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EFFECTS OF BIOGAS DIGESTATE FROM COWDUNG AND POULTRY MANURE ON GROWTH AND YIELD OF SPINACH (*Spinacea oleracea L.*)

T. SHORMIN* AND M.G. KIBRIA
Department of Soil Science, University of Chittagong, Chittagong-4331, Bangladesh

ABSTRACT

A pot experiment was conducted to study the effects of biogas digestate from cow dung and poultry manure, and raw cow dung and poultry manure on growth and yield of spinach (*Spinacea oleracea L.*) at glass house of the Department of Soil Science, University of Chittagong, Bangladesh. Treatments with three replications were as follows: T_1 (control), T_2 (100% N of recommended dose @ 90 kg N ha^{-1} from urea) , T_3 (100% N from cow dung digestate), T_4 (100% N from poultry manure digestate), T_5 (100% N from raw cow dung), T_6 (100% N from raw poultry manure), T_7 (50% N from urea+ 50% N from cow dung digestate), T_8 (50% N from urea+ 50% N from poultry manure digestate) T_9 (50% N from urea+ 50% N from raw cow dung) and T_{10} (50% N from urea+ 50% N from raw poultry manure). Pots were arranged in a randomized block design. Results showed that there were significant variations among the treatments in number of leaves in each plant, plant height, and fresh and dry weight of shoot and root. Treatment T_7 and T_8 had significantly increased number of leaves and plant height at 15, 25 and 40 DAS. Treatment T_7 showed the best performance compared to other treatments in producing fresh and dry weight of shoot and root biomass of spinach.

Key words: Spinach, growth, digestate, cow dung, poultry manure.

INTRODUCTION

Bangladesh is an agricultural country where depletion of soil fertility is a major constraint for higher crop production. The content of organic matter in the soil of Bangladesh is below 1% in about 60% of cultivable lands compared to an ideal minimum value of 3% (Islam, 2006). Low soil organic matter content is considered as one of the most serious threats to the sustainability of agriculture. The soil fertility status of the country is declining day-by-day due to intensification of agriculture to grow more food for the teeming million and indiscriminant as well as imbalanced use of chemical fertilizers with little or no addition of organic fertilizers. Organic fertilizers play a vital role in restoring fertility as well as organic matter status of the soils. Despite the large quantities of plant nutrients contained in inorganic fertilizers as compared to organic nutrients, the presence of growth promoting agents in organic fertilizers make them important for enhancement of soil fertility and productivity (Sanwal et al., 2007). A vast range of organic fertilizers is

* Corresponding Author : Tanjia Shormin, E-mail : tanjiashormin@gmail.com

available in different forms in our surroundings including cow dung, farm yard manure (FYM), poultry manure, composted FYM and digested biogas plant residues.

Biogas digestate, the residues generated during the production of biogas through anaerobic digestion of organic wastes, may be considered as a good source of organic fertilizer because it contains considerable amounts of nutrients and organic matter (Bachmann et al., 2011; Lošák et al., 2012). Application of biogas digestate in soil could be one of the options to maintain soil fertility. Depending on the biogas technology, the digestate could be a solid or a liquid material (Makadi et al., 2012). The biogas digestate has 93% water and 7% of dry matter of which 4.5% is organic matter and 2.5% inorganic matter (Kumar et al., 2015). The digestate is a very useful organic fertilizer that can be used to reduce the financial as well as the environmental costs associated with the use of mineral fertilizer (Lukehurst et al., 2010). Islam et al., (2010) suggested that digestate is an environmental friendly and non-polluting organic fertilizer that could be used as a source of organic matter and nutrients for sustainable crop production. Bangladesh has a good opportunity to use digestate as a nitrogen fertilizer, because 2000 biogas plants are already established in the country (Islam, 2006). From these existing biogas plants at least 60 tons of biogas digestate is produced daily and proper utilization of these huge amount of digestate to crop land may help improving soil organic matter status.

The biogas plant technology uses cow dung, poultry litter, water hyacinth and other biomass wastes to produce biogas thereby ensuring a smoke free, odor free, clean and healthy cooking environment for rural women. Combined application of biogas digestate from cow dung and poultry manure along with synthetic fertilizer could be a soil management practice to improve crop productivity, soil fertility, and sustainability (Moyin-Jesu, 2015). This strategy can reduce the rate of synthetic fertilizer incorporation to the soil, decreasing risks of soil degradation and nutrient leaching and maintaining soil quality (Moyin-Jesu, 2015).

Spinach is a leafy vegetable with a good cooking adoptability, high nutritive value and many important vitamins and minerals (Nishihara et al., 2001). Spinach, (*Spinacea oleracea L.*) a member of the chenopodiaceae family, is also known as "Palak". It is a rich source of vitamin A, vitamin C, vitamin E, vitamin K, magnesium, manganese, folate, betaine, iron, vitamin B2, calcium, potassium, vitamin B6, folic acid, copper, protein, phosphorus, zinc, niacin, selenium and omega-3 fatty acids. Spinach, along with other green leafy vegetables is considered to be rich in iron (Ahmed et al., 2004; Toledo et al., 2003). In addition, spinach is extremely rich in antioxidants, especially when fresh, steamed, or quickly boiled. Keeping the above views in mind, an experiment was conducted to investigate the comparative effects of biogas digestate from cow dung and poultry manure on growth and yield of spinach.

MATERIALS AND METHODS

Pot experiment

A pot experiment was conducted in the glass house of the Department of Soil Science, University of Chittagong. Ten treatments with three replications were as follows: T_1 (control), T_2 (100% N of recommended dose @ 90 kg N ha^{-1} from urea) , T_3 (100% N from cow dung digestate), T_4 (100% N from poultry manure digestate), T_5 (100% N from raw cow dung), T_6 (100% N from raw poultry manure), T_7 (50%N from urea+ 50% N from cow dung digestate), T_8 (50% N from urea+ 50% N from poultry manure digestate) T_9 (50% N from urea+ 50% N from raw cow dung) and T_{10} (50% N from urea+ 50% N from raw poultry manure). Air dry soil was mixed and sieved (<2mm size). Eight kilogram soil was used per pot. Pots were arranged in a randomized complete block design (RCBD). All treatments received recommended doses of P (P 18 kg ha^{-1}) and K (K 60 kg ha^{-1}) according to BARC (2012) as triple super phosphate (TSP) and muriate of potash (MP), respectively along with N (90 kg ha^{-1}) as urea according to treatment plan. One-third of the nitrogen and all phosphorus and potassium fertilizers were applied as basal dose prior to sowing, while remaining two thirds of nitrogen was applied in equal amounts at 15 and 25 days after sowing (DAS) as top dressing followed by irrigation. All of digestate from cow dung and poultry manure and raw cow dung and poultry manure were applied as basal during soil preparation and soils mixed with these amendments were allowed to equilibrate for 2 weeks prior to sowing seeds. Healthy seeds of spinach were sown in the pots. Eight healthy seedlings were kept in each pot. Irrigation was applied as and when necessary.

Properties of soil and organic amendments

Soil texture was determined by hydrometer method (Day, 1965), pH in a 1:2.5 soil: water suspension with glass electrode pH meter, organic carbon by wet-oxidation method (Walkley and Black, 1934), total nitrogen by micro-Kjeldahl distillation. Organic matter was calculated by multiplying the organic carbon content with 1.72. The same methods used for soil were followed for determination of the properties of cow dung digestate, poultry manure digestate, raw cow dung and poultry manure. The texture of the experimental soil was sandy clay loam containing 60% sand, 18% silt and 22% clay. The pH of the soil was 6.74, organic matter content 1.61%, total nitrogen 0.19%. Total nitrogen content of the digestate from cow dung and poultry manure was 1.14 % and 1.13%, respectively. Raw cow dung and poultry manure contained 1.40% and 1.83% total nitrogen, respectively.

Data Collection

Plant height and number of leaves of spinach were recorded at 15, 25 and 40 DAS. Fresh and dry weight of shoot and root were recorded after harvest. Dry weight was measured after drying the samples at 65^0C for 72 hours in oven.

Statistical analysis

The significance of differences among the means of the treatments was evaluated by one way analysis of variance followed by Duncan's Multiple Range Test at the significance level of 5%. The statistical software Microsoft Excel and SPSS version 16 were used for the analysis.

RESULTS AND DISCUSSION

Plant height

Shoot height under different treatments is shown in Table 1. Plant height varied from 12.00-16.50 cm at 15 DAS, 13.50-24.50 cm at 25 DAS, and 15.50-28.75 cm at 60 DAS. The minimum value of plant height was always obtained in the control (T_1) and the maximum values were obtained with 50%N from urea+50% N from poultry manure digestate (T_8) at 15 DAS, with 50% N from urea+50% N from cow dung digestate (T_7) at 25 DAS. The highest plant height at 40 DAS was observed in treatment T_7, T_8 and T_9. The treatments T_2 (100%N from urea), T_3 (100%N from cow dung digestate), T_4 (100%N from poultry manure digestate), T_5 (100%N from raw cow dung) and T_6 (100%N from raw poultry manure) significantly increased the plant height compared to control at 25 and 40 DAS, but not at 15 DAS. However, there were no significant differences among the treatment groups in producing the height of spinach at 25 and 40 DAS. Application of cow dung digestate and poultry manure digestate in combination with urea (T_7 and T_8) significantly increased plant height compared to urea alone (T_2) at the all the growth stages recorded. Cow dung digestate, poultry manure digestate, raw cow dung and raw poultry manure generally showed better performance when these amendments were used along with urea than their utilization alone for supplying N for growth of spinach.

Table 1 Effects of biogas digestate from cow dung and poultry manure on plant height of spinach grown in soil.

Treatment	Plant height (cm)		
	15 DAS	25 DAS	40 DAS
T1	12.00 d	13.50 f	15.50 d
T2	13.50 bcd	17.00 e	23.25 c
T3	12.75 cd	18.25 de	26.25 abc
T4	13.50 bcd	19.50cde	26.25 abc
T5	13.50 bcd	20.75 bcd	25.50 bc
T6	13.25 bcd	18.75 de	26.25 abc
T7	15.25 ab	24.50a	28.75 a
T8	16.50 a	23.25 ab	28.75 a
T9	16.00 a	21.50 ab	28.75 a
T10	14.50 abc	20.75 bcd	27.00 ab
Significance of F value	0.05	0.01	0.001

Figures in the column denoted by same letter (s) did not differ significantly according to DMRT at $p \leq 0.05$

Number of leaves per plant

The number of leaves per spinach plant of was recorded at 15, 25 and 40 DAS of seed. Mean values of number of leaves per plant are given in Table 2. Number of leaves was the minimum in the control treatment (T_1) during the entire period of experimentation. The maximum number of leaves was observed in treatment T_8, T_7 and T_7 at 15, 25 and 40 DAS, respectively. A significant variation in number of leaves was observed among the treatments. Addition of 50% N from urea+50% N from cow dung digestate (T_7), 50% N from urea+50% N from poultry manure digestate (T8), significantly increased the number of leaves compared to control. However, there was no significant difference between T_7 and T_8 treatments. Application of 100% N from urea fertilizer (T_2) produced significantly higher number of leaves compared to control at 25 DAS and 40 DAS, but not at 15 DAS. The number of leaves found in treatments T_6, T_9 and T_{10} were also significantly higher than that of control both at 25 and 40 DAS, but they were statistically similar with each other. However, 100% N from cow dung digestate (treatment T_3) did not have much effect on the number of leaves when compared to control at any growth stage.

Table 2. Effects of biogas digestate from cow dung and poultry manure on number of leaves of spinach grown in soil.

Treatment	Number of leaves plant^{-1}		
	15 DAS	25 DAS	40 DAS
T1	4.00 c	4.33 d	6.33 d
T2	4.67 abc	5.33 bc	7.67bc
T3	5.00 abc	5.00 cd	6.33 d
T4	5.00 abc	5.33 bc	7.33 cd
T5	5.00 abc	5.33 bc	7.33 cd
T6	4.67 abc	6.00 ab	7.67 bc
T7	5.33 ab	6.33 a	9.33 a
T8	5.67 a	6.00 ab	8.67 ab
T9	4.33 bc	6.00 ab	7.67 bc
T10	4.67 abc	5.33 bc	7.67 bc
Significance of F value	0.01	0.001	0.001

Figures in the column denoted by same letter (s) did not differ significantly according to DMRT at $p \leq 0.05$

Fresh weight of shoot and root

Fresh weight of shoot and root varied from 43.03-114.34 g pot^{-1} and 7.24-13.95 g pot^{-1}, respectively (Table 3). Application of biogas digestate from cow dung and poultry manure, raw cow dung and poultry manure and urea alone or their different combinations significantly increased fresh weight of shoot and root compared to the control. The lowest shoot and root weight was observed in control treatment T_1 where neither digestate nor raw cow dung and poultry manure and inorganic fertilizer was applied. The highest shoot and root weight was observed in treatment T_7 where 50%N from urea +50% N from cow dung was applied. However, the treatments T_5, T_6, T_8, T_9 and T_{10} were similar to T_7 in producing fresh weight of shoot and root. The fresh weight of shoot obtained with treatment T_3 (100% N from cow dung digestate) and T_4 (100% N from poultry manure digestate) was similar to each other but were significantly lower than those with treatment T_6 (100% N from raw poultry manure), T_7 (50% N from urea+ 50% N from cow dung digestate),T_8 (50% N from urea+ 50% N from poultry manure digestate),T_9 (50% N from urea+ 50% N from raw cow dung) and T_{10} (50% N from urea+ 50% N from raw poultry manure).

Table 3 Effects of biogas digestate from cow dung and poultry manure on fresh and dry weight of spinach grown in soil.

Treatment	Fresh weight (g pot^{-1})		Dry weight (g pot^{-1})	
	Shoot	Root	Shoot	Root
T1	43.03 d	7.24 c	4.88 c	1.35 d
T2	83.02 bc	10.24 b	10.90 ab	1.85 cd
T3	76.51 c	10.09 b	9.16 b	2.26 abc
T4	78.47 c	10.61 b	9.19 b	2.09 bc
T5	94.41 abc	11.41 ab	10.70 ab	2.38 abc
T6	104.08 ab	10.88 ab	11.99 a	1.87 cd
T7	114.34 a	13.95 a	12.25 a	2.80 a
T8	111.03 a	12.17 ab	12.69 a	2.27 abc
T9	110.07 a	12.33 ab	11.97 a	2.61 ab
T10	106.23 ab	11.30 ab	11.15 ab	2.21 bc
Significance of F value	0.001	0.01	0.001	0.001

Figures in the column denoted by same letter (s) did not differ significantly according to DMRT at $p \leq 0.05$

Dry weight of shoot and root

Dry weight of shoot and root ranged from 4.88-12.69 g pot^{-1} and 1.35-2.80 g pot^{-1}, respectively (Table 3). The lowest shoot and root weight was found in treatment T_1 (control); and the highest shoot and root weight was found in treatment T_8 and T_7, respectively. A significant variation in shoot and root dry weight was observed among the treatments. Application of 100% N from urea (T_2) significantly increased dry weight of shoot but not root compared to control. However, 100%N from cow dung digestate (T_3) and poultry manure digestate (T_4) did not affect dry weight of shoot and root of spinach. Similar results were found between raw cow dung and raw poultry manure in treatment T_5 (100% N from cow dung) and T_6 (100% N from raw poultry manure). Dry weight of shoot found with T_3 (100% N from cow dung digestate) and T_4 (100% N from poultry manure digestate) was significantly higher than that with T_1 (control), but lower than that with T_6 (100% N from raw poultry manure), T_7 (50% N from urea+ 50% N from cow dung digestate), T_8 (50% N from urea+ 50% N from poultry manure digestate) and T_9 (50% N from urea+ 50% N from raw cow dung). However, there were no significantly differences among the treatments T_6, T_7, T_8 and T_9 treatments.

The growth characteristics in terms of number of leaves per plant and plant height, and biomass production of spinach were significantly affected by treatments of urea fertilizer, digestate from cow dung and poultry manure, raw cow dung and poultry manure and their different combinations. In accordance with the present study, Islam (2016) reported that application of solid waste slurry from biogas plant resulted in increase of plant height of spinach. Manna and Hazra (1996) also found an increase of cob yield of maize by application of biogas slurry. Application of raw cow dung (100% N from cow dung; T_5) and raw poultry manure (100% N from raw poultry manure) did not differ significantly in producing fresh and dry weight of shoot and root of spinach. Addition of 50% N from urea+ 50% N from cow dung digestate (T_7) and 50% N from urea+ 50% N from poultry manure digestate (T_8) were comparatively more effective than other combinations in ensuring good performance in growth and fresh weight of spinach shoot. Fresh weight of shoot was increased by165% and 158% over control with these treatments (T_7 and T_8), respectively. In agreement with the present study, Begum et al., (2017) observed that combined use of poultry manure and biogas slurry with urea demonstrated significant effects on the number of effective tillers hill^{-1}, panicle length, filled grains per panicle and 1000 grain weight of BRRI dhan 29. Islam (2018) reported that poultry manure biogas residues alone and its different combination with inorganic fertilizer gave higher number of leaves per plant, plant height, number of fruits per plant and fresh fruit yield of tomato than 100% RDF alone. Yu et al., (2010) reported that the application of bio-slurry in combination with inorganic N fertilizer increased fruit yield of tomato including increased in organic matter, available N, P, and K and total N and P in soil. Shakti (2006) reported that application of 50% recommended dose of inorganic fertilizer +2 t ha^{-1} cow dung biogas residues increased the yield of cabbage, brinjal and tomato by 480, 336 and 284%, respectively compared to control. The yield responses were comparable with those of 100% recommended fertilizer doses. BARI (2008) recorded about 371% yield increase of cabbage over native fertility by 5 t ha^{-1} cow dung slurry with integrated plant nutrient system (IPNS) base inorganic fertilizer. Yield increase due to application of 3 t ha^{-1} poultry manure slurry with IPNS base inorganic fertilizer was 394% (BARI, 2008).

The low response of spinach to urea fertilizer in the present study as compared to combined application of urea fertilizer with raw cow dung and poultry manure or their digestate corroborates the response patterns reported by other researchers on okra (Kibria et al., 2013) and on maize crop (Olaniyi et al., 2005).. The integration of organic sources and synthetic sources of nutrients not only supply essential nutrients but also have some positive interaction to increase nutrient use efficiency (Karim et al., 2011) and thereby reduce environmental hazards (Khaliq et al., 2004). In general, biogas digestate presents an efficient nitrogen source for plants with the potential to improve crop yield and soil properties (Prasad and Power, 1991; Pathak et al., 1992). However, it is important to remember that N is the most common limiting factor for crop growth in organic farming systems (Pang and Letey, 2000; Möller et al., 2006) owing to failure in synchronizing crop N demand and supply to the soil by mineralization of organic fertilizers (Möller and Stinner, 2009).

CONCLUSION

Application of 50% N of recommended dose from urea + 50%N from cow dung digestate (T_7) and 50% N of recommended dose from urea+ 50%N from poultry manure digestate (T_8) resulted higher fresh shoot yield of spinach compared to other treatments. Therefore, combined application of urea and biogas digestate from cow dung and poultry manure may be recommended for sustainable productivity of spinach.

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