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Evaluating manurial value of bioslurry for tomato cultivation in sub-tropical floodplain soil

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ABSTRACT

Bioslurry is an anaerobically decomposed product, which comes out of the digester after extraction of biogas (chiefly CH_4). Recently a huge amount of bioslurry is being produced in Bangladesh for enormous installation of biogas plants. Utilization of bioslurry is yet to be addressed adequately though it has potential value as a good quality organic fertilizer. Therefore, a field experiment supported by a laboratory analysis was conducted in floodplain soil of Bangladesh to evaluate the performance of bioslurry along with chemical fertilizers on the yield of tomato (*Solanum lycopersicum*). The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments *viz.*, Control (no fertilizer/manure), $N_{200}P_{90}K_{180}$ (100% Recommended Fertilizer Dose, RFD), $N_{120}P_{54}K_{108}$ (60% RFD) + Poultry manure (PM), $N_{120}P_{54}K_{108}$ (60% RFD) + Poultry slurry, $N_{120}P_{54}K_{108}$ (60% RFD) + Cowdung (CD), $N_{120}P_{54}K_{108}$ (60% RFD) + Cowdung slurry, each treatment replicated thrice. Chemical analysis of cowdung, cowdung bioslurry, poultry manure and poultry bioslurry showed that the organic carbon, N, P, K and S varied from 10.1-35.1, 0.70-2.52, 0.18- 1.28, 0.86- 3.80 and 0.13- 0.61% respectively. Cowdung and poultry manure had the higher organic carbon content as well as higher nutrient concentration compared to cowdung bioslurry and poultry bioslurry. Nutrient concentration particularly N, P and S in cowdung and cowdung bioslurry was found lower than the poultry manure and poultry bioslurry. The fruit yield of tomato increased by 81-225% due to the application of different slurry, manure and chemical fertilizers compared to no application of manure or fertilizer (control). The highest fruit yield (27.2 t ha^{-1}) of tomato was obtained from $N_{120}P_{54}K_{108}$ + Poultry slurry treatment. Hence application of poultry bioslurry in combination with 60% recommended dose of fertilizers can help improve the production of tomato in sub-tropical floodplain soil.

Keywords: Bioslurry, chemical fertilizers, tomato yield

INTRODUCTION

Biogas technology is getting popular in Bangladesh due to high cost of fuel and fertilizer. It is a natural process of anaerobic digestion to produce biogas from animal or any other type of waste. After extraction of biogas, bioslurry comes out of digester as a waste. In Bangladesh, the installation of biogas plant has been increasing around 4000-5000 per year between 2005 and 2015 (Khan and Martin, 2016). Up to June 2015, a total of around 77,500 biogas plants of varying gas producing capacities (2-6 m^3) have installed (Khan and Martin, 2016) and many are in progress. The installed biogas plants generate more than 6,20,000 tons of slurry on dry weight basis which is equivalent to about 28000 tons of urea + 77,500 tons of triple super phosphate (TSP) + 9900 tons of muriate of potash (MOP) plus other secondary and micronutrients (Islam, 2006). Large amount of this bio- slurry and their disposal is a major concern for the environment. Therefore, resource utilization of bioslurry appears to be prospective and obligatory for now a day.

Bioslurry is a sort of organic manure that can be utilized as a potential bio-manure in crop production. It contains considerable amounts of plant nutrients, its application as soil amendment may improve crop production and soil properties by preventing adverse environmental impacts of chemical fertilizers and waste disposal. Bioslurry can improve the physical and biological quality of soil by adding organic matter to the soil, improve in water holding capacity, cation exchange capacity, lesser soil erosion and provision of nutrients to plants and soil micro-flora including N fixing and phosphorous solubilzing organisms (Warnars and Oppenoorth, 2014). Apart from the nutrient supply, it can be used to treat seeds for higher germination, disease resistance, better yields, improve coloration of fruits and vegetables, increase quality and quantity of organic grown flowers and vegetables, it can also inhibit pest attack and weed seed germination (Warnars and Oppenoorth, 2014).

Fertilizer value of cowdung or poultry manure slightly increase after gas production. The fermentation process reduces C/N ratio by removing some of the carbon thus increases nutrient concentration. Bioslurry is environmental friendly, has no toxic or harmful effects and can easily reduce the use of chemical fertilizers up to 50% (Islam, 2006, Haque *et al*, 2018). Nutrients from organic sources are more efficient than those from chemical sources (Haque *et al*, 2018). Bioslurry is a 100% organic fertilizer most suitable for organic farming for some high value field and horticultural crops (Islam, 2006).Vegetable crops produced with bioslurry have better quality as compared to those produced with chemical fertilizer (Krishna, 2001). Warnars and Oppenoorth (2014) also reported that the bioslurry combined with chemical

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fertilizers shows better yields than bioslurry utilisation on its own. Therefore, application of bioslurry in combination with inorganic fertilizers may be a good option for increasing soil health while sustaining higher yield of crops. Several studies have revealed that bioslurry combined with inorganic fertilizers could help increasing soil fertility, yield and quality of both field and horticultural crops (Shaheb and Nazrul, 2011; Nasir *et al.*, 2012; Islam *et al*., 2013; Warnarsand Oppenoorth, 2014; Malav *et al*., 2015; Shaheb *et al.*, 2015 and Nanyanzi *et al*., 2018).

Tomato (*Solanum lycopersicum*) is one of the most popular, important and widely used vegetable crops grown throughout the world and ranks next to the potato and sweet potato in terms of area, but ranks first as a processing crop (FAO, 2010). The cultivated area under tomato in Bangladesh was 28.1 thousand hectares with a total production and yield of 3,85,000 metric tons and 13.69 tha^{-1}, respectively in 2018 (FAOSTAT, 2018). Since tomato plays an important role in human diet, its nutritional quality is of particular concern to consumers throughout the world (Chapagain and Wiesman, 2004). Tomatoes are the major dietary source of the antioxidant lycopene, which has been linked to many health benefits, including reduced risk of heart disease and cancer (Healthline, 2016; Aune *et al*., 2012 and Karppi *et al.*, 2012). They are also a great source of vitamin C, potassium, folate and vitamin K that are very good for body and protect the body against diseases (Olaniyi *et al.*, 2010)..Tomato is grown both in the summer and winter seasons in Bangladesh while winter is the major season.

Research work on the manurial value of bioslurry and its effect on performance of crops grown in different soils and environment is lacking in Bangladesh. Therefore, it is important to evaluate the quality of bioslurry and its effect on crop performances particularly vegetables where manuring suits better than chemical fertilization for its quality. Under such circumstances, this piece of research work was conducted to study the nutrient concentration in bioslurry and its effect on tomato yield.

MATERIALS AND METHODS

Experimental site and soil

A field experiment was conducted in floodplain soil of Bangladesh Agricultural University (BAU) farm, Mymensingh during November 2011 to April 2012. Geographically the experimental site was located at 24°75′ N Latitude and 90°50′ E Longitude at an elevation of 18 m above the sea level. The site is classified as medium high land on a Non-calcareous Dark Grey Floodplain Soils under the Agro-Ecological Zone (AEZ-9), Old Brahmaputra Floodplain (FAO/UNDP, 1988). The soil (0-15 cm) was silt loam in texture having a pH 6.15, organic matter content 3.13%, total N 0.11%, exchangeable K 0.082 meq $100g^{-1}$ soil, available P 11.2 mg kg^{-1} and available S 12.5 mg kg^{-1}. The experimental area has sub-tropical climate which is characterized by moderate to high temperature, heavy rainfall, high humidity and relatively long day during Kharif (April to September) and scanty rainfall, low humidity, low temperature and short day period during Rabi season (October to March) (Begum *et al*, 2018). The experiment was conducted during the cooler, dry and sunny Rabi season, the major tomato-growing season in Bangladesh.

Treatments and design

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and six treatments *viz.*, Control (no fertilizer/manure), $N_{200}P_{90}K_{180}$ (100% Recommended Fertilizer Dose, RFD), $N_{120}P_{54}K_{108}$ (60% RFD) + Poultry manure (PM), $N_{120}P_{54}K_{108}$ (60% RFD) + Poultry slurry, $N_{120}P_{54}K_{108}$ (60% RFD) + Cowdung (CD), $N_{120}P_{54}K_{108}$ (60% RFD) + Cowdung slurry. Nitrogen @ 200, phosphorus @ 90 and potassium @ 180 kg ha^{-1} were applied as recommended fertilizer dose for tomato as per BARI (2011). Other treatments contain 40% nutrients from manure based on N.

Crop management

Land preparation for the field experiment was started in early November ploughing and cross ploughing with a power tiller and kept open to sunlight for four days. Afterwards, the experimental plots (18 plots) were prepared by several ploughing and cross ploughing followed by laddering. The unit plot size was 4 m x 2.5 m. All kinds of weeds, stubbles and crop residues were removed from the field before final ploughing and leveling. All treatments of the experiment were assigned at random to each unit plot for each replication. Cowdung, poultry manure, cowdung slurry and poultry manure slurry was mixed with soil a week before transplanting whereas recommended doses of triple super phosphate (as a sources of P) and muriate of potash (as a sources of K) were applied at final land preparation as basal. Urea (as a sources of N) was applied in three equal installments, one third at the final land preparation and the rest two thirds were applied at 30-day intervals after transplanting.

Tomato cultivar Ruma VF was used as test crop for the experiment. The seedlings were collected from Department of Horticulture, BAU, Mymensingh. Healthy and uniform sized 30-day old seedlings were transplanted in the experimental plots Intercultural operations such as weeding, irrigation, plant protections etc. were done as and when necessary throughout the growth period of the crop. Fruits were harvested at maturity stage. Harvesting was done at several times and duration of harvesting was mid February to the end of April 2012. Ten plants from each treatment were selected randomly to collect data on plant height and number of fruits $plant^{-1}$. The fruit weight was calculated by taking mean value of ten fruits per plot. After harvesting of fruits, the weight was calculated in kg plot^{-1} and then it was converted into ton per hectare.

Chemical analysis of manure and bioslurry

Manures and slurry samples were digested and then analyzed for the determination of N, P, K and S contents. Total N content in soil and manure was determined by semi-micro Kjeldahl method (Bremmer and Mulvaney, 1982). For P, K & S determination, HNO_3- $HClO_4$ (2:1) digestion was done. The P content was determined colorimetrically by $SnCl_2$ reduction method. The exchangeable K content of soil was determined by 1N NH_4OAc (pH 7) method, followed by measurement with a flame photometer (Thomas, 1982). Available S content of soil was determined by $CaCl_2$ (0.15%) extraction method (Williams and Steinberg, 1959), the extractant was determined turbidimetrically by spectrophotometer.

Statistical analysis

All the data were analyzed for ANOVA with the help of MSTAT-C statistical software (Michigan State University, USA). A one-way ANOVA was made by F variance test. The pair comparisons were performed by Least Significant Difference (LSD) test at 1% level of probability (Gomez and Gomez, 1984).

RESULTS

Nutrient composition of manures and bioslurry

Chemical composition of cowdung, cowdung slurry, poultry manure and poultry slurry differed significantly at 1% level of probability.

Organic carbon

The organic carbon content of different manures and bioslurry varied from 10.11% to 35.11% over the treatments (Table 1), the highest organic carbon content being observed in poultry manure and the lowest in cowdung slurry; it was found only 1.82% in soil. The organic carbon content of cowdung and poultry manure slurry was 29.79% and 16.32%, respectively. Organic carbon content of cowdung was statistically superior to cowdung slurry, and organic carbon content of poultry manure was statistically superior to poultry manure slurry.

Nitrogen

Significant differences ($p<0.01$) were also observed in nitrogen content of different manures and bioslurry. Nitrogen content varied from 0.70% to 2.52% among the treatments (Table 1) with the highest value recorded for poultry manure and the lowest for cowdung slurry. The nitrogen content of poultry manure slurry and cow-dung was 1.40 and 1.12%, respectively. In all cases, N content of cowdung and poultry bioslurry was always found lower than the cowdung and poultry manure.

Phosphorus

The available phosphorus content of different manures and bioslurry ranged between 0.180% and 1.28% (Table 1). The highest P content was observed in poultry manure and the lowest was in cowdung slurry. The phosphorus content of poultry manure and poultry manure slurry was statistically at par. Phosphorus content in cowdung was 0.307%.

Potassium

The value of available K in different manures and bioslurry ranged between 0.860% and 3.81% (Table 1), the highest K content was observed in poultry manure and the lowest K content in cowdung slurry. The trend of K content in manures followed the order: poultry manure> cowdung > poultry manure slurry> cowdung slurry. In all cases, the K content of cowdung and poultry bioslurry was always found lower than the cow-dung and poultry manure.

Sulphur

The S content varied from 0.137 to 0.613% among the treatments (Table 1), the highest S found in poultry manure slurry and the lowest S in cowdung slurry. The S content of poultry manure and cowdung was 0.503 and 0.233%, respectively.

Table 1. Nutrient content of cowdung, cowdung slurry, poultry manure and poultry manure slurry.

Particulars	%OC	%N	%P	%K	%S	C:N	C:P	C:S
Cowdung	29.79b	1.120c	0.307b	1.113b	0.233c	26.06	97.03	125.28
Cowdung Slurry	10.11d	0.700d	0.180c	0.860c	0.137d	14.44	56.17	73.80
Poultry manure	35.11a	2.520a	1.280a	3.807a	0.503b	13.93	27.43	69.80
Poultry manure Slurry	16.32c	1.400b	1.260a	0.883c	0.613a	11.66	12.95	26.62
SE±	3.078	0.206	0.156	0.374	0.059	-	-	-
LSD	5.089	0.189	0.090	0.090	0.020	-	-	-
Level of sig.	**	**	**	**	**	-	-	-

** Significant at 1% level of probability respectively; SE (±) = standard error of means;
Values having same lowercase letters in a column do not differ significantly at $P < 0.05$ by Duncan's multiple range test

Growth and yield contributing characters of tomato

The growth and yield contributing characters like plant height, number of fruits plant^{-1}, fruit weight and yield were significantly influenced by different treatments at 1% level of probability.

Plant height

The plant height of tomato was recorded once at the peak of vegetative growth stage at 56 days after transplanting. The effect of different treatments on plant height was statistically significant at 1% level of probability (Table 2). All the treatments showed higher plant height over control. Plant height was found to vary from 25.17 to 61.10 cm among the treatments (Table 2), the tallest plant observed in $N_{120}P_{54}K_{108}$ + poultry manure treatment and the shortest plant in control. The plant height recorded in $N_{200}P_{90}K_{180}$ and $N_{120}P_{54}K_{108}$+ poultry slurry was statistically similar and superior to $N_{120}P_{54}K_{108}$+cowdung and $N_{120}P_{54}K_{108}$+ cowdung slurry treatment. The latter two were also statistically similar. The plant height obtained from different treatments ranked in the order of $N_{120}P_{54}K_{108}$+ poultry manure> $N_{120}P_{54}K_{108}$+ poultry slurry>$N_{200}P_{90}K_{180}$ > $N_{120}P_{54}K_{108}$ + cowdung > $N_{120}P_{54}K_{108}$+ cowdung slurry > control.

Table 2. Effect of manure and bioslurry on yield and yield contributing characters of tomato cv. Ruma VF

Treatments	Plant height (cm)	Fruits plant^{-1} (no)	Fruit wt (g)	Yield (tha^{-1})
T_0 (Control)	25.17d	9.77b	26.00c	8.35c
T_1 ($N_{200}P_{90}K_{180}$)	53.80b	27.87a	38.33abc	18.87b
T_2 ($N_{120}P_{54}K_{108}$ + PM)	61.10a	25.27a	50.00a	16.13b
T_3 ($N_{120}P_{54}K_{108}$+ PS)	56.80b	26.50a	48.33a	27.20a
T_4 ($N_{120}P_{54}K_{108}$ + CD)	47.43c	21.23a	33.33bc	16.03b
T_5 ($N_{120}P_{54}K_{108}$ + CS)	45.53c	21.33a	41.67ab	15.15b
SE (±)	2.84	1.65	2.44	1.46
LSD	1.80	4.04	7.10	2.77
Level of sig.	**	**	**	**

** Significant at 1% level of probability; SE (±) = standard error of means;
Values having same lowercase letters in a column do not differ significantly at $P < 0.05$ by Duncan's multiple range test
PM=Poultry manure, PS=Poultry slurry, CD=Cowdung, CS=Cowdung slurry

Number of fruits plant^{-1}

The number of fruits plant^{-1} is the most important yield attributing character of tomato plant. The highest number of fruits plant^{-1} was obtained in $N_{200}P_{90}K_{180}$(RDF) treatment (27.87) which was statistically at par in all the other treatments except control where no fertilizer, manure and biogas slurry were applied. The number of fruits plant^{-1} ranked in the order of $N_{120}P_{54}K_{108}$+ poultry manure > $N_{120}P_{54}K_{108}$+ poultry slurry > $N_{120}P_{54}K_{108}$+cowdung slurry > $N_{120}P_{54}K_{108}$+ cowdung >control treatment, as shown in Table 2.

Fruit weight

The fruit weight of tomato was significantly influenced by the application of fertilizer, manure and slurry treatments. It was observed that the average highest fruit weight was recorded in $N_{120}P_{54}K_{108}$+ poultry manure treatment (50.00 g fruit^{-1}) which was statistically similar with $N_{120}P_{54}K_{108}$+ poultry slurry (48.33 g fruit^{-1}) followed by$N_{120}P_{54}K_{108}$+ cowdung slurry(41.67 g fruit^{-1}), $N_{200}P_{90}K_{180}$(38.33 g fruit^{-1}), $N_{120}P_{54}K_{108}$+ cowdung (33.33 g fruit^{-1}) and the lowest in control (26.00 g fruit^{-1}) treatment. The fruit weight of tomato was statistically similar in all the treatment except control.

Fruit yield

The yield of tomato was significantly influenced by the application of different slurry, manure and chemical fertilizers. The yield of tomato varied from 8.35 to 27.20 tha^{-1} in different treatments combinations. The highest yield (27.20 t ha^{-1}) was recorded in $N_{120}P_{54}K_{108}$+ poultry slurry treatment followed by the treatment $N_{200}P_{90}K_{180}$(18.87 t ha^{-1}), $N_{120}P_{54}K_{108}$+ poultry manure (16.13 t ha^{-1}), $N_{120}P_{54}K_{108}$+ cowdung (16.03 t ha^{-1}), $N_{120}P_{54}K_{108}$+ cowdung slurry (15.15 tha^{-1}) and the lowest yield (8.35 tha^{-1}) was observed in control treatment (Table 2). The yield of tomato was statistically similar in $N_{200}P_{90}K_{180}$ (RDF), $N_{120}P_{54}K_{108}$+poultry manure and $N_{120}P_{54}K_{108}$+ cowdung treatments. The percentages of yield increased over control due to different treatments were presented in the Figure 1. The yield of tomato increased by 126, 93, 225, 92 and 81 % over control in $N_{200}P_{90}K_{180}$, $N_{120}P_{54}K_{108}$+ poultry manure, $N_{120}P_{54}K_{108}$+ poultry slurry, $N_{120}P_{54}K_{108}$+ cowdung, and $N_{120}P_{54}K_{108}$+ cowdung slurry treatment, respectively.

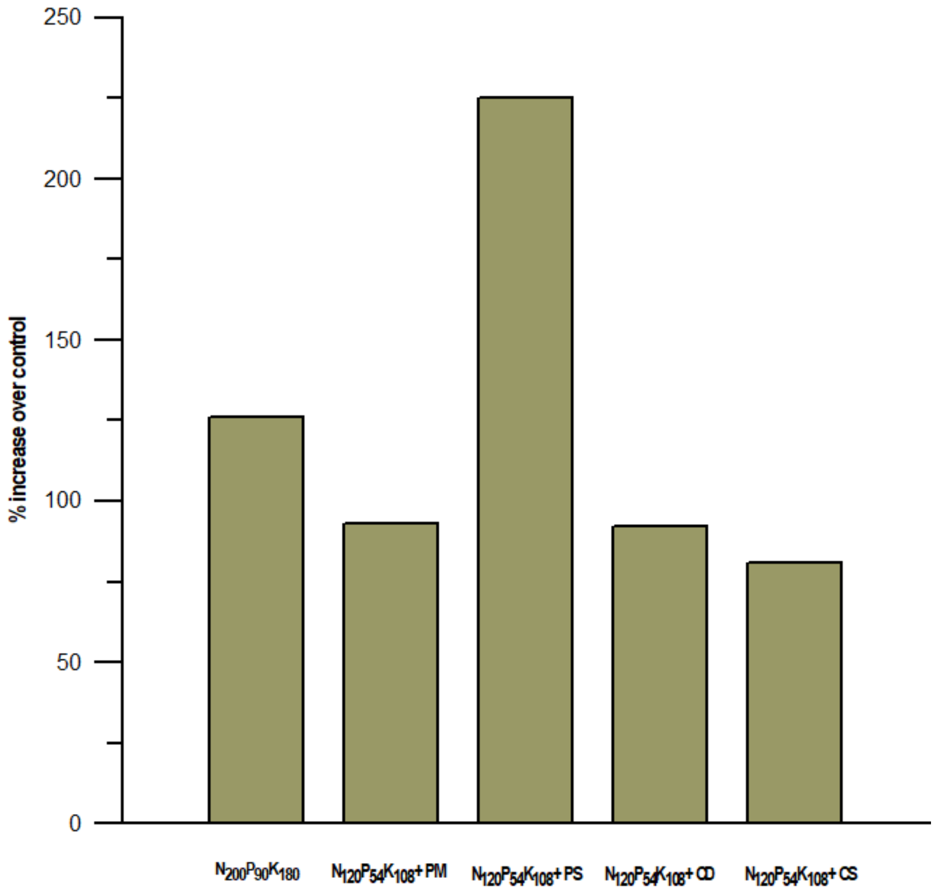

Figure1. Percent increase of tomato yield over control both in field and pot experiment

DISCUSSION

Chemical composition of manures and bioslurry

Chemical composition of cowdung and poultry manures and bioslurry is important in regulating the function of soil for agricultural productivity. Thus, chemical composition of two commonly applied manure in Bangladesh along with two byproduct of very recently popularized biogas was studied in floodplain soil that accounts 80 % of Bangladesh soils.

Organic carbon content of cowdung and poultry bioslurry was always found lower than the cowdung and poultry manure. This result is logical as about 25 to 30 percent of the organic matter from the faecal matter (cowdung and poultry manure) is converted into biogas during the anaerobic fermentation process while the rest becomes available as a residual manure (Chawla, 1986; Kumar *et al,* 2015) which is generally considered to be rich in major plant nutrients (NPK) as well as in micronutrients (Tripathi, 1993). However, a large amount of nutrients particularly N and K is lost from slurry during the drying of slurry through volatilization and leaching loss. This is evident from the lower N and K content of cowdung and poultry bioslurry as compared to cowdung and poultry manure (Table 1). Lower N content of cowdung and poultry bioslurry could be due to the fact that the water soluble N in bioslurry remains as ammoniacal form accounting 12-18% of total N which lost through volatilization (around 96 percent of the dissolved ammonia escaped into the air) during the evaporation and drying of the digested paste like slurry under alkaline environment (Chawla, 1984). Indeed, an anaerobic fermentation in the biogas digester does not result in any absolute increase in the nitrogen content of the slurry; the relative increase is noticed due to the loss of 25 to 30 percent organic carbon of the dung during biogas generation (Kumar *et al*, 2015). However, volatilization loss of the ammoniacal-N during drying of the slurry decreased the total N content of the slurry compared to manure. Similar to N, K content of cowdung and poultry bioslurry was always found lower than the cowdung and poultry manure. It could be due to the fact that the water soluble K in bioslurry was lost through leaching during the drying of the digested slurry in soil pit.

Effects on growth and yield attributes of tomato

Yield is the ultimate output of crop production. Therefore, the growth parameter and yield attributing characters such as plant height, number of fruits plant^{-1} and fruit weight of tomato with the application of different treatments were studied in floodplain soil of Bangladesh (Table 2). It was observed from the results that the highest yield of tomato was obtained with the application of $N_{120}P_{54}K_{108}$ + poultry manure slurry treatment. This might be due to the ability of poultry manure slurry to supply more readily available nutrients that promoted the yield and yield attributes of tomato. Lower C:N, C:P and C:S ratio of poultry manure slurry in this study indicate the faster rate of mineralization and release of nutrients. This result is in line with the findings of Ferdous *et al*. (2018) who reported that application of synthetic fertilizer + poultry bioslurry produced the highest fruit yield of tomato. Increased tomato yield was also reported by Warnars and Oppenoorth (2014) in combined application of slurry @ 20 tha^{-1}and NPK 45-60- 30 kg ha^{-1}. Similar result was also noticed by Nanyanzi *et al*. (2018) in case of *Solanum aethiopicum* Shum (*Nakati*) in Uganda. Application of inorganic fertilizer (Recommended dose) + Biogas slurry compost at eight tha^{-1} resulted the highest cabbage yield increment of 66.7 % compared to the control i.e. no fertilizer (Debebe & Itana, 2016). Furthermore, the results are also similar to that of Shaheb *et al.* (2015) and Shaheb & Nazrul (2011) who reported that CD slurry @ five tha^{-1} along with IPNS basis inorganic fertilizers produced the highest yield of radish and cabbage, respectively in AEZ 20 of Bangladesh. However, the ratio of poultry manure, cowdung and cowdung slurry with chemical fertilizer had might be inappropriate in this study to maintain proper C:N, C:P and C:S ratio resulting immobilization of nutrients in soil. Therefore, the beneficial effect of those manures were not observed as expected on the yield of tomato.

It was observed from the results that the application of $N_{120}P_{54}K_{108}$ + poultry manure significantly increased the plant height of tomato might be due to the higher value of percent N, P, K and S in poultry manure. Although the highest number of fruits plant^{-1} of tomato were observed in $N_{200}P_{90}K_{180}$ (100%RFD) treatment but it was statistically similar with other treatments except control which indicate that both manure and slurry has positive effect likewise chemical fertilizers. Therefore, instead of synthetic fertilizer having negative effect on environment as well as soil, can easily replace by these environmentally healthy manures to produce quality crops. The heaviest tomato fruit harvested in $N_{120}P_{54}K_{108}$ + poultry manure and poultry slurry treatments pointed to the beneficial effect of manure on quality products.

CONCLUSION

Both the poultry and cowdung bioslurry having narrow C:N, C:P and C:S ratios compared to their respective feedstock indicate that they have better manurial value. Better growth and yield of tomato in bioslurry based two treatments further proven this. Between the poultry and cowdung bioslurry, poultry bioslurry performed well when co-applied with chemical fertilizer. However, further studies are needed to determine an appropriate ratio of bioslurry and inorganic fertilizer for better crop performance as well as soil fertility management.

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