Original Research Article||

Yield and growth response of hot pepper (*Capsicum annum*) and lettuce (*Lactuca sativa* L.) to bioslurry fertilizer application at Dilla Zuria, Gedio Zone, Ethiopia

Fikru Tamiru Kenea[1]*, Mitiku Muanenda Adula[1] and Chemir Chewaka Asume[1]

[1]*Department of Horticulture, College of Agriculture and Natural Resources, Dilla University, Ethiopia*

Abstract

Agricultural production of most vegetables, including pepper and lettuce, often uses chemical fertilizers and pesticides which pollute the environment. Bioslurry, which is byproduct of biogas production process, is a good organic fertilizer for crops and improves the soil fertility, soil structure and yields of crops. The main objective of this study was to evaluate the effect of bioslurry for growth and yield of pepper and lettuce under Dilla zuria condition. Four levels of bioslurry (0, 10, 15 and 20 t ha^{-1}) were used for the experiment. The experiments of both vegetable were laid out separately and implemented in randomized complete block design with three replications. The analysis of variance indicated significant differences ($p<0.05$), where maximum leaf number (357.47), leaf length (8.34 cm), leaf width (4.13 cm), plant height (46.95 cm), pod number (57.27), pod length (5.67 cm) and pod yield (3.75 t ha^{-1} (for pepper), and maximum lettuce leaf number (8.35), leaf length (9.77 cm), leaf width (10.33 cm) plant height (21.5 cm) and leaf yield per plant (87.16 g) corresponded to the application of 20 t ha^{-1} of bioslurry. Based on this result, for the farmers of study area, application of 20 t ha^{-1} bioslurry is recommended tentatively for pepper pod (fruit) and lettuce leaf yield. However, since the experiment was done only once and at one location, similar experiments should be carried out using additional higher rates of bioslurry over several seasons and locations to make a conclusive recommendation.

Key words: Bioslurry, lettuce, leaf, pepper, pod

Original submission: August 16, 2022; **Revised submission**: September 27, 2022; **Published online**: October 23, 2022
***Corresponding author's address:** Fikru Tamiru Kenea, Email: *fikr1.kenea@gmail.com*
Authors: Mitiku Muanenda Adula: *mmaunenda@gmail.com*; Chemir Chewaka Asume: *chemirchewaka44@gmail.com*;

INTRODUCTION

Peppers (*Capsicum annum* L.) belongs to the family *Solanaceae* and warm season crops grown mainly for their fruits (pods) and contain three to six times as much vitamin C as orange (Bosland and Votava, 2007; Nadeem et al., 2011). Like other vegetable crops, green pepper contributes micronutrients that are lacking in many other staple foods (Grubben, 1997). It is particularly rich in vitamin C (Bosland and Votava, 2007).

Lettuce (*Lactuca sativa* L.) is the most widely grown green leafy salad vegetable (Maboko, 2007) and it is important staple in terms of consumption rate and economic value throughout the world (Coelho et al., 2005). It is an important leafy vegetable crop that is considered as an excellent source of dietary minerals and vitamins since it is consumed as fresh green salad (Abu-Rayyan et al., 2004). In Ethiopia, lettuce is one of the significant cash and food security vegetable crops (Geberamariam and Mohammed, 1985). Area covered by lettuce and chicory, in the 2016 cropping season was 117 ha, with average yield of 649.6 kg ha^{-1} (FAO, 2016), which is below the world average (Kroll, 1997), likely due to poor agronomic management practices like irrigation, fertilizer, spacing, weeding and disease control. Among many contributing factors low yields of lettuce is lack of proper knowledge on optimum amount of nitrogen and farm yard manure fertilization rate. Lettuce requires a soil that is high in organic matter and has adequate nutrient (Kroll, 1997; Solkaiman et al., 2019).

Vegetable cultivation is becoming more costly due to the increasing use of purchased inputs such as pesticides and fertilizers to sustain production levels (Salim, 1999). At the same time, substances of these chemicals remain in fruits and vegetables, which make most products to be tainted and to affect the human's health. Meanwhile, long term of chemical fertilizers application resulted in soil degradation, soil pH fluctuations and losing soil microbes that would have improved the soil fertility (Kim, 2003).

Biogas technology is made from waste that undergoes anaerobic digestion to produce methane gas for cooking and lighting. The residue of the biogas production process leaves organic, nutrient-rich bioslurry for use as a fertilizer (Fokhrul, 2009; Yasar et al., 2017). Bioslurry is an excellent fertilizer, rich in major nutrients (nitrogen, phosphorous and potassium) and organic matter (humus) that enhances soil fertility and improve yield of different crops and vegetables. Due to the decomposition and breakdown of parts of its organic content, digested bioslurry provides readily available nutrients that easily enter into the soil solution, thus becoming immediately available to plants (Bonten *et al*., 2014). Bioslurry is a good source of plant nutrients and can improve soil properties (Garg *et al.*, 2005). It is therefore suggested that bioslurry is applied at a rate of 10 to 20 t ha^{-1} to have a significant increase in yields of most crops (Nanyanzi et al., 2018). Bioslurry is environment-friendly organic fertilizer with no toxic or harmful effects and can easily reduce the use of chemical fertilizers up to 15-25% (Kumar et al., 2015). However, in Ethiopia, little attention has been given by the biogas farmers having biogas digesters and experts to use and recommend digested sludge as organic fertilizer (Fokhrul, 2009; Sime, 2020).

Dilla Zuria District of Gedeo Zone, Southern Ethiopia has suitable area for pepper and lettuce production though there is limited research on agronomic practice of these vegetables. According to Fekadu and Dendena (2006), the decline of hot pepper production and productivity is due to poor cultural practice (fertilizer application, planting density, among others), lack of better varieties, diseases and insect pests. The present situation indicates that in the study area there is no recommended cultural practice on the application of bioslurry to the soil for crop cultivation, particularly for the production of vegetables targeted in this research (both pepper and lettuce). As a result, research based cultural practices for the improvement of the crop for yield and quality in the existing agro-ecology is insufficient. Thus the objective of this study is to evaluate effect of bioslurry on the growth and yield of pepper and lettuce at Dilla Zuria District.

MATERIALS AND METHODS

Description of the Study Site

The experiment was conducted in Gedeo Zone, at Dilla University's farms of Botanical and Ecotourism Center. Geographically, the area is located in Southern Ethiopia at 6° 18' 11" to 6° 25' 32" N latitude and from 38° 17' 40" to 38° 23' 43" E longitude with an altitude of about 1476 m.a.s.l. The mean annual daily minimum and maximum air temperatures are 12.8°C and 28.4°C, respectively (Demelash 2010). The agro-ecology of the area is characterized as '*Weyna Dega'* (sub-humid) and '*Moist Kola*' (semi-arid). However, most part of the area is found in the semi-arid agro-ecological zone, with bi-modal rainfall characteristics. The topography is characterized by flat, gentle to steep slopes (Temesgen, 2010). The study was conducted during the main rainy season of 2021.

Experimental Design, Materials and Treatments

The study was carried out using pepper (*Capsicum annum* L.) Melka Oli variety and lettuce (*Lactuca sativa* L.) Great Lake variety as test crops. Each of the experiment was arranged in a Randomized Complete Block Designs (RCBD) with three replications. Separate design was implemented for pepper and lettuce trials. Bioslurry free trial (without application of bioslurry) for both vegetables was used as a control. Three levels of bioslurry (t ha^{-1}) were used as treatments for both crops. Treatments are T1 – Control (without application of biogas slurry), T2 - 10 t ha^{-1} biogas slurry, T3- 15 t ha^{-1} biogas slurry and T4- 20 t ha^{-1} biogas slurry.

Seedling Preparation

Seeds were sown on a seed bed size of 1 x 5 m in rows that were 15 cm wide on well prepared for both plants separately. The seed beds were covered with a dry grass until emergency of seedlings. Then, beds were covered by raised shade to protect the seedling from strong sun shine and heavy rainfall after its emergency. Since drought happened during rainy season, supplementary watering was done based on climatic conditions with a fine watering can, and weed was handpicked. The Seedlings were kept until ready for transplanting and hardened before transplanting to the field to make sure they withstand the field conditions. The hardening was done by reducing the frequency of watering and making the soil with low moisture status when the seedlings were ready for field planting.

Experimental Procedures

The experiment was implemented using a plot size of 1.8 x 4.2 m at 70 cm inter-rows and 30 cm intra-row spacing for pepper, and 2 x 2.25 m at 45 cm inter-rows and 25 cm intra-row spacing for lettuce. Recommended agronomic practices such as spacing, weeding, cultivation and disease management were carried out uniformly during the growing season for all plots.

Preparation of bioslurry

The bioslurry was prepared from the waste food products like bread, peel of banana, mango, papaya, avocado and faeces and cow dung which provided better biogas. After biogas was reached at 50 days, bioslurry residue was applied when the plant were at the stage of being able to best exploit the additional nutrient supply, which were 10 days for lettuce and 4 weeks for pepper after transplanting. To retain the fertilizing quality of bioslurry, it was stored in liquid form in a closed tank. Normally, the residue from anaerobic bio-digester (the bioslurry) was collected in liquid form using containers. The liquid bioslurry was pressed in order to remove excess water and to make solid bioslurry fertilizer for the trials. After the bioslurry was collected in the container, it was left for a day to allow the solid bioslurry to sink down and to remove the remaining supernatant. Then, the solid/residue was prepared for application in the experiments.

Soil and Bio-slurry Samples Analysis

The soil samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. Before planting, ten soil samples were taken from the top soil layer to a depth of 15 cm and composited in a bucket to represent the site. The soil was broken into small crumbs and thoroughly mixed. From this mixture, a composite sample weighing 1 kg was filled into a plastic bag. The chemical content of biogas slurry was determined using similar procedures used for the soil. Soil texture was determined by Bouyocous hydrometer method (Moodie et al., 1954).

The sample was broken into small crumbs and prepared for determining chemical properties. The sample was air-dried and sieved through a 2 mm sieve and then its pH was determined from the filtered suspension of 1:2.5 soil to water ratio using a glass electrode attached to a digital pH meter (Jones, 2003). Total N was determined using the Kjeldhal method (Jackson, 1958). Available P was analysed by extraction with 0.5 M sodium bicarbonate ($NaHCO_3$) according to the methods of Olsen *et al.* (1954). Exchangeable potassium was determined with a flame photometer after extraction with 0.5 ammonium-acetate (Hesse, 1971). Organic carbon of the soil samples was determined by the Walkley-Black method (1934).

Data Collection

Growth Parameters for Pepper and Lettuce

Plant Height (cm): height of 10 randomly selected and pre tagged plants from the net area in each plot was measured from the soil surface to the tip of the plant using ruler and their average was expressed as height per plants.

Number of Leaves*:* leaves of ten randomly selected and pre-tagged plants from the net area in each plot were counted and their average was expressed as number of leaves per plant.

Leaf Width*:* leaf width of ten randomly selected and pre-tagged plants from the net area in each plot was measured using ruler at the central leaf width and their average was expressed as leaf width per leaf of a plant.

Leaf Length*:* leaf length of ten randomly selected and pre-tagged plants from the net area in each plot was measured using ruler at the central leaf form the bottom of the leaf to the tip and their average was expressed as leaf length per leaf of a plant.

Yield Parameters for Pepper and Lettuce

Yield parameters used for pepper included:

Fruit (pod) Number*:* ten randomly selected and pre-tagged plants from the net area in each plot was counted and their average was expressed as pod number per pepper plant.

Fruit (pod) Length*:* ten randomly selected and pre-tagged plants from the net area in each plot was measured using ruler and their average was expressed as fruit (pod) length per fruit (pod).

Fruit (pod) Weight*:* fruits (pods) from the net area in each plot were collected, sun dried, weighed and converted to ton per hectare.

Leaf Yield of Lettuce*:* fresh leaves of lettuce from the net area in each plot were collected, weighed and their average was expressed as leaf yield per a plant.

Data Analysis

The collected data was first checked for meeting all the assumptions of analysis of variance (ANOVA) and subjected to analysis (by using SAS computer software version 9.2 (SAS Institute Inc., 2008). For those showed significant differences, mean separation was carried out using LSD (Least Significant Difference) test at 5% significance level.

RESULTS AND DISCUSSIONS

Analysis of Soil and Bio-slurry

Physico-chemical Properties of the Soil

The laboratory analysis result of selected properties of soils of the experimental area is shown in Table 1. Based on the soil textural triangle of the International Society of Soil Science System (Rowell, 1994), the textural class of the soil was sandy loam. The soil pH of the experimental site was 6.6 which is neutral on the basis of pH limit (6.6 to 7.3) as described by Bruce and Rayment (1982). The pH in the range of 5.5 to 7 is favorable for lettuce production.

Table 1. Physio-chemical properties of the soil of the experimental site at Dilla University Botanical Garden.

Soil properties									
Parameters	Sand (%)	Clay (%)	Silt (%)	Textural class	pH 1: 2.5 (H_2O)	OC (%)	Total N (%)	available P (ppm)	Available K [Cmol (+)/kg]
Value	68	16	16	Sandy loam	6.6	2.008	0.173	6.51	12.7

OC = organic carbon; ppm refers to parts per million

The OC% of experimental site was 2.008. According to Charman and Roper (2000), a soil with 1.80–3.00 OC% is high in organic matter and has good structural condition and high stability.

As per the total N rating (0.12 to 0.25%) described by Berhanu (1980), the total N content of the soil (0.173%) was medium. This value shows that both tested crops might respond to the applied bioslurry fertilizers (Table 1) as the application of the organic fertilizer could increase the soil fertility. The available P of the soil (6.51 ppm) was low according to the rating (0 to 7 mg P kg^{-1}) suggested by Clements and McGowen (1994). According to Charman and Roper (2000), when the available soil P is in low range as in the case of the soil of the current study site, it needs to be improved. Hence, external application of mineral and/or organic fertilizers containing phosphorous is important for enhancing the fertility of the soil and yield of the crops.

Results of Bio-slurry Analysis

Chemical analysis of bioslurry is (total N, available p, exchangeable K, OC and pH) were found to be 0.104 %, 184.92 ppm, 34.7 [Cmol(+) kg^{-1}], 1.20%, and 9.08, respectively (Table 2). Biogas slurry contains a considerable amount of nutrients besides appreciable quantities of organic matter than other organic fertilizers like farmyard manure and compost (Kumar et al. 2015). Total N (%), available P (%), and exchangeable K (%) of farmyard manure; compost; and bioslurry is 0.5-1, 0.5-0.8, 0.5-0.8; 0.5-1.5, 0.4-0.8, 0.5-1.9; and 1.4-1.8, 1.1-2, 0.89-1.2, respectively. In this study the raw material used for preparation of organic matter bore significant impact on its content. Thus, bioslurry increases soil fertility without polluting the environment and improves the quantity and quality of crops. Biogas slurry is a good source of plant nutrients to improve soil properties (Garg *et al.*, 2005).

Table 2. Chemical properties of bioslurry

Chemical properties	Total N (%)	Available P (ppm)	Exchangeable K [Cmol (+) kg^{-1}]	OC (%)	pH
Value	0.104	184.92	34.7	1.20	9.08

Where: OC is organic carbon, and ppm referrers to parts per million

Effects of Bio-slurry on Vegetative Growth of Pepper

Significant difference ($p<0.05$) were observed among the average leaf number of pepper plants of different treatments (Table 3). Among the treatments, 20 t ha^{-1} of bioslurry was found to be significantly superior (357.47) over the other treatment levels in terms of number of leaves. The control treatment (no application of bioslurry), the least leaf number (226.6) was recorded. The result obtained due to application of 20tha^{-1} is statistically par with the leaf number (327.93) recorded in the case of 15 t ha^{-1} bioslurry application. In agreement with the present result, Joyce et al. (2020) reported increment of leaf number of pepper due to amendment of soil with bioslurry. Khalil et al., (2005) also reported that organic fertilizers have high nitrogen that could be available to plants under stress condition and improves the vegetative growth.

Table 3. Effect of different levels of bioslurry application on average leaf number, leaf length, leaf width and plant height for pepper

Treatment	LNO	LL (cm)	LW (cm)	Plht (cm)
1	226.60^{c}	6.07^{c}	2.90^{c}	32.54^{b}
2	275.73^{b}	6.69b^{c}	3.3b^{c}	37.09^{b}
3	327.93^{a}	7.37^{ab}	3.77^{ab}	43.82^{a}
4	357.47^{a}	8.34^{a}	4.13^{a}	46.95^{a}
LSD (0.05)	38.83	0.98	0.55	6.26
CV	6.54	7.35	8.37	8.30

LNO = leaf number; LL = leaf length; LW = leaf width; Plht = plant height

The results revealed that the average length of leaves of pepper was significantly ($p<0.05$) increased due to amendment of bioslurry in the experiment (Table 3). Soil amended with 20 t ha^{-1} bioslurry gave the highest leaf length (8.34 cm), and was statistically similar to the result of 15 t ha^{-1} bioslurry application. Moreover, the leaf length of plants grown on treatments with 15 and 20 t ha^{-1} were significantly higher than that of the control and 10 t ha^{-1} bioslurry treatments. Similarly, Yamika et al. (2009) reported that applications of bioslurry increased the length of cucumber leaves.

The results obtained in the present work indicated that different rate of application of bioslurry significantly ($p<0.05$) enhanced the leaf width of pepper plants (Table 3). Application of 20 t ha^{-1} of bioslurry gave the highest width of leaves (4.13 cm), which was statistically similar to the results obtained from the 15 t ha^{-1} bioslurry application. The results from the two (15 and 20 t ha^{-1}) were significantly higher than those observed for the other two treatment levels (10 t ha^{-1}and and the control).

Significant difference ($p<0.05$) was observed in the average plant height of pepper grown on soil with different rates of bioslurry treatments (Table 3). The tallest plant (46.95 cm) was obtained from 20 t ha^{-1} bioslurry application. The least plant height (32.54 cm) on the other hand was corresponded to the control treatment. The increase in plant height could mainly be due to improvement in aeration, water holding and nutrient availability in the bioslurry treated soils which have enhancing effect on the vegetative growth of the plants. Similarly, Joyce et al. (2020) reported that plot treated with bioslurry significantly increased the height of pepper plant compared to the plot with no bioslurry. In agreement with the current results, Okoroigwe (2007) obtained higher plant height in soils treated with wastes from anaerobic digestions. Similar trends were reported in the literatures wehre application of organic fertilizers to soil increase cell division and elongation in plants (Vos and Frinking, 1997; El-Tohamy et al., 2006). Moreover, Gonzalez et al. (2001) reported that organic fertilizers supply most of the essential nutrients at growth stages and resulting in increased growth variables including plant height.

Effect of Bio-slurry on Yield and Yield Components for Pepper

Significant difference ($p<0.05$) effect was observed on average number of fruit (pod number) per plant (Table 4). Maximum number of average fruits per plant (57.27) was produced by the pepper plants grown on the soil treated with 20 t ha^{-1} bioslurry, which was statistically similar with number of fruits per plants (44.73) grown on the soil treated with 15 t ha^{-1} bioslurry. The least number of fruits per plant (23.60) was recorded for the control (the treatment with no bioslurry). The variations in fruit numbers among plants grown on the soil with different rate of bioslurry could be due to the nutrient availability from the amount of applied bioslurry. The result of the present study is in agreement with the finding of Okoroigwe (2007) in which the application of anaerobically digested piggery waste (bioslurry) increased the number of pepper fruit per plant.

Different rate of biogas residue slurry showed significant differences ($p<0.05$) in pepper fruit length (Table 4). Consequently, the longest average fruits length (5.67 cm) were recorded for the plants treated at the rate of 20 t ha^{-1}, followed by application of 15 t ha^{-1}. The shortest fruit length (4.71 cm) was recorded for the control treatment. The longest fruits were obtained from plants grown on the soil treated with maximum amount of bio-slurry, which is likely due to greater availability of plant nutrients from the abundantly applied bio-slurry. The results obtained in the present trial was in agreement with other reports in the literatures, where organic fertilizers supplied most of the essential nutrients at growth stage resulting in increased growth variables including fruit length (Gonzalez et al., 2001).

Table 4. Effect of bio-slurry application on the average number of pods per plant, pod length, and fruit yield of pepper

Treatment	Av. Pod no. per Plant	Pod length (cm)	Fruit yield (tha^{-1})
1	23.60^{c}	4.71^{d}	2.29^{c}
2	36.80^{bc}	4.98^{c}	2.62^{c}
3	44.73^{ab}	5.29^{b}	3.19^{b}
4	57.27^{a}	5.67^{a}	3.75^{a}
LSD (0.05)	17.19	0.26	0.39
CV	22.49	2.71	6.64

Results indicated significant difference ($p<0.05$) among plants grown with application of different rates of biogas residue slurry in terms of pepper fruit yield (Table 4). Accordingly, the highest total fruit yield (3.75 t ha^{-1}) was recorded for plants receiving 20 t ha^{-1} biogas slurry application. The least total fruit yield was recorded for the plants of the control treatment (nil application of biogas slurry). Similarly, Okoroigwe (2007) reported significant influence of different rates of biogas slurry on pepper fruit yield. In line with this, El-Tohamy et al., (2006) reported enhancing effect of bioslurry application on vegetative growth due to increasing cell division and elongation thereby facilitating flowering and fruit bearing due to high nutrient availability under higher rates of applied organic fertilizers.

Effect of Bio-slurry on Growth and Yield of Lettuce

The average number of lettuce leaves per plant was significantly ($p<0.05$) different across all treatments. The highest number of leaves (8.35) was obtained from lettuce provided with 20 t ha^{-1} bioslurry (Table 5) followed by 7.90 which is statistically similar to the results from the application of 15 t ha^{-1} bioslurry. The number of leaves decreased with the decrease in the level of bioslurry applied. The least number of leaves was obtained from the control treatment (nil application of bioslurry). In agreement with this, Michael et al. (2010) reported that organic fertilizer has been found to enhance the number of leaves in lettuce by providing sufficient amount of nutrients that accelerates the vegetative growth. Similarly, Yamika et al. (2009) reported that the application of 30 t biogas slurry ha^{-1} increased the number of leaves on the cucumber plant up to 17.33% compared to the one treated with only 10 t biogas slurry ha^{-1}.

Table 5. Effect of bioslurry application on the average leaf number, leaf length, leaf width, plant height and leaf yield for lettuce

Treatment	LNO	LL (cm)	LW (cm)	Plht (cm)	Av. Leaf yield per plant (g/plant)
1	5.95^{b}	7.29^{c}	7.24^{b}	14.50^{d}	58.74^{b}
2	6.27^{b}	7.54^{c}	8.52^{ab}	16.41^{c}	67.59^{b}
3	7.90^{a}	8.64^{b}	9.41^{ab}	19.17^{b}	73.72b^{a}
4	8.35^{a}	9.77^{a}	10.33^{a}	21.5^{a}	87.16^{a}
LSD (0.05)	1.19	0.31	3.03	1.81	15.38
CV	3.33	4.55	18.16	8.66	33.4

LNO = leaf number; LL = leaf length; LW = leaf width; Plht = plant height

Significant difference ($p<0.05$) was observed on average lettuce leaf length (Table 5). Lettuce treated with the application of maximum rate of biogas slurry (20 t ha^{-1}) gave the highest leaf length (9.77 cm) while plant with the control treatment (nil application of biogas slurry) gave the least leaf length (7.29 cm). The result of the present study agrees with that reported by Okoroigwe (2007), where bioslurry application at different rates increased the cucumber leaf length. Application biogas slurry significantly ($p<0.05$) influenced leaf width of lettuce (Table 5) where the highest lettuce leaf width (10.33 cm) was recorded for plants from the treatment with application of 20 t ha^{-1} of biogas slurry.

Application of biogas slurry also significantly ($p<0.05$) influenced lettuce plant height (Table 5), with the highest lettuce plant height (21.5 cm) obtained from of 20 t ha^{-1} biogas slurry application. The lowest plant height (14.5 cm) was obtained from the control treatment that had no bioslurry applied. The highest plant height at of 20 t ha^{-1} of biogas slurry application was due to the supply of major nutrients at the early stage of plant growth. Ashenafi and Tewodros (2018) also reported that the height of kale plant was increased with the rate of applied bioslurry.

Different rate of biogas slurry showed significant differences ($p<0.05$) in the lettuce leaf yield (Table 5). The highest leaf yield (87.1 g/plant) was recorded for those plots receiving 20 t ha^{-1} biogas slurry. .The least leaf yield (58.74g/plant) on the other hand, were recorded for the control treatment (without biogas slurry). Lettuce plants that exhibited high vegetative growth due to effects of treatments, also gained high leaf area and length, increased photosynthetic capacity and assimilate partitioning that resulted in higher leaf yield. In agreement with this, Ashenafi and Tewodros (2018) reported that leaf yield of kale increased with application of bioslurry.

CONCLUSIONS

Application of different rate of bioslurry improved growth and yield of pepper and lettuce plants. The results indicated that the application of bioslurry resulted in significant effects ($p<0.05$) on leaf number, leaf length, leaf width and plant height of both pepper and lettuce. Similarly pod number, pod length, fruit (pod) yield of pepper and leaf yield of lettuce were significantly influenced due to application of different rate of bioslurry. Application of 20 t ha^{-1} bioslurry best performance of both plants in vegetative growth and yields.

On short term basis, the application of high amounts of bioslurry could result in higher pepper and lettuce yield than the lower rates of bioslurry and nil application. Hence, for the farmers of study area, application of 20 t ha-1 bioslurry is recommended tentatively for pepper pod (fruit) and lettuce leaf yield. However, since the experiment was done only once and at one location, repeating similar experiments using higher rates of bioslurry over several seasons and locations is recommended to get to a conclusive recommendation.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

REFERENCES

Abu-Rayyan, A., Kharawish B.H. and Al-Ismail K. 2004. Nitrate content in lettuce (Lactuca sativa L.) heads in relation to plant spacing, nitrogen form and irrigation level. J. Sci. Food Agric., 84: 931-936 [Scholar Google].

Aikins, S.H.M., Afuakwa, J.J. and Baidoo, D. 2006. Effect of planting depth on maize stand establishment. Ghana Institute of Engineers, 4(2): 20-25. [Scholar Google].

Ashenafi Haile and Tewodros Ayalew. 2018. Comparative study on the effect of bio-slurry and inorganic N-fertilizer on growth and yield of kale (Brassica oleracea L.) [Scholar Google].

Berhanu Debele. 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia [Scholar Google].

Bonten, L.T.C., Zwart, K.B., Rietra, R.P.J.J., Postma, R., De Haas, M.J.G. and Nysingh, S.L. 2014. Bio-slurry as fertilizer: is bio-slurry from household digesters a better fertilizer than manure? a literature review [Scholar Google].

Bosland PW, and Votava, EJ. 2007. Peppers: Vegetable and Spice Capsicums.CABI Nth America, Cambridge, MA [Scholar Google].

Bruce, R. C., and Rayment, G. E. 1982. Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys [Scholar Google].

Campbell, C.A., Selles, F., Zentner, R.P., Mcleod, J.G. and Dyck, FB. 1991. Effect of seeding date, rate and depth on winter wheat grown on conventional fallow in S.W. Saskatchewan. Plant Science, 71: 51–61. [Scholar Google].

Charman, P. E. V., and Roper, M. M. 2000. Soil organic matter. In 'Soils – their properties and management'. 3rd edn [Scholar Google].

Clements, B., and McGowen, I. 1994. Strategic fertilizer use on pastures. NSW Agriculture. Agnote Reg. 4/57, Orange, NSW [Scholar Google].

Coelho A.F.S., Gomes E.P., Sousa A.P., and Gloria M.B.A. 2005. Effect of irrigation level on yield and bioactive amine content of American lettuce. J. Sci. Food. Agric., 85: 1026-1032 [Scholar Google].

Demelash Wondimeneh. 2010. Characterization and Classification of the Soils of Upper Sala Watershed in DillaZuria District of Gedeo Zone, Southern Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia [Scholar Google].

El-Tohamy. W. A., Ghoname A. A. and Abou-Hussein, S. D. 2006. Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. Journal of applied Science Research, 2: 8-12. [Scholar Google].

FAO. 2016. FAO statistical database. Food and Agriculture Organization of the United Nations, Rome, Italy. http://faostat3.fao.org [Scholar Google].

Fekadu, M. and Dandena, G. 2006. Status of Vegetable Crops in Ethiopia. Ugandan Journal of Agriculture, 2006, 12(2): 26-30 [Scholar Google].

Fokhrul Islam M. 2009. Proceedings of International Bio-slurry Workshop and Study Tour. Dhaka, Bangladesh 10-13 November, 2008. [Scholar Google].

Garg, R.N., Pathak, HDas. D.K. and Tomar, R.K. 2005. Use of fly ash and biogas slurry for improving wheat yield and physical properties of soil. Environ. Monitoring and Assessment, 107: 1-9. [Scholar Google].

Geberamariam, E. and Mohammed Sherif. 1985. A review of crop protection research in Ethiopia. Proceedings of the First Ethiopian Crop Protection Symposium, February 4-7, 1985, Department of Crop Protection, Institute of Agricultural Research. [Scholar Google].

Gonzalez, D. R. Avarez and J. Matheus. 2001. Comparison of three organic fertilizers for the production of sweet corn. Proceedings of the Inter American Society for Tropical Horticulture, 45: 106-109.

Grubben GJ. 1997. Tropical vegetables and their genetic resources. IPRGR, Rome, Italy. [Scholar Google].

Joyce Fidelis Akpan, Idorenyin Asukwo Udo, Sunday Marcus Afu, Isong Abraham Isong and Marian Gwendoline Solomon. 2020. Influence of biofertilizer on soil properties, growth and yield of hot pepper (Capsicum frutescens) in Calabar, Cross River state, Nigeria. Asian J. Plant Sci., 19: 166-176. [Scholar Google].

Khalil M. I., Schmidhalter U. and Gutser, R. 2005. Turnover of chicken manure in some upland soils of Asia: Agricultural and Environmental Perspective. Proc. Intl. [Scholar Google].

Kim, S. 2003. The effect of chemical fertilizers using in Kean Svay district, Kandal. Bachelor Thesis, Faculty of Agronomy, Royal University of Agriculture, Cambodia, 46-47. [Scholar Google].

Kirby, E.J.M. 1993. Effect of sowing depth on seedling emergence, growth and development in barley and wheat. Field Crops Research, 30: 101-111. [Scholar Google].

Krishna, P.G. 2001. Response to bio-slurry application on maize and cabbage in Lalitpur District.Final Report his Majesty's Government of Nepal, Ministry of Science and Technology.Alternative Energy Promotion Centre, Nepal [Scholar Google].

Kroll, R. 1997. Market Grading. Macmillan Education Ltd. London, pp. 67-69.

Kumar Sandeep, Chand Malav, Kumar Malav and Shakeel A. 2015. Biogas slurry: source of nutrients for eco-friendly agriculture. International Journal of Extensive Research, 2: 42-46. [Scholar Google].

Jackson, M.L. 1958. Soil chemical analysis. Prentice Hall, Inc., Englewood Cliffs. Newjers. America [Scholar Google].

Jit Gurung B. 1997. Review of literature on effects of slurry use on crop production. [Scholar Google].

Jones, J.B. 2003. Agronomic Handbook: Management of crops, soils, and their fertility.

CRC Press LLC, Boca Raton, FL, USA. 482p. [Scholar Google].

Maboko, M. M. 2007. Leafy lettuce grown in a hydroponics system undercover farming. [Scholar Google].

Nanyanzi, M., Kizito, E.B., Masanza, M., Sseruwu, G. and Makoma, M.T. 2018. Effect of different rates of poultry manure and bio-Slurry on the yield of Solanum aethiopicum Shum. [Scholar Google].

Moodie, C., Smith, D., and Mc. R. Creerry. 1954. Laboratory manual for soil fertility. Washington State College, Monograph, 31-39.

Nadeem, M., Anjum, F.M., Khan, M.R., Saeed, M. and Riaz, A. 2011. Antioxidant potential of bell pepper (Capsicum annum L.)-A review. Pakistan Journal of Food Science, 21(1-4): 45-51. [Scholar Google].

Okoroigwe E.C. 2007. Application of Biomass Technology in Sustainable Agriculture. Journal of Applied Sciences Research, 2(6): 549-553. [Scholar Google].

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. Agric. Circ.939, USA. [Scholar Google].

Rowell, D.L. 1994. Soil science: Method and applications. Addison, Wesley, England: Longman Scientific and Technical, Longman Group UK Limited, 350p.

Salim, M. 1999. Diversity: Role in integrated pest management. Sci. Tech. Dev., 18(4): 26-31. [Scholar Google].

Sam-Aggrey. W. G. and Bereke-Teshai Tuku. 2005. Proceeding of the 1st Horticultural Workshop. 20-22 February. IAR. Addis Ababa. 212p.

Sime, G. 2020. Technical and socioeconomic constraints to the domestication and functionality of biogas technology in rural areas of southern Ethiopia. Cogent Engineering, 7(1): 1765686. [Scholar Google].

Solaiman, Z.M., Hongjun, Y.A.N.G., Archdeacon, D., Tippett, O., Michaela, T.I.B.I. and Whiteley, A.S. 2019. Humus-rich compost increases lettuce growth, nutrient uptake, mycorrhizal colonisation, and soil fertility. Pedosphere, 29(2): 170-179. [Scholar Google].

Temesgen Kebede. 2010. Evaluation of Different Mulch Types for Soil Moisture Conservation and Yield of Tomato (Lycopersiconesculentum Mill.). MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Vos, J.G.M. and Friking, H. D. 1997. Nitrogen fertilization as a component of integrated crop management of hot pepper (Capsicum species) under tropical lowland conditions. International Journal of Pest Management. 43: 1-10.

Walkley, A. and Black, I.A. 1934. An Examination of the degtjareff for determining soil organic matter and a proposed chromic acid titration method. Soil sci., 37: 29-38.

Yamika W.S.D., Herlina N. and Amriyanti S. 2019. The effect of biogas and inorganic fertilizer on soil fertility and yield of cucumber (Cucumis sativus L.). J. Degrade. Min. Land Manage. 6(4):1829-1835. DOI:10.15243/jdmlm.2019.064.1829. [Scholar Google].

Yasar, A., Rasheed, R., Tabinda, A.B., Tahir, A. and Sarwar, F. 2017. Life cycle assessment of a medium commercial scale biogas plant and nutritional assessment of effluent slurry. Renewable and Sustainable Energy Reviews, 67: 364-371. [Scholar Google].