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E J E D

EFFECT OF VERMICOMPOST APPLICATION ON POTATO TUBER YIELD AT BULE DISTRICT, HIGHLAND OF GEDEO ZONE, SOUTHERN ETHIOPIA

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Abstract

Ethiopia is known for its high potato production potential though the average productivity compared to other countries is low. Various factors were contributed for its low productivity including soil acidity and unbalanced soil nutrient concentrations which are serious challenges to small scale farmers for crop production in the highlands of Ethiopia. Therefore, the objective of this study was to investigate the effect of vermicompost on potato tuber yield at Bule District, Highland of Gedio Zone, Southern Ethiopia. The treatment consisted of four treatment levels of vermicompost (0 $t.ha^{-1}$, 2.5 $t.ha^{-1}$, 5 $t.ha^{-1}$, and 7.5 $t.ha^{-1}$) laid out in a randomized complete block design with three replications. The following data was collected and discussed. The highest and significant days of maturity (121.67 days), leaf number (78.33), plant height (78.78cm), tuber number (11.12), total tuber yield (33.23 $t.ha^{-1}$, and tuber dry matter percentage (30.26%) were recorded at maximum level application of vermicompost (7.5 $t.ha^{-1}$) in this study. Therefore, 7.5 $t.ha^{-1}$ of vermicompost should be considered for potato production at the study area as it was effective on potato yield particularly highest tuber dry matter percentage.

Keywords: Lime, Potato tuber, Vermicompost, Yield

1 Introduction

Potato (*Solanum tuberosum* L.) is one of the most productive food crops in the world. In volume of world crop production, it ranks fourth following wheat, maize, and rice (Adane *et al*., 2010). The production of potato is expanding at a faster rate than other food crops in developing countries, including Ethiopia. Currently, potato is one of the most common and important horticultural crops in the highlands of Ethiopia both as food and cash crop (Gildemacher *et al*., 2009). The crop has also proved that it has great potential for adaptation to the diverse growing conditions of the tropics where the majority of the developing countries are located. It is an important crop in Ethiopia and plays a major role in national food and nutritional security, poverty alleviation, and income generation. With increasing urbanization in Ethiopia, the use of potato is not only as fresh tubers but also as processed products such as chips, French fries and crisps is rising (Abebe *et al*., 2012). In Ethiopia, the area coverage is reached 66,923.33 *ha* and harvesting 921,403.185 tons with involving of 1,197,018 householders (CSA, 2016/17). But national average yield of potato is 13.7 $t.h^{-1}$ (CSA, 2016/17), which is below the world average production 17.7 $t.ha^{-1}$ (FAO, 2010). Among African countries, Ethiopia has possibly the greatest potential for potato production but average productivity is low compare to other country. Some of the challenge includes: narrow genetic basis of potato varieties, inappropriate agronomic practices, soil nutrient depletion and soil acidity, moisture stresses, diseases, insect pests, poor seed quality, shortage of seed tubers of improved potato varieties, and susceptibility to diseases. Among others soil acidity is the major constraints of potato production in the country (Alemayehu *et al.*, 2015).

Acid soils limit crop production on 30 to 40% of the world's cultivated land and up to 70% of the world's potentially arable land (Haug, 1983). It is becoming a serious challenge to small scale farmers for crop production in the highlands of Ethiopia (Kiflu *et al.*, 2016). Currently, it is estimated that about 40% of the arable lands of Ethiopia are affected by soil acidity (Taye, 2007).

Vermicompost (VC) was reported to increase the p*H* of acid soils and improve soil fertility by supplying essential plant nutrients (Materechera, 2012). Similarly, Wael *et al.* (2011) reported that VC can be used to increase the p*H* in acidic soils and reduce *Al* and *Mn* toxicity due to its alkalinity properties. It has been reported that application of VC increases the supply of easily assimilated as well as micronutrients to plants besides mobilizing unavailable nutrients into available form (Zeinab *et al.*, 2014). Vermicompost contains high levels of total and available *N*, *P*, *K* (Tesfaye, 2017), stimulates microbial activities and growth regulators (Chaoui *et al.*, 2003). Generally, VC can improve seed germination, growth and yield of crops (Nagavallemma *et al.*, 2004). There is an increasing interest in the potential use of VC as soil amendment, where the addition of VC improves the soil physical and chemical properties (Angin *et al.*, 2013; Lordan *et al.*, 2013). Continuous and adequate use of VC with proper management can increase soil organic carbon (O*C*), soil water retention and permeability (Mahdavi *et al.*, 2007) and increase yield of potato. Abdullah (2008) also figured out increased levels of vermicompost reclaim the soil and increase the yield of potato in South America. With continuing consumer concerns related to food quality and safety, as well as the chemicals used in food production, the demand for organic products is gradually increasing all over the world (Gaurilcikiene *et al.*, 2008). For organic potato producers one of the main challenges is nutrient management.

Soil acidity limits or reduces crop production primarily by impairing root growth as a result of the toxicity to roots of high concentrations of soluble aluminum (Tisdale *et al.*, 1985). Moreover, low p*H* enhances the fixation of *P* through sorption by forming compounds with *Al* and irons. Hence, it is a serious threat to crop production in most highlands and a major crop production constraint in the small-scale farmers of the country. Based on the problem that soil acidity causes on a larger areas in Ethiopia, it needs due attention to be addressed by different coping mechanisms (Mesfin, 2007).

In Ethiopia there is limited research finding on effect of vermicompost on growth and yield of potato. Therefore, it is time to apply this golden in the garbage (vermicompost) to solve soil problems and increase yield of potato at study site as well as elsewhere similar environment in Ethiopia. Therefore, the objective of this research was to investigate the effect of vermicompost on potato tuber yield of potato at Gubato village of Bule District, Highland of Gedio Zone, Southern Ethiopia.

2 Materials and Methods

2.1 Description of the Study Area

The experiment was conducted under rain fed condition during the rainy season of 2019 cropping season at Gedeo zone, Bule District. Bule District is among the six Districts in the Gedeo Zone of SNNPR. It is located at 117 *km* from the region's capital and 27 *km* from the Zone's capital Dilla. Bule District is bordered on the south, East and west by Oromia region and on the north by Sidama zone. The District has a total area of 27,300 *ha*, with its altitude ranging between 2,001–3,000 meters above sea level (masl). It comprises 32 villages (three town administration village), of which 70% have a dega agro-ecology, while the remaining 30% can be characterized as woyina dega (mid altitude) agro-ecology. The area lies between 6°04′16″ and 6°23′50″ N latitude and from 38°16′20″ to 38°26′11″ E longitude. Mean annual rainfall of the wereda is 1600mm, with minimum and maximum temperature of 12.6 °C - 20 °C. (Bule woreda BOA, 2017). The dominant soil type of the study area is Nitisols (Tarekegn, 2008).The land use system of the study area is a mixture of crop farming and agroforestry system.

2.2 Soil Sampling and Analysis

Soil sampling was done before sowing. The sampling was done on farmer's lands of Gubato village of Bule district for evaluation of some physicochemical properties in 2019. The villages were selected on the basis of crop produced there. Before investigation of this research, a soil sample was taken and analyzed. Soil samples were collected by auger from 0 to 30 cm depth in zigzag pattern and a composite sample were done. All the soil analysis was undertaken according to standard laboratory procedures.

Soil particle size distribution was analyzed by the Bouyoucus hydrometer method (Bouyoucos, 1951). Soil bulk density (ρ_b) was measured from undisturbed soil samples collected using a core sampler as per the procedure described by Jamison *et al.* (1950), while particle density (ρ_s) was measured using pycnometer (Barauah and Barthakulh, 1997). Total porosity (ϕ) was calculated from the values of ρ_b and ρ_s (Brady and Weil, 1996) as:

$$\phi = (1 - \frac{\rho_b}{\rho_s}) * 100$$

Soil pH was measured potentiometrically in 1:2.5 soils: H_2O solution using a combined glass electrode pH meter (Chopra and Kanwar, 1976).

Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution as described by Rowell (1994). From the same extract, exchangeable Al in the soil samples was determined by application of 1 M NaF. Acid saturation (AS) was calculated from exchangeable acidity and CEC Rowell (1994).

$$\text{AS} = \frac{Exchangeable\ acidity\ (cmol\ c\ kg^{-1})}{CEC\ (cmol\ c\ kg^{-1})} * 100$$

Where: AS = Acid saturation, CEC = Cation exchange capacity

Organic carbon (OC) content of the soil was determined by the wet combustion procedure of Walkley and Black (1934) and OM% was obtained by multiplying OC% by 1.724. The total nitrogen (N) content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was extracted by the Bray II method (Bray and Kurtz, 1945). Potassium (K) was determined by saturating the soil samples with 1M NH_4OAc solution at pH 7.0 and was measured by flame photometer from the same extract. The cation exchange capacity (CEC) of the soil was determined from the NH_4^+ saturated samples that was subsequently replaced by K from a percolated KCl solution (Chapman, 1965).

2.3 Vermicompost Analysis

Vermicompost was brought from Hawassa Research Center. It was prepared from raw materials such as cow dung, sheep and goat feces, dried chopped maize residues and chopped grasses by using red worm (*Eisenia fetida*). Selected parameters of VC was determined using dried samples which was ground to pass through a 2 mm sieve as described by Pisa and Wuta (2013).

pH was determined from a suspension of 1:10 VC: H_2O as described by Ndegwa and Thompson (2001). The total OC was estimated by wet combustion procedure of Walkey and Black (1934). Total OM% was obtained by multiplying total OC% by 1.724 (Emeterio and Victor, 1992). The total N content of the VC was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Total Ca, Mg, K, and Na was extracted by wet digestion using concentrated sulphuric acid (H_2SO_4), selenium (Se) powder, lithium sulphate (Li_2SO_4), and hydrogen peroxide (H_2O_2) mixture (Okalebo *et al.*, 2002). Total Ca and Mg were determined from the wet digested samples by AAS while K and Na were estimated by flame photometer. Total P was extracted using concentrated H_2SO_4, Se powder, salicylic acid ($C_7H_6O_3$), and H_2O_2 mixture (Okalebo *et al.*, 2002).

2.4 Treatments, Experimental Design, and Procedures

This article was emanated from the main effect of vermicompost of the following treatments of the research implemented. The research was carried out on farmer's land of Gubato village, Bule District.

Land preparation was carried out well in advance before planting the potato tuber. 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 was leveled manually. The experiment was laid out in factorial randomized complete block design with three replications; the plot size was 4.25m by 2.6m (11.05m^2).

Four rates of vermicompost (0, 2.5, 5, and 7.5) were used as treatment. Potato variety of Gudene was used with intra and inters row spacing of 35cm and 70cm, respectively. The distance between adjust plots and blocks were 0.6m and 1m respectively.

Each plot had 6 rows and each row had 7 potato plants. There were a total of 42 potatoes per plot. The potato was purchased from the farmers produce Gudane variety. One month prior to planting, vermicompost was applied in the plots and thoroughly incorporated into the soil. All agronomic practices such as weed control, earthing up and disease and insect inspection were done regularly.

2.5 Data Collections and Measurements

The data collected were crop phenology, growth parameters, tuber yield and yield components of potato.

a. Crop phenology

Days to maturity: days to maturity was recorded when 75% of the plants in plots are ready for harvest as indicated by senescence of leaves and haulms. The days were counted from date of planting to maturity of the crop.

b. Growth parameters

Plant height (cm): refers to the height from the base to the apex of the plant. It was measured using a measuring tape at 50% flowering from the main stem originating directly from mother tubers to the apex of the plant by taking five sample plants from each plot. Mean value of height measurements was then taken.

Leaf number: It was determined by counting from five plants at 50% flowering. Mean number of leaves was then used.

c. The tuber yield and yield component of potato

Tuber number per hill: refers to the number of tubers per plant and it was taken from five plants during harvest in each plot. Mean number of tubers was then taken for the analysis.

Total tuber yield: This was recorded from the weight (in kg) of total tuber per plot. The data were taken from plants in the net plot area at harvest.

Dry matter Content (%): Five fresh tubers were randomly selected from each plot and weighed. The tubers was sliced and dried in oven at 70 $^\circ C$ until a constant weight was obtained. The dry matter percent was calculated using the following formula (Tekalign, 2011)

$$\text{Dry matter content (\%)} = \frac{Dried\ tuber\ yield}{Fresh\ tuber\ yield} * 100$$

2.6 Statistical Analysis

Data on soil physicochemical properties, growth and yield components of potato tuber were subjected to analysis of variance (ANOVA) (SAS, 2009). Significant differences between treatment means were separated using the Least Significance Difference test at 5% level of significance for the parameters showed significance difference between treatments.

3 Results and Discussions

3.1 Soil Physico-chemical Characteristics of the Study Sites

The result of textural class determination of composite soil sample taken before treatment with vermicompost showed that the study site was clay soil as presented in Table 1. The bulk density of the soil was high which could limit plant growth due to restriction of root penetration in clay soil (Jones, 2003). Due to the high bulk density value, the total porosity of the soil was relatively high. The percent of O*C* and T*N* were 1.47 and 0.50, respectively. As per rating of Tekalign (1991), soil samples percent of O*C* of the study area qualified in the range of 0.5-1.5% which is low organic carbon. Hence, the present study revealed low soil organic carbon. In comparing with the rating of Murphy (1968), the percent of T*N* qualified as medium in soil total nitrogen. Long term cultivation without organic fertilizers leads to a decrease in soil O*C* and total *N* contents (Alexandra, *et al*. 2013).

Table 1 Soil physical and chemical characteristics of experimental site before sowing potato tuber

Soil Properties	Value	Status	Remarks
Physical property			
Sand (%)	25	Low	
Clay (%)	45	High	
Silt (%)	30	Moderate	
Textural class	Clay		
Bulk density ($g\,cm^{-3}$)	1.36		
Particle density ($g\,cm^{-3}$)	2.35		
Total Porosity	42.13		
Chemical property			
Soil pH H_2O	4.80	Strongly acidic	Marx *et al*., 1999
OC (%)	1.47	Low	Tekalign, 1991
TN (%)	0.50	Medium	Murphy, 1968
Av. K $cmol$ (+) kg^{-1}	1.04	Low	Marx *et al*., 1999
C:N	2.49		
Av. P ($mg.\,kg^{-1}$)	13.75	Low	Marx *et al*., 1999
CEC $cmol$ (+) kg^{-1}	14.80		
Ex. Acidity (meq $100g^{-1}$)	5.72		
Ex. H^+ (meq $100g^{-1}$)	1.90		
Ex. Al^{3+} (meq $100g^{-1}$)	3.01	High	

Where: OC, organic carbon; TN, total Nitrogen; Av. K, Available Potassium; C, Carbon; N, Nitrogen; Av. P, Available Phosphorus; CEC, Cation Exchange Capacity; Ex. H^+, exchangeable Hydrogen ion; Ex. Al^{3+}, exchangeable Aluminium ion.

The measured soil pH of the study site was 4.8. This indicated that the soils are strongly acidic. The available phosphorus content was 13.75 $mg\,kg^{-1}$. Based on the rating of so available Phosphorus suggested by Ethio SIS (2014), the study site qualified (< 15 $mg\,kg^{-1}$) as very low. The low content of available P is common characteristic in most of the cultivated and acidic soils of Ethiopia (Tekalign, 1991). The available K of the study site was 1.04 $cmol$ (+) kg^{-1}. As per rating suggested by Marx *et al*., (1999), the study site qualified as low in available K. The CEC, Ex. H^+, Ex. Al_3^+ and Ex. acidity of soil of the study site was 14.8 $cmol$ (+) kg^{-1}, 5.27, 1.9 and 3.46 meq 100 g^{-1}, respectively. In general, from the results of soil analysis before treatment of lime and vermicompost clearly indicated that the soil of the study site had soil fertility problems and soil acidity that limited successful growth and production of tubers or crops. This calls for development of appropriate management practices that enhance tuber or crop production.

3.2 Vermicompost Analysis

The analyzed chemical character of VC was pH: 7.26, OC: 13.69%, OM: 23.60, total N: 1.40%, available P: 4.78 $mg\,Kg^{-1}$, and exchangeable K: 9.12 $cmol$ (+) kg^{-1} (Table 2). This indicated as VC had high nutrient that can increase soil fertility and create suitable environment for beneficial soil micro-organisms that suit plant growth. These VC also increases soil fertility without polluting the soil, as well as the quantity and quality of crops. Similarly, Singh *et al.*, 2011 indicated as VC is used as a soil activator, soil conditioner, and soil fertility booster with all required plant nutrient, Vitamins, enzymes, growth hormones and beneficial micro-organisms.

Table 2 Chemical properties of Vermicompost (VC)

	Chemical Properties of Vermicompost						
	pH H_2O	OC (%)	OM (%)	TN (%)	Exc. K $cmol$ (+) kg^{-1}	C:N ratio	Av. P ($mg.kg^{-1}$)
Value	7.26	13.69	23.60	1.40	9.12	9.78:1	4.78

Where: OC, organic carbon; OM, organic matter; TN, total nitrogen; Exc. K, exchangeable potassium; C, Carbon; N, Nitrogen; Av. P, available phosphorus

3.3 Effect of Vermicompost on Phenology and Growth of Potato

Analysis of variance showed that vermicompost treatments had significant effect on the 75% day's to maturity. As indicated in table 3, minimum days (110.44) and maximum days (120.67) to maturity was recorded. The minimum days to maturity were due to lack of enough nutrient supply that leads a crop to senescence. Prolonged maturity in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in vermicompost contribution through enhanced leaf growth and photosynthetic activities, thereby increasing in synthesis of photoassimilate, which was further utilized in building up of new cells, and prolonged maturity of potato. This is because of application of vermicompost makes the plant to use more environmental factors during the growth period and thus obtain optimal conditions for the photosynthesis process (Jayanthi *et al.* 2002).

Significant variation was obtained among different vermicompost level on leaf number of potato. The lowest leaf number (63.48) was recorded with nil applications of vermicompost, while the highest leaf number (78.33) at the maximum levels of vermicompost (7.5 $t.ha^{-1}$) application was recorded. In agreement with this, Mohamed *et al.*, (2017) reported that increased levels of vermicompost increased the leaf number of potato. This is due to the ability of humic substances (HS) found in mineral-organic materials stimulates growth of numerous plants part by encouraged nutrient and water uptake (Theunissen *et al.*, 2010; Chen *et al.*, 2004; Nardi *et al.*, 2002). Because of vermicompost contains essential nutrients in plant-available forms, enzymes, vitamins and plant growth hormones (Borah *et al.*, 2007), leaf number is increased.

Table 3 Effect of vermicompost on 75% day's to maturity, leaf number, and plant height of potato

Factors	Treatment	75% day's to maturity	Leaf number	Plant height (cm)
Vermicompost	0	110.44^d	63.48^d	49.78^d
($t.ha^{-1}$)	2.5	114.00^c	70.33^c	62.40^c
	5	117.78^b	74.71^b	70.62^b
	7.5	121.67^a	78.33^a	78.78^a
LSD (0.05)		1.09	2.93	2.21
CV		0.96	4.18	3.46

3.4 Effect of Vermicompost on Tuber Yield and Yield Components

The number of potato tuber per hill was significantly increased due to the application of vermicompost (Table 4). Increasing vermicompost is improving the physical conditions and vital processes of the soil which makes the nutrients such as nitrogen, phosphorus and potassium, and plant growth promoters and vitamins (Vitamin B12) more accessible to the plants, which will increase the number of tubers and yield of the plant (Monaghesh *et al*,. 2015). Ajudan *et al*. (2005) showed that with increasing of organic fertilizer up to 20 tons per hectare, potato yield increased. This indicates the importance of using organic fertilizers in increasing potato tuber yield and also the sensitivity of this plant to improvements of the physical properties of the soil.

A significant difference was found on potato tuber yield. This implies how total tuber yield was affected by vermicompost (Table 4). The maximum total tuber yield (33.23 $t.ha^{-1}$) was recorded with application of maximum level of vermicompost (7.5 $t.ha^{-1}$), while the minimum total tuber yield (27.31 $t.ha^{-1}$) was recorded without application of vermicompost. In line with this, Joshi *et al*., (2015) also figured out the increased tuber yield of potato due to increased rate of vermicompost application that have high porosity, aeration drainage and water-holding capacity which had positive effects on tuber development and total yield. Similarly, Osvalde *et al*. (2016) reported that using peat and vermicompost in organic potato production system enhanced P uptake that contribute for the tuber yield of potato. In acidic soils with high levels of exchangeable Al, organic matter (OM) in vermicomposts plays a significant role in the reduction of P adsorption site of soil and increased P availability due to cumulative effects of several mechanisms (Opala *et al*., 2010). These include release of organic P from decaying residues, blockage of P adsorption sites by organic molecules released from the residues, a rise in soil pH and complexation of soluble Al and Fe by organic molecules (Iyamuremye and Dick, 1996). These contribute for the increment of potato yield and yield components.

Dry matter percentage revealed significant differences between the various vermicompost treatments (Table 4). The lowest tuber dry percentage (28.03) was recorded in the control treatment (0 $t.ha^{-1}$). The mean dry matter percentage ranged between 28.03 to 30.26%.The highest tuber dry percentage (30.26%) was obtained with the application of 7.5 $t.ha^{-1}$ which was followed by the application of 5 $t.ha^{-1}$, and 2.5 $t.ha^{-1}$. The vermicompost may have essential nutrients that increase tuber dry matter. This revealed that quality produce of potato was recorded. Similarly, Mohamed *et al*. (2017) reported that increased levels of vermicompost increase dry matter content of potato tuber. Stimulation of root growth (initiation and proliferation of root hair), increased root biomass, enhanced plant growth and development have been reported with the application of vermicompost, because of the presence of humic acids (Suh *et al*., 2014).

Table 4 Effect of vermicompost on tuber number, tuber yield, and tuber dry matter percentage of potato

Factor	Treatment (level of vermicompost)	Tuber number per hill (No.)	Total tuber yield ($t.ha^{-1}$)	Dry matter (%)
Vermicompost	0	9.54^{d}	27.31^{c}	28.03^{d}
($t.ha^{-1}$)	2.5	10.01^{c}	29.76^{b}	28.70^{c}
	5	10.57^{b}	32.04^{a}	29.50^{b}
	7.5	11.12^{a}	33.23^{a}	30.26^{a}
LSD (0.05)		0.25		0.23
CV		2.49	5.09	0.81

4 Conclusion

At highland of Ethiopia, potato productivity is low due to unbalanced nutrient and soil acidity. The objective of this research was to investigate the effect of vermicompost on potato tuber yield at Gubato village, Bule Wereda, Gedio Zone, Southern Highland of Ethiopia. The result of soil sample taken before plough showed as the study area had the problem of low soil fertility and strong acidity. The treatments used for this study were four rates of vermicompost (0, 2.5, 5, and 7.5 $t.ha^{-1}$) that laid out in randomized complete block design with three replications. Increased levels of vermicompost had significantly a stimulating effect on days to maturity and, growth, tuber yield and dry matter percentage of potato. The result of analysis indicated that the highest and significant days of maturity (121.67 days), leaf number (78.33), plant height (78.78cm), tuber number (11.12), total tuber yield (33.23 $t.ha^{-1}$, and tuber dry matter percentage (30.26%) were recorded at maximum level application of vermicompost (7.5 $t.ha^{-1}$) in this research. Though the result of potato tuber yield at application of 5tha-1 was not significantly different from the result obtained due to 7.5 $t.ha^{-1}$ of vermicompost application, the tuber dry matter percentage was significantly different. From this study, it was concluded that vermicompost is good organic fertilizer to obtain good yield of potato tuber. Therefore, 7.5 $t.ha^{-1}$ of vermicompost should be considered for potato production at the study area as it was effective on potato tuber dry matter percentage and soil amendment.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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