1.57
3	6.11	0.16	1.66
4.5	7.41	0.17	1.78
LSD (5%)	0.26	0.035	0.22
CV (%)	4.76	10	15.5
Sig.	*	Ns	Ns

LM: lime t ha^{-1}; VC: vermicompost t ha^{-1}; ava.P: available phosphorus mg kg^{-1} soil

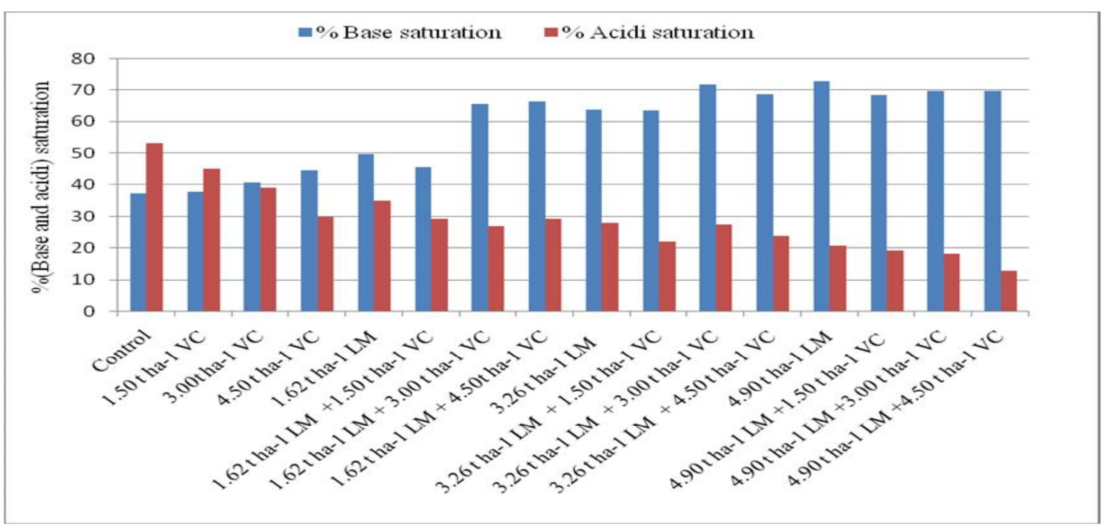

Fig. 2. Changes of PBS and PAS with increases in rates of the treatments after harvesting

Table 7. Correlation analysis among soil chemical properties

Soil parameters	PH	Ex acid	EX.al	AV.P	Tot N	OC	Ex K	EX Ca	Ex Mg	Ex Na	ECE	PBS	PAS
PH	1												
Ex acid	-0.797**	1											
EX. Al	-0.831**	0.911**	1										
AV.P	0.415^{NS}	-0.687**	-0.655**	1									
Tot N	0.811**	-0.793**	-0.753^{NS}	0.395^{NS}	1								
OC	0.565*	-0.389^{NS}	-0.342^{NS}	0.505*	0.474^{NS}	1							
Ex K	0.798**	-0.733**	-0.654*	0.375^{NS}	0.709**	0.343^{NS}	1						
EX Ca	0.803**	-0.836**	-0.850**	0.715**	0.603*	0.470^{NS}	0.786**	1					
Ex Mg	0.846**	-0.837**	-0.861**	0.559^{NS}	0.757**	0.434^{NS}	0.837**	0.895**	1				
Ex Na	0.479^{NS}	-0.612*	-0.512*	0.295^{NS}	0.522*	-0.023^{NS}	0.729**	0.475^{NS}	0.573*	1			
ECE	0.645**	-0.430^{NS}	-0.565*	-0.034^{NS}	0.552*	0.178^{NS}	0.275^{NS}	0.291^{NS}	0.321^{NS}	0.053^{NS}	1		
PBS	0.808**	-0.845**	-0.893**	0.690**	0.657**	0.467^{NS}	0.735**	0.938**	0.899**	0.460^{NS}	0.364^{NS}	1	
PAS	-0.771**	0.960**	0.921**	-0.669**	-0.848**	-0.371^{Ns}	-0.711**	-0.786**	-0.808**	-0.543*	-0.503*	-0.806**	1

*NS: non-significant; * significant and ** highly significant at 5% probability level; PBS: Percent base saturation: PAS percent acid saturation; ECE: cation exchange capacity; Ex (K, Ca, Na, Mg): Exchangeable Potassium, Calcium, Sodium and Magnesium) respectively; OC: organic carbon; Ex. Al: Exchangeable Aluminum and Ex. acid: Exchangeable acidity*

On the same manure soil total N and OC also shows improvement on both main effects of lime and vermicompost and all were on medium to very high range from the very low rate as before experiments' soil results (Table 1). The increment in soil OC and total N contents due lime and vermicompost application, (sole or combined) might be associated with the improvement of soil conditions, which might be enhanced biomass production, proliferation of soil microbial and their activity in the soil. [46] also attributed increase in soil organic carbon to the dropping of leaves, which added organic C to the soil. The increment in total nitrogen content of the soil due the amendments might be due to addition/improvement of the organic matter content of the soil. (This agrees with the results reported by [46,47,48] who reported application of organic materials like compost and manure had significant increased soil total nitrogen and organic carbon.

3.2 Response of Soybean to Lime and Vermicompost on Nodulation

3.2.1 Soybean nodulation

3.2.1.1 Number of nodules per plant

The number of nodules per soybean plant was significantly ($p < 0.01$) affected by vermicompost and lime rates. Similarly, the interaction effects of different rates of lime and vermicompost were highly significant ($P < 0.01$) on number of nodules (Table 8).

Application of vermicompost alone, at the rate of 4.50 t ha^{-1} produced the highest nodules number per plant (69.5) which was about 172.5% increment over the control treatment (25.5 nodules per plant). This could be possibly due to the increased soil organic carbon, nitrogen available P and favorable pH range (> 5.5) for proliferation of nodule forming *Bradyrhizobium* bacteria. [49] also recorded 39% of significant increase in number of nodules as a result of manure application to soybean crop.

Main effect of lime also produced highly significant difference in nodulation among treatments within its levels and about 37–122.7% increments over the control. This observation agrees with France and Day (1980) who reported increased nodulation and nitrogen fixation of *Phaseolus vulgaris* (L.) in the acid soils of Brazil as a result of liming.

Furthermore, combined application of lime and vermicompost showed significant differences in number of nodules per plant among treatments, but there were slight differences within the rates. This finding showed that there was positive effect on number of nodules by application of vermicompost alone and combined with lime (Table 8). The soil of the experiment site was strongly acidic, moderate in N and low in P and other plant nutrients. Application of vermicompost might be contributed not only by supplying nutrients (including N, P, K and micronutrients) through mineralisation but also by making P available to the plant as result of its liming effect.

Furthermore, vermicompost is known by its ability of improving soil physical properties such as structure which in turn improves soil moisture, microbial activity and makes nutrients available [50]. This result agrees with [31] report that application of lime and organic fertiliser at the same time produced more nodule number, nodule volume and nodule dry weight per plants of all the combinations.

3.2.1.2 Number of effective nodules per plant

Active nodules were selected by their reddish to pink colour indicating intact leghemoglobin in the infected zone at flowering stage. Analysis of variance showed significant variation on number of effective nodule per plant for lime and vermicompost application ($p < 0.01$) and ($p < 0.05$) respectively. On the other hand, the two-way Anova interaction effects (LR*VC) were non-significant ($P > 0.05$) on effective nodule per plant (Table 9).

The favorable response to vermicompost application might be due to nutrient availability of plants as a result of fast mineralisation [51]. Organic matter increases the moisture retention of soil and improves soil structure and in turn soil porosity which allows better root growth and hence active nodules and better grain yield [52]. In addition vermicompost supply necessary nutrients (N, P, K and Fe) important for nodules formation and Rhizobia bacteria are sensitive to soil acidity and require P, adequate soil moisture for their multiplication [53]. Phosphorous present in the vermicompost perhaps resulted in positive effect of vermicompost on nodulation. Phosphorous and FYM have been reported to improve both the total and active nodules and nodule dry weight [54]. This contradicts with reported by [50] in which manure application did not improve nodulation of Lima beans, Lablab, Common beans and Green grams.

The lowest number of effective nodules was recorded from the un-amended treatments. This poor performance under control may be due to prevalence of soil acidity and lower soil fertility status that acts as inhibitors for rhizobial population development and hence their performance. Deficiencies of soil nutrients, especially P may restrict the development of a population of free-living rhizobia in the rhizosphere, limit the growth of the host plant, restrict nodulation itself, and cause an impaired nodule function [55,56].

3.2.1.3 Nodule volume per plant

The volume of nodules per soybean plant was significantly affected by the treatments of vermicompost and lime ($p < 0.01$). The two-way ANOVA showed significant interaction effects ($P<0.05$) on volume of nodules per plant (Table 10).

Combine application of 3.26 t ha^{-1}of lime with 3 t ha^{-1}of vermicompost gave the highest nodule volume (9.3 ml). It could be due to the ability of the two materials in improving the growth environment such as soil pH and availability of nutrients required by plants and *Rhizobium* [57]. This finding is in agreement with reports of [31] who observed lime and *Bradyrhizobium japonicum* at the same time produced the highest nodule volume on soybean crop. [33] and [32] also reported combined application of Lime and Bradyrhizobium produced the highest nodule number, nodule volume and nodule dry weight per plant.

3.2.2 Plant height

Analysis of variance on soybean plant height showed significant difference among the applied treatments. Moreover, interaction effect of different rates of lime and vermicompost were highly significant ($P < 0.01$) on plant height (Table 11).

Soybean grown in lime treated soil had significantly effect ($p < 0.05$) on plant height compered to grown in non limed soils with increasing levels, i.e 21.1 - 36.4% increaments over the control treatment. Similarly, significant effect observed on vermicompost application alone on soybean growth at the rate of 4.50 t ha^{-1} which gave the highest plant height (66.46 cm) but lodging effect was observed. It is also interesting to refer the beneficial effect of vermicompost in relation to plant height increment. The highest plant height (67.20 cm) was recorded from the application of combined 3.26 t ha^{-1} of lime and 3.00 t ha^{-1} of vermicompost.

Vermicompost alone or combined with lime increased soybean growth. Vermicompost might have provided different nutrients and together with lime improved soil environment and enhanced mineralisation. These results are similar with the results reported by several other researchers [58,59].

Organic matter is a reservoir of nutrients that are released through mineralisation and are availed for plant growth [60]. The nutrient content of the vermicompost was fair (Table 6), and the quantity applied must have

Table 8. Effect of lime and vermicompost on number of nodule per plant of soybean

Lime rate(t ha^{-1})	Vermicompost rate(t ha^{-1})				
	0	1.50	3.00	4.50	Mean
0	25.5^{e}	32.5^{e}	66^{ab}	69.5^{a}	48.38
1.62	35^{e}	50^{d}	52.73^{bcd}	53.67^{bcd}	47.85
3.26	51.6^{cd}	64.83^{abc}	60^{abcd}	61^{abcd}	59.36
4.90	56.8^{abcd}	56^{abcd}	56^{abcd}	64^{abcd}	58.20
Mean	42.23	50.83	58.68	62.04	
Tukey (0.05)	12.07				
CV (%)	13.57				

a,b,c,d'. Any two means designated by the same letter are not significantly different at (P: 0.05), Tukey's Test.

Table 1. Effect of lime and vermicompost on effective nodule numbers on soybean (%)

Treatments					Sig.
Lime rate(t ha^{-1})	**0**	**1.62**	**3.26**	**4.90**	
	45.6^{b}	53.8^{b}	57.1^{a}	56.7^{a}	**
Vermicompost (t ha^{-1})	**0**	**1.50**	**3**	**4.50**	
	37.4^{b}	51.1^{b}	67^{a}	67.1^{a}	*
Tukey (5%)	36.6				
CV (%)	23				

a,b, Any two means designated by the same letter are not significantly different (P=0.05), Tukey's Test

Table 10. Effect of lime and vermicompost rates on Nodule volume per plant (ml)

Lime rate(t ha^{-1})	Vermicompost rate(t ha^{-1})				
	0	**1.50**	**3.00**	**4.50**	**Mean**
0	3.5^{e}	6.25^{bcd}	8^{abc}	8.5^{ab}	6.56
1.62	7^{abcd}	7.67^{abc}	8.167^{abc}	8^{abc}	7.99
3.29	8$_{abc}$	8.5^{ab}	9.3^{a}	7^{abcd}	7.92
4.90	5.5^{cde}	5.67^{cde}	5de	5.5c^{de}	5.42
Mean	6.00	7.02	7.62	7.00	
Tukey (5%)	2.33				
CV(%)	20.27				

a,b,c,d, e'. Any two means designated by the same letter are not significantly different (P: 0.05), Tukey test

Table 11. Effect of lime and vermicompost on plant height of soybean (cm)

Lime rate(t ha^{-1})	Vermicompost rate (t ha^{-1})				
	0	**1.50**	**3.00**	**4.50**	**Mean**
0	45.00^{g}	58.30^{def}	60.30^{bcdef}	66.46^{ab}	57.50
1.62	54.50^{f}	60.07^{cdef}	61.73^{abcde}	66.53^{ab}	60.72
3.26	60.67^{bcde}	57.40^{ef}	67.20^{a}	65.93^{abc}	62.80
4.90	61.40^{abcde}	64.00^{abcd}	64.27^{abcd}	65.47^{abc}	63.79
Mean	55.40	59.94	63.38	66.08	
Tukey (5%)	2.68				
CV (%)	5.26				

a,b,c,d,e,f'. Any two means designated by the same letter are not significantly different (P: 0.05), Tukey's Test

supplied the important nutrients such as N, P and K which are critical for soybean growth. In addition, the good performance of plant grown on plots treated with vermicompost combined with lime might be due to the improvement in soil conditions and increased availability of nutrients through vermicompost and lime application [61]. From statistical point of view combined application of 3.26 t ha^{-1}of lime and 3.00 t ha^{-1} vermicompost were elective to produce better plant growth which was important combination for soybean production in this area.

3.3 Grain Yield and Yield Components

3.3.1 Number of pods per plant

The effect of vermicompost on number of pods per plant was significant (*p* = 0.01), that was 17.5 - 42.9% increment over the control with the highest from the highest rate while, the effect of lime and its interaction with vermicompost was non-significant (Table 12).

This might be due to presence of medium amount of available phosphorous (6.11 mg kg^{-1}) explained by (Table 9). High available soil P has been demonstrated to increase productivity and biological nitrogen fixation of legumes [62]. As [63] who noted that a strong positive correlation between yields of soybean and soil available P. This result accepted with [64] who reported significantly higher number of pods per plant in soybean plots treated with NPK+ vermicompost than in the control plots. The lowest number of pod records from un-treated (15 pods per plant) which was grown without input.

Table 12. Effect of lime and vermicompost on number of pods per plant of soybean

	Rates				
Lime ($t\ ha^{-1}$)	**0**	**1.62**	**3.26**	**4.90**	**Sig.**
	25.37	30.33	26.98	29.25	NS
Vermicompost ($t\ ha^{-1}$)	**0**	**1.50**	**3.00**	**4.50**	**Sig.**
	22.73^{c}	26.7^{bc}	29.98^{ab}	32.5^{a}	**
Tukey (5%))	4.85				
CV (%)	20.8				

a,b,c '. Any two means designated by the same letter are not significantly different (P: 0.05), Tukey's Test

3.3.2 Number of seeds per pod

Analysis of variance showed significant difference in number of seeds per pod among the treatments. The effect of lime alone was highly significantly high ($p < 0.01$) and increased with increasing rates. Similarly, the effect of vermicompost alone was highly significant ($p < 0.01$) and increased the number of seeds per pod with increasing rates. The interaction effect of lime and vermicompost on the number of seeds per pod was also significant (LR*VCR < 0.05) (Table 13). This might be due to the improvement of soil pH improved by the applied lime, improvement of the growth and yield parameters due to the addition of vermicompost.

The significant differences in number of seeds per pod and number of pods per plant might have led to the positive effect on the grain yield. This result agrees with that of [65] who reported that application of lime and vermicompost has increase the number of seeds per pod and thereby, increased grain yield of soybean. [66] also reported that application integrated fertilisation methods affect grain yield and yield components of soybean by increasing the number of seeds per pod and pod per plants.

3.3.3 Grain yield

Analysis of variance on soybean grain yield showed significant difference among the treatments. Application of lime and vermicompost alone gave highly significant difference ($p < 0.01$) while, the effect of their interaction was significant ($P<0.05$) (Table 14).

Table 13. Effect of lime and vermicompost on number of seed per pod of soybean

Lime ($t\ ha^{-1}$)	Vermicompost ($t\ ha^{-1}$)				
	0	**1.50**	**3**	**4.5**	**Mean**
0	1.67^{cd}	1.67^{cd}	2.33^{abc}	2.67^{ab}	2.09
1.62	1.0^{d}	1.67^{cd}	2.67^{ab}	3.0^{a}	2.09
3.26	2.0^{bc}	2.67^{ab}	3.0^{a}	3.0^{a}	2.67
4.9	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}	3.00
Mean	1.92	2.25	2.75	2.92	
Tukey (5%)	0.41				
CV (%)	18.56				

a,b,c,d'. Any two means designated by the same letter are not significantly different (P: 0.05), Tukey's Test

Table 14. Effect of lime and vermicompost on grain yield of soybean ($t\ ha^{-1}$)

Lime rate($t\ ha^{-1}$)	Vermicompost rate($t\ ha^{-1}$)				
	0	**1.50**	**3.00**	**4.50**	**Mean**
0	0.66^{g}	0.92^{fg}	1.35^{de}	1.49^{cd}	1.10
1.62	1.12^{ef}	1.29^{de}	1.38^{de}	1.68^{abc}	1.37
3.26	1.43^{cd}	1.53^{bcd}	1.85^{a}	1.85^{a}	1.67
4.90	1.80^{ab}	1.91^{a}	1.95^{a}	1.89^{a}	1.89
Mean	1.25	1.41	1.63	1.73	
Tukey (5%)	0.13				
CV (%)	10.60				

a,b,c,d,f,g'. Any two means designated by the same letter are not significantly different (P: 0.05), Tukey's Test

Results showed that application of lime alone produced a significant increase in grain yield of soybean. The magnitude of increment was 69.7 - 172.7% over the control. The highest grain yield of soybean (1.95 t ha^{-1}) was obtained from plots received with 4.90 t ha^{-1} lime combined with vermicompost (3.00 t ha^{-1}) and the lowest (0.65 t ha^{-1}) was obtained from untreated (control) plot which is more than 195% yield difference.

Similarly, application of vermicompost alone increased soybean grain yield by 39.4 - 125.8% over the control with the highest yield from the highest rate. The results in line with [49,60] who reported the application of manure increased dry matter and grain yield per hectare.

The results indicate that applying lime to the soil might considerably improve the nutrient availability, particularly phosphorus, since it improve soil pH under which maximum availability of the nutrient may be obtained. Studies by [67] showed significant grain yield increase when excess acidity was neutralised over time. [68] also found that application of lime at a single rate 4.4 t ha^{-1} in an Ultisols increased grain yield by almost a factor of three as compared to the un-limed Ultisols. Furthermore, indirect effects of lime include increased availability of P, Mo and B, and more favorable conditions for microbial mediated reactions such as nitrogen fixation and nitrification, and in some cases improved soil structure [69]. For instance application of lime significantly increased root and shoot yields and grain yields of soybean [70]. [71] also reported increased soybean yield due to application of lime.

4. SUMMARY AND CONCLUSION

Based on these, the study was conducted to ameliorate the soil with lime and vermicompost alone and in combination to investigate the effects on soil properties and soybean productivity. Combined application of lime and vermicompost significantly improved the soil properties and theses improvements have resulted in increased grain yield and yield related parameters of soybean grown on the acidic nitisols of Assosa. Combining 3.00 t ha^{-1} of vermicompost with 4.90 t ha^{-1} lime was the best practice and increased soil pH, soil reaction from strongly acidic to moderately acidic and reduced exchangeable acidity by 196% below the control. This closely followed by vermicompost at the rate of 3.00 and 3.62 t ha^{-1} of lime which improves soil acidity. Soybean yields were increased more than 195% over the control. Combined application of lime and vermicompost at the rates of 3.26 and 3.00 t ha^{-1}, practically, found to be feasible for farmers of the Assosa area for soybean production. This study clearly showed the ameliorative benefits of combined application of lime and vermicompost on acidic soil for soybean production. However, more studies should be carried out for more seasons to assess the consistence of these findings, and the response of other crops to lime and combined applications with vermicompost, other organic and inorganic fertilisers since K deficiency symptoms were observed on the plots applied with lime alone during this study. Therefore, for improved soil chemical properties and soybean yields, smallholder farmers of the study are shall be advised to adopt integrated application of lime with vermicompost.

ACKNOWLEDGEMENTS

The authors appreciate Ethiopian Institute of Agricultural Research (EIAR) for their financial support that enabled me to carry out my coursework and research and Assosa ARC for tolerating materials and experimental field for conducting experimental research. My deep and heartfelt gratitude goes to my husband Dessalegn Tammene for their data management, moral support, encouragement, and valuable advice during my study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Masuda T, Goldsmith PD. World soybean production: Area harvested yield, and long-term projections. International Food and Agribusiness Management, Review. 2009;12(4):143-162.
2. Collombet RN. Investigating soybean market situation in Western Kenya: constraints and opportunities for smallholder producers. Wageningen University. 2013;1-43.
3. IITA (International Institute of Tropical Agriculture). 1990. Research Highlights for 1989. International Institute of Tropical Agriculture, Ibaban, Nigeria.
4. WHO (world health organization). 2003. Technical Report Series 916. Report of a Joint WHO/FAO Expert Consultation.

5. CSA (Central Stastical Agency) 2015/16. Report on the preliminary results of area, production and yield of temporary crops. Centeral Stastical Authority, Ethiopia.
6. IFPRI (International Food Policy Research Institute). 2015/16. Pulses value chain potential in Ethiopia: Constraints and opportunities for enhancing exports. *Pulses Diagnostics,* IFPRI. INC, United States of America.
7. Carter J, Gardner K, Gibson AH. Improved growth and yield of faba bean (*Vicia fabae* Fiord) by inoculation with strains of rhizobium leguminosarum biovar. viciae in acid soils in South West Victoria. Austerlian Journal of Agricultural Research. 1998;45(3):613-623.
8. IFPRI (International Food Policy Research Institute). 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. Working paper, Washington,USA;. Available:www.ifpri.org (Accessed: 12 April 2011)
9. Schlede H. Distribution of acid soils and liming materials in Ethiopia. Ethiopian Institute of Geological Surveys, Ministry of Mines and Energy. Addis Ababa, Ethiopia; 1989
10. Taye Bekele. Developing alternative for barley cropping system in western Shewa. Annual report. Holetta Research Center, Holetta, Ethiopia; 2001
11. Mesfin Abebe. Nature and management of acid soils in Ethiopia. Addis Ababa, Ethiopia. 2007;99:23-25 and 35–126.
12. Edmeades DC, Ridley AM. Using lime to ameliorate topsoil and subsoil acidity. In: Rengel, Z., (eds.), Handbook of Soil acidity. Marcel Dekker, Inc., NewYork, Basel. 2003;297- 336.
13. Fageria NK, Santos AB. Influence of pH on productivity, nutrient use efficiency by dry bean, and soil phosphorus availability in a no-tillage system. Communication in Soil Science and Plant Analysis. 2008;39:1016-1025.
14. Delhaize E, Gruber BD, Ryan PR. The roles of organic anion p in aluminium resistance and mineral nutrition. FEBS Letters. 2007;581:2255-2262.
15. Crawford TW, Singh U, Breman H. *Solving* Problems related to soil acidity In: Central africa's geat lakes region. International Center for Soil Fertility and Agricultural Development (IFDC)-USA' 2008.
16. Bishop HO. Ecology of earthworms and their impact on carbon distribution and chemical characteristics of soil. MSc. Thesis, University of Stirling; 2003
17. Mengesha D, Mekonnen L. Integrated agronomic crop managements to improve teff productivity under terminal drought. Water Stress, I. Md, M. Rahman, and H. Hasegawa, Eds., Intech Open Science, London, UK. 2012; 235–254.
18. Arancon N, Edwards C, Atiyeh R, Metzger Effects of vermicompost produced from food waste on the growth and yields of greenhouse peppers. Bio-Resources Technology. 2004;93(2):139–144.
19. Sinha R, Agarwal S, Chaudhan K, Valani D. The ewonders of earthworms and its vermicomposting in farm production: Charles Darwin's friends of farmers', with potential to replace destructive chemical fertilizers from agriculture," Agricultural Science. 2010;1(2):76–94.
20. Latifah AM, Che Jusoh ML, Yusoff MK, Ismail THH, Harun R, Juahir H. Influences of bedding material in vermicomposting process. Int J Biol.; 2009:1:81-91.
21. Lordan J, Pascual M, Fonseca F. Use of rice husk to enhance peach tree performance in soil switch limiting physical properties. Soil Tillage and Research, 2013;129:19–22.
22. Abafita R. Evaluation of vermicompost on maize productivity and determine optimum rate for maize production. World Journal of Biology and Medical Sciences, 2016;3(1):9–22.
23. Haj M, Darzi M, Ghandehari Z, Riazi H. Effects of vermicompost and amino acids on the flower yield and essential oil production from Matricaria chamomilla L. J. of Med. Plants Research. 2011;5(23):5611–5617.
24. Glenda S, Ismet B, Skender K, Astrit B. The influence of vermicompost on plant growth characteristics of cucumber (*Cucumis sativus* L.) seedlings under saline conditions. Journal of Food, Agriculture and Environmental. 2009;7:869–872.
25. Mahajan A, Bhagat M, Gupta R. Integrated nutrient management in sustainable rice-wheat cropping system for food security in India. SAARC Journal of Agriculture. 2008;6(2):29–32.
26. Gafar AF, Yassin M, Ibrahim D, Yagoob SO. Effect of different (bio organic and inorganic) fertilizers on some yield

components of rice (*Oryza sativa* L.). Universal Journal of Agricultural Research. 2014;2(2):67–70.

27. Angachew G. Ameliorating eﬀects of organic and inorganic fertilizers on crop productivity and soil properties on reddish-brown soils. Proceedings of the 10th Conference of the Ethiopian Society of Soil Science. Addis Ababa, Ethiopia. 2009; 127–150.
28. Agboola AA, Obigbesan GO, Fayemi A. Effect of organic materials (farm yard manure), lime and phosphorus fertilizer on the yield of cowpea. Food and Agriculture Organization Soil Bulletin No. 1982;29: 39.
29. FAO (Food and Agriculture Organization). 2004. Use of phosphate rocks for sustainable agriculture. Fertilizer and plant Nutrition Bulletin. (Zepata, F. and Roy, R.N.).
30. Eliott ET, Lambardella CA, Cole CV. Modification of ecosystem processes by management and the mediation of soil organic matter dynamics. Mulongoy, K. and Mercx, R. (*eds*.), Soil organic matter dynamics and sustainability of tropical agriculture, Wiley Sayce Company. IITA/K.U. Leuven; 1993.
31. Workneh Atomsa, Tesfu Kebede and Jafer Dawud. Growth and nodulation response of soybean lime, *Bradyrhizobium Japonicum* and nitrogen ferlilizer in acid Soil at Melko. South Western Ethiopia. International journal of science. 2013;8(1):25-31.
32. Chalk PM, Aleves BJR, Boddey RM, Urquiage S. Integrated effects of abiotic stresses on inoculants performance, legume growth and symbiotic dependence estimated by ^{16}N dilution. Plant Science. 2010;328:1- 6.
33. Gou Y, Niyu L, Jianguo H, Effect of liming and *sinorhizobium* inoculation on growth, nodulation and nutrient concentrations of lucerne in acid soil. Tropical Grasslands. 2009;43:112-117.
34. Naramabuye N. Use of organic amendments as ameliorants for soil acidit in laboratory and fields experiments. PhD Thesis, University of KwaZulu-Natal; 2004.
35. Statistical Analysis System (SAS) Institute.2002. SAS procedures guidelines: Version 9.2, Vol.1.
36. Awodun MA, Omonijo L, Ojeniyi SO. Effects of goat dung and NPK fertilizer on soil and leaf nutrient content, growth and yield of pepper. International Journal of Soil Science. 2007;*2*(2):142-127.
37. Kanyanjua SM, Ireri L, Wambua S, Nandwa SM. Acidic soils in Kenya: Constraints and remedial options. KARI Technical Note No. 11. Nairobi, Kenya; 2002.
38. Kisinyo PO, Othieno CO, Okalebo JR, Kipsat MJ, Serem AK, Obiero DO. Effects of lime and phosphorus application on early growth of Leucaena in acid soils. African Crop Science Conference Proceedings. 2005;*7*:1233-1236.
39. Caires EF, Churka S, Garbuio FJ, Ferrari RA, Morgano MA. Soybean yield and quality as function of lime and gypsum application. Scientia Agricola. Piracicaba, Brazil. 2006;63(4):370-379.
40. Chimdi Achalu, Gebrekidan Heluf, Kibret Kibebew, Tadesse Abi. Effects of liming on acidity related chemical properties of soils of different land use systems in Western Oromia, Ethiopia. World Journal of Agricultural Science. 2012;8(6):560-567.
41. Rahman MA, Meisner CA, Duxbury JM, Lauren J, Hossain ABS. Yield response and change in soil nutrient availability by application of lime, fertilizer and micronutrients in an acidic soil in a rice-wheat cropping system. Paper Presented in 17th WCSS, 14th - 21st August 2002. Thailand; 2002.
42. Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret, Abi Tadesse. Response of barley to liming of acid soils collected from different land use systems of Western Oromia, Ethiopia. Journal of Biodiversity and Environmental Sciences. 2012;2(7):1-13.
43. Suge JK, Omunyin ME, Omami EN. Effect of organic and inorganic sources of fertilizer on growth, yield and fruit quality of eggplant (*Solanum melongena* L). Archives of Applied Science Research. 2011;3(6):470-479.
44. Onwonga RN, Lelei JJ, Freyer B, Friedel JK, Mwonga SM, Wandhawa P. Low cost technologies for enhance N and P availability and maize (*Zea mays* L.) performance on acid soils. World Journal of Agricultural Sciences. 2008;*4*(5):862-873.
45. Maerere AP, Kimbi GG, Nonga DLM. Comparative effectiveness of animal manures on soil chemical properties, yield and root growth of amaranthus (*Amaranthus cruentus* L.). African Journal

of Science and Technology. 2001;1(4):14-21.

46. Amba AA, Agbo EB, Voncir N, Oyawoye, MO. Effect of phosphorus fertilizer on some soil chemical properties and nitrogen fixation of legumes at Bauchi. Continental Journal of Agricultural Science. 2011;5(1):39-44.
47. Adeleye EO, Ayeni LS, Ojeniyi SO. Effect of poultry manure on soil physico-chemical properties, leaf nutrient contents and yield of Yam (*Dioscorea rotundata*) on Alfisol in Southwestern Nigeria. Journal of American Science. 2010:6(10):871-878.
48. Verde BS, Danga B, Oginga M, Jayne N. Effects of manure, lime and mineral P fertilizer on soybean yields and soil fertility in a humic nitisol in the Central Highlands of Kenya. International Journal of Agricultural Science Research. 2013;2(9): 283-291.
49. Tagoe ST, Horiuchi T, Matsui T. Preliminary evaluation of the effects of carbonized chicken manure, refuse derived fuel and K fertilizer application on the growth, nodulation, yield, N and P contents of soybean and cowpea in the greenhouse. African Journal of Agricultural Research. 2008;3(11):759-774.
50. Otieno P, Muthomi W, Chemining'wa N, Nderitu J. Effects of rhizobia inoculation, farm yard manure and nitrogen fertilizer on growth, nodulation and yield of selected food grain legumes. African Crop Science Conference Proceedings. 2007;8:305-312.
51. Mukindia CB. Response of pigeon pea (*Cajanus cajan* (L) Millsp) to phosphate and nitrogen fertilizers and animal manure. M.Sc. Thesis, University of Nairobi; 1994.
52. Saad A, Tageldin M. Effect of phosphorous and farmyard manure on nodulation and growth attributes of common beans (*Phaseolus vulgaris* L.) 2009:5(4):458-464.
53. Bekere W, Kebede T, Dawud J. Growth and nodulation of soybean (*Glycine max* L.) to lime, *Bradyrhizobium japonicum* and nitrogen fertilizer in acid soil at Melko, South West Ethiopia. International Journal of Soil Science. 2013;8(1):25-31.
54. Ganeshamurthy AN, Sammi-Reddy K. Effect of integrated used of farmyard Manure and Sulphur in a soybean and wheat cropping systems on nodulation dry matter production and chlorophyll content of soybean on swell-shrink soil in central India. Journal of Agronomy and Crop Science. 2000;185:91-97.
55. Better C. Effects of phosphorus on nitrogen fixation. 1999;83:1.
56. Danso SKA. Biological nitrogen fixation in tropical agro-ecosystems: Twenty years of biological nitrogen fixation research in Africa. *In:* K. Mulongoy, M. Gueye and D. S. C. Spencer *(ed.*), Biological nitrogen fixation and sustainability of tropical agriculture, Chichester, UK: John Wiley and Sons Ltd. 1992;3-13.
57. Brockwell J, Pilka A, Holliday RA. Soil pH is a major determinant of the numbers of naturally-occurring rhizobium meliloti in Non-cultivated soils of New South Wales. Journal or Experimental Biology and Agricultural Science. 1991;31:211-219.
58. Umoetok SBA, Uko AE, Archibong BE, Ukeh DA. Udo IA. Effect of application of inorganic fertilizer and poultry manure on insect pests and yield of soybean (*Glycine max* L.) in the rain forest zone of Nigeria. Journal of Food, Agriculture and Environment. 2007;5(2):149-152.
59. Javaid A, Mahmood N. Growth, nodulation and yield response of soybean to bio fertilizers and organic manures. Pakistan Journal of Botany. 2010;42(2):863-871.
60. Chiezey UF, Odunze AC. Soybean response to application of poultry manure and phosphorus fertilizer in the Sub-humid Savanna of Nigeria. Journal of Ecology and Natural Environment. 2009;1(2):025-031.
61. Abbas G, Aslam M, Malik AU, Ishaque M, Hussain F. Effects of organic and inorganic fertilizers on mungbean (*Vigna radiata* L.) yield under arid climate. International Research Journal of Plant Science. 2011;*2*(4):094-098.
62. Giller KE. Nitrogen fixation in tropical cropping systems. CAB International, Walliford, UK; 2001.
63. Zingore S. Giller KE. Optimizing phosphorous and manure application in maize soybean rotation in Zimbabwe. Better Crops. 2012;96(2):23-25.
64. Mandal G, Hati M, Misra K. Biomass yield and energy analysis of soybean production in relation to fertilizer-NPK and organic manure. Biomass and Bioenergy. 2009;33:1670-1679.
65. Kobraee S, Shamsi K, Rasekhi B. Effect of micronutrients application on yield and yield components of soybean. Annals of Biological Research. 2011;2(2):476-482.
66. Mohammad K, Khosro M, Mohsen J. Grain yield and yield components of soybean

affected by integrated fertilization methods. International Journal of Agriculture and Forestry. 2014;4(3):1-3.
67. Fuentes JP, Bezdicek DF, Flur M, Albrechy S, Smith JL. Microbial activity affected by lime in a long-term no-till soil. Soil and Tillage Research. 2006;88:123-131.
68. Caires EF, Churka S, Garbuio FJ, Ferrari RA, Morgano MA. Soybean yield and quality as function of lime and gypsum application. Scientia Agricola. Piracicaba, Brazil. 2006;63(4):370-379.
69. Nekesa K, Okalebo J, Othieno N, Thuita T, Kipsat GD, Bationo K, Sanginga TG, Kimettu HP, Vanlauwe D. The potential of minjingu phosphate rock from Tanzania as a liming material: effect on maize and bean intercrop on acid soils of western Kenya. African Crop Science Conference Proceedings. 2005;7:1121-1128.
70. Anetor MO, Akinrinde EA. Response of soybean [glycine max (l.) Merrill] to lime and phosphorus fertilizer treatments on an acidic alfisol of Nigeria. Pakistan Journal of Nutrition. 2006;5(3):286-293.
71. Andric L, Rastija M, Teklic T, Kovacevic V. Response of maize and soybean to liming. Turkish Journal of Agriculture and Forestry. 2012;36:415- 420.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/44605