Research Article

EFFECT OF DIGESTATE /BIOGAS SLURRY IN WHEAT UNDER RICE – WHEAT CROPPING SYSTEM

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ABSTRACT

Soil fertility in several parts of Nepal is declining mainly due to continuous cultivation and without replenishing soil nutrient removal by crops with quality fertilizers in required quantity. Nepal does not produce chemical fertilizers and most farmers cannot afford to buy the imported fertilizer. Under these circumstances, emphasizing locally available low cost organic manure may become an important option. This research compares the effect of different stages [5 days (fresh), 90 days (3 months) and 180 days (6 months)], and dose (0, 5, 10 and 15 t ha^{-1}) of digestate/biogas slurry on wheat yield. Field experiments were conducted during winter seasons of 2016 – 2017 (first year) and 2017 - 2018 (second year) in a silt loam soil to identify suitable stage and appropriate dose of digestate regarding yield maximization of wheat. The experiment was done by using 2 factors Randomized Complete Block Design (RCBD), each treatment with three replications. Grain yield was significantly higher (2.2 t ha^{-1}) due to application of biogas slurry of 5 days stage than the stage of 90 days (2.1 t ha^{-1}) in 2016 - 2017, 2017 – 2018 and in pooled analysis. Grain yield increased significantly up to the dose of 10 t ha^{-1} as compared to that of no use (check), and became saturated, in 2016 – 2017, 2017 – 2018, and also in pooled analysis. Hence, the use of biogas slurry of the stage of 5 days with the dose of 10 t ha^{-1} resulted higher grain yield of wheat (*cv*. Vijay), is edaphically and economically viable option for wheat production.

Key words: crop productivity, organic matter, *Triticum aestivum*, nitrogen

INTRODUCTION

Due to recent changes in agricultural practices and increasing resource constraints, Nepal is facing a serious problem of soil quality decline (Bista et al., 2010). Hartemink et al., (2008) documented several constrains in soil fertility management in Nepal because of deforestation and other land use changes. These changes comprises non-agricultural uses of fertile land, land fragmentation and cultivation in marginalized areas, cultivation on the slopes, overgrazing, burning of crop residues, imbalanced use of agrochemicals, and declining use of organic manure. The main soil degradation processes associated with land use changes include accelerated erosion by water and wind, salinization, flooding, water logging, and soil fertility depletion; in South and South-East Asia (Jacinthe et al., 2004). Biogas slurry/digestate, in agriculture, is a typical high-quality organic material. The secondary use of biogas slurry in agriculture production is to avoid environmental pollution and to achieve the ecological sustainable development is of great practical significance and the social meanings.

Wheat (*Triticum aestivum* L.) is the most extensively grown cereal crop in the world with production of 750 million tons per year (USDA, 2017). Wheat is the third most important cereal crop after rice and maize, in terms of both area and production, in Nepal. In 2016/2017, wheat was cultivated in 7, 40, 150 hectare with production of 18, 56, 191 metric tons, in Nepal (AICC, 2075). Wheat contributes essential amino acids, minerals, and vitamins, and beneficial phytochemicals and dietary fibre components to the human diet, and these are particularly enriched in whole-grain products (Shewry, 2009).

Nearly 65.6 % Nepalese depend on agriculture and manure is the major source of the fertilizer used in the country (AICC, 2075). There are not any chemical fertilizer industries in Nepal. The digested bio-slurry, a byproduct of the biogas has been proved to be the best nutrients or farms in the rural households. The use of biogas slurry has replaced the use of raw dung as well as chemical fertilizer. In contrary to composting and direct burning of animal manure, Anaerobic Digestion (AD) provides fuel and fertilizer, rather than simply one or the other. The spent digestate exiting the biogas plant remains rich in both macro- and micro-nutrients, and when applied to the land, enhances physical, chemical, and biological attributes of the soil as well as increases crop productivity (Surendra et al., 2014).

Biogas slurry is used to improve soil fertility, soil structure and crop productivity. Biogas slurry has so many advantages that it can be referred to as ‘bio gold'. Animal manure when undergone anaerobic digestion provides several benefits by improving their fertilizer qualities, reducing odors and pathogens and producing a renewable fuel – the biogas (Holm-Nielsen et al., 2009). The slurry produced from the digestion process has superior manurial value as compared to the raw animal waste and finds several applications (Gurung, 1997).

Suitable stage and appropriate dose of digestate regarding yield maximization of wheat has not yet been identified in Nepal. Hence, this study was done to investigate the effect of different stage and dose of digestate /biogas slurry in wheat under rice – wheat cropping system, in southern plain of Nepal.

MATERIAL AND METHODS

Study site

Field experiments during 2016 - 2017 and 2017 - 2018 were conducted at research farm of National Wheat Research Program (NWRP) (27°31′49″ N, 83°27′36″ E and 82 m above mean sea level) which is located 2 km north from Bhairahawa on the Siddhartha highway. The climate is of sub-tropical type with three distinct seasons: summer, rainy and winter. NWRP consists of land with silt loam soil type, varied from lower wetland to medium wetland (Khadka et al., 2015).

Experimental design and crop management

The experiment was laid out in 2 factors Randomized Complete Block design (RCBD), each treatment with three replications. The first factor was stage of digestate [5 days (fresh), 90 days (3 months) and 180 days (6 months)] and second factor was dose of digestate [0 (Check), 5, 10 and 15 t ha^{-1}]. The plot size was 16 m^2 (4 m × 4 m). The wheat variety used in the experiment was Vijay. Chemical properties of soil of the experimental field have been depicted in Table (1) whereas main characteristics of biogas slurry used in the field experiment are presented in Table (2).

Table 1. Chemical properties of Soil

pH	Organic matter (%)	Nitrogen (%)	Phosphorus (Kg ha^{-1})	Potassium (Kg ha^{-1})
6.69	**2.51**	**0.11**	**84**	**89.33**

Note: Textural class: Silt Loam

Table 2. Main characteristics of biogas slurry used in the field experiment

Parameters	Test Method	Observed Values		
		Fresh	3 Months	6 Months
pH (1:5 Extration)	pH Metric	7.4	7.53	8.40
Moisture, %	Gravimetric	86.64	78.63	78.46
Dry Matter, (%)	Gravimetric	13.36	21.37	21.54
Nitrogen, % (Oven dry basis)	Kjeldal Digestion	2.54	1.97	2.14
Potassium as K_2O, % (Oven dry basis)	AAS	0.47	0.47	1.54
Phosphorous as P_2O_5, % (Oven dry basis)	Spectrophotometer	2.61	2.55	2.84
Organic Matter, %	Titration	70.37	56.44	60.58

Measurement of plant growth and yield

Plant growth stages were recorded on 50 marked plants in the second to the outer row in each plot. A particular stage was supposed to be completed when 75% plants showed the characteristics of that phase, and numbers of days were counted from date after sowing (DAS). Plant height and spike length were measured from randomly selected 10 plants per plot at physiological maturity stage. Spikes from the 10 randomly selected plants were sampled to count grains per spike. The number of effective tillers per square meter was counted at physiological maturity stage from 1 m^2 areas in each plot.

After final harvesting, the crop was sun dried, threshed, cleaned and grain was sun dried again. Grain yield was adjusted at 12% moisture since the grain was sun dried instead of oven drying. Thousand grain weight were determined by weighing 1000 kernels from each plot.

Statistical analysis

Data from individual year and from combined years were analyzed for analysis of variance (ANOVA) using Fischer's protected least significant difference at $p < 0.01$ and $p < 0.05$. All data were statistically analyzed using a statistical software package i.e. Gen Stat 13.2 (VSN International, Hemel Hempstead, Hertfordshire, United Kingdom).

RESULTS AND DISCUSSION

Plant height

Plant height was significantly affected by stage and dose of biogas slurry in 2016 – 2017, 2017 – 2018 and in pooled analysis. A perusal of data (Table 3) indicated that plant height due to the application of biogas slurry of 5 days was one cm taller than plant height obtained from the use of biogas slurry of 90 and 180 days, in 2016 - 2017. Plant height obtained due to the use of biogas slurry of the stage of 5 and 180 days was 1 cm taller than plant height obtained from the use of biogas slurry of 90 days, in 2017-2018 as well as in pooled analysis.

In 2016 – 2017, plant height attained due to use of biogas slurry of the dose of 10 and 15 t ha^{-1} was significantly ($p < 0.01$) taller (90 cm) than the check (88 cm) and of 5 t ha^{-1} (89 cm) (Table 3). A perusal of data (Table 5) revealed that plant height was significantly ($p < 0.01$) higher with different dose (5 t ha^{-1}, 10 t ha^{-1} and 15 t ha^{-1}) of biogas slurry than the check (0 t ha^{-1}), in 2017 – 2018. It was noticed that plant height increased by 1 cm as in each dose incremented. In pooled analysis, plant height obtained due to the use of biogas slurry of 10 and 15 t ha^{-1} was significantly taller than of check and 5 t ha^{-1}. Similarly, plant height obtained with the dose of biogas slurry of 15 t ha^{-1} was one cm taller than of use of 10 t ha^{-1} (Table 7). Makádi (2012) confirmed that due to the high available nutrients content, digestate application resulted in significantly higher above ground biomass yields in the case of winter and spring wheat than the farmyard manure and undigested slurry treatment. Plant height of wheat in first year was significantly higher (89 cm) than that of second year (82 cm) in pooled analysis (Table 3).

Table 3. Effect of different stages and dose of biogas slurry on plant height and occurrence of heading as well as physiological maturity of wheat at NWRP, Nepal

Treatments	PH			DH			DM		
	2016 - 17	2017 - 18	Pooled	2016 - 17	2017 - 18	Pooled	2016 - 17	2017 - 18	Pooled
Stages of biogas slurry									
5 days	90	83	86	75	82	78	119	124	122
90 days	89	82	85	76	83	79	119	124	122
180 days	89	83	86	75	82	79	119	124	122
F test	**	**	**	**	**	**	ns	ns	ns
LSD	0.50	0.35	0.37	0.37	0.35	0.24	0.41	0.14	0.22
Dose of biogas slurry									
0 t ha^{-1}	88	81	85	76	84	80	120	125	122
5 t ha^{-1}	89	82	85	76	83	79	119	125	122
10 t ha^{-1}	90	83	86	75	82	78	118	124	121
15 t ha^{-1}	90	84	87	75	81	78	118	123	121
F test	**	**	**	**	**	**	**	**	**
LSD	0.58	0.40	0.43	0.43	0.40	0.28	0.47	0.16	0.26
Year									
First Year	-	-	89	-	-	75	-	-	119
Second Year	-	-	82	-	-	82	-	-	124
F test	-	-	**	-	-	**	-	-	**
LSD	-	-	0.30	-	-	0.19	-	-	0.18
Interaction									
F test	ns	ns	ns		ns	ns	ns	ns	ns
Grand mean	89	82	86	75	82	79	119	124	122
CV (%)	0.7	0.5	0.7	0.6	0.5	0.5	0.4	0.1	0.3

** indicate significant F values at $p < 0.01$ and ns indicate non-significant at $p < 0.05$; PH = Plant height, DH= days to heading, DM = Days to maturity

Days to heading and physiological maturity

Different stage and dose of biogas slurry significantly ($p < 0.01$) affected days to heading of wheat in 2016 – 2017, 2017 – 2018 and in pooled analysis (Table 3). Heading was 1 day earlier with biogas slurry of 5 and 180 days than with 90 days in 2016 – 2017 and 2017 – 2018, respectively. Heading was 1 day earlier with 5 days biogas slurry than 90 and 180 days slurry in pooled analysis. Field experiments and incubation tests have determined that biogas slurry positively affects plant growth, soil properties, and soil microbes (Xu et al., 2019).

Heading occurred one day earlier with the dose of 10 and 15 t ha^{-1} of biogas slurry than the dose of 5 t ha^{-1} and check in 2016 – 2017. Heading of check was 1 day later than 5 t ha^{-1}, 2 days later than 10 t ha^{-1} and 3 days later than 15 t ha^{-1} doses of biogas slurry; in 2017 – 2018. Heading due to the dose of 10 and 15 t ha^{-1} of biogas slurry was 1 and 2 days earlier than the dose of 5 t ha^{-1} and the check while averaged across two years. Heading was 7 days earlier in first year than second year, in pooled analysis (Table 3).

Non - significant difference was observed in attaining physiological maturity due to the application of biogas slurry of different stage in 2016 – 2017 and 2017 -2018 and in pooled analysis.

Different dose of biogas slurry significantly ($P < 0.01$) affected the occurrence of physiological maturity in 2016 - 2017, 2017 – 2018 and in pooled analysis. In 2016 – 2017, the attainment of physiological maturity of wheat with the dose of 10 and 15 t ha^{-1} of biogas slurry was 1 day earlier than the dose of 5 t ha^{-1}. Similarly, the attainment of physiological maturity of wheat with the dose of 10 and 15 t ha^{-1} of biogas slurry was 2 days earlier than the check. The occurrence of physiological maturity of wheat with the dose of 15 t ha^{-1} was 1 day earlier than the use of biogas slurry of 10 t ha^{-1} and 2 days earlier than the check as well as the use of biogas slurry of 5 t ha^{-1}, in 2017 – 2018. The attainment of physiological maturity of wheat due to the use of biogas slurry of the dose of 10 and 15 t ha^{-1} was 1 day earlier than the dose of biogas slurry of 5 t ha^{-1} as well as check, while averaged across two years. Physiological maturity was 5 days earlier in first year than in the second year, in pooled analysis (Table 3).

Yield attributing characters (tiller number, length of ear – head / spike length, grains per spike and thousand kernel weight)

Tiller number

Effective tiller number per square meter of wheat was significantly ($p < 0.01$) affected by different stage and dose of biogas slurry in 2016 – 2017, 2017 – 2018 and in pooled analysis (Table 4). The use of biogas slurry of the age of 5 days had significantly more tillers than 90 and 180 days in 2016 - 2017, 2017 – 2018 and averaged across two years. Similarly, tillers produced due to the application of biogas slurry of the age of 180 days had significantly more tillers than that of 90 days in 2016 - 2017, 2017 – 2018 and in pooled analysis.

Significant effect was observed with the different dose of biogas slurry incremented with respect to check and each other in 2016 - 2017, 2017 – 2018 and in pooled analysis. The numbers of effective tillers per square meter in first year were significantly higher (209) than that of second year (196) in pooled analysis (Table 4).

Length of ear – head /Spike length

Significant difference was observed on length of ear – head due to the stage of biogas slurry, in 2016 – 2017, 2017 – 2018 and in pooled analysis (Table 4). Application of nitrogen (N) through organic manure (biogas slurry) or by the integrated use of chemical + organic sources, and increasing N rate led to significant improvements in yield and yield attributes of wheat (Gopal et al., 2000). The use of biogas slurry of the stage of 5 days had longer ear – head than the ear – head under the use of biogas slurry of 90 and 180 days; in 2016 – 2017, 2017 – 2018 and in pooled analysis. However, biogas slurry of the stage of 180 days resulted longer ear – head than the use of biogas slurry of the stage of 90 days; in 2016 – 2017, 2017 – 2018 and in pooled analysis.

The length of ear – head of wheat increased as the dose of the biogas slurry was increased, in 2016 – 2017, 2017 – 2018 and in pooled analysis. The longest ear – head was observed with the dose of biogas slurry of 15 t ha^{-1} whereas shortest with the check; in 2016 – 2017, 2017 – 2018 and averaged across two years. Length of ear - head in first year was significantly longer (9.8 cm) than that of Year – 2, in pooled analysis (Table 4).

Table 4. Effect of different stages and dose of biogas slurry on yield attributes and yield of wheat at NWRP, Nepal

Treatments	Tillers per square meter			Length of ear – head / Spike L.			Grains per spike			Thousand Kernel Weight			Grain yield		
	2016 - 17	2017 - 18	Pooled	2016 - 17	2017 - 18	Pooled	2016 - 17	2017 - 18	Pooled	2016 - 17	2017 - 18	Pooled	2016 - 17	2017 - 18	Pooled
Stages of biogas slurry															
5 days	211	197	204	10	9.7	9.9	33	33	33	51	52	51	2.2	2.2	2.2
90 days	208	194	201	9.5	9.4	9.4	33	33	33	51	51	51	2.1	2.1	2.1
180 days	209	196	202	9.9	9.6	9.7	33	33	33	51	51	51	2.2	2.1	2.2
F test	**	**	**	**	*	**	ns	ns	ns	ns	**	ns	**	**	**
LSD	0.97	0.72	0.67	0.14	0.28	0.16	0.15	0.21	0.16	0.40	0.19	0.21	0.01	0.01	0.01
Dose of biogas slurry															
0 t ha^{-1}	206	192	199	9	9	9	32	32	32	50	50	50	2	2	2
5 t ha^{-1}	208	194	201	9.7	9.3	9.5	33	33	33	51	51	51	2.1	2.1	2.1
10 t ha^{-1}	210	197	204	10	9.8	9.9	33	33	33	52	52	52	2.2	2.2	2.2
15 t ha^{-1}	212	199	205	10.6	10.2	10.4	34	34	34	52	52	52	2.2	2.2	2.2
F test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
LSD	1.12	0.83	0.78	0.16	0.32	0.19	0.18	0.24	0.18	0.46	0.22	0.25	0.01	0.01	0.01
Year															
First Year	-	-	209	-	-	9.8	-	-	33	-	-	51	-	-	2.2
Second Year	-	-	196	-	-	9.5	-	-	33	-	-	51	-	-	2.1
F test	-	-	**	-	-	**	-	-	ns	-	-	ns	-	-	**
LSD	-	-	0.55	-	-	0.13	-	-	0.13	-	-	0.17	-	-	0.01
Interaction															
F test	ns	Ns	ns	**	ns	*	ns	ns	ns	ns	*	ns	ns	ns	ns
Grand mean	209	196	202	9.8	9.5	9.7	33	33	33	51	51	51	2.1	2.1	2.1
CV (%)	0.6	0.4	0.6	1.7	3.5	3	0.6	0.8	0.8	0.9	0.5	0.7	0.8	0.8	1

Interaction effect of stage and dose of biogas slurry on length of ear – head/spike length of wheat

Different stage and dose of biogas slurry had highly significant effect on length of ear – head of wheat in 2016 – 2017. Biogas slurry of 5 days produced significantly longer length of ear – head than 90 days with the dose of 5 t ha^{-1}. Biogas slurry of 180 days produced significantly longer length of ear – head than 90 days with the dose of 5 t ha^{-1} (Table 5).

Biogas slurry of 5 days produced significantly longer spike length than 90 days with the dose of 15 t ha^{-1}. Biogas slurry of 180 days produced significantly longer spike length than 90 days with the dose of 15 t ha^{-1} (Table 4).

Table 5. Interaction effect of stage and dose of biogas slurry on length of ear – head of wheat at NWRP, Bhairahawa, Rupandehi; 2016 - 2017

Treatments	Length of ear - head (cm)			
	Dose of biogas slurry			
	No use (check)	5 t ha^{-1}	10 t ha^{-1}	15 t ha^{-1}
Stages of biogas slurry				
5 days	9	10	10	11
90 days	9	9	10	10
180 days	9	10	10	10.7
F test	**		LSD	0.28

** indicate significant F values at $p < 0.01$

Grains per ear – head / spike

The effect of stage of biogas slurry in the formation of number of grains per ear – head was found non – significant in 2016 – 2017, 2017 – 2018 and in pooled analysis (Table 4). However, significant ($p < 0.01$) difference was observed in the formation of number of grains per ear – head due to different doses of biogas slurry in 2016 – 2017, 2017 – 2018 and averaged across two years. Biogas slurry gave the highest value of grains per spike (Bharde et al., 2003). Slightly higher number of grains per ear head was observed with the dose of biogas slurry of 5, 10 and 15 t ha^{-1} than the check. In pooled analysis, there was insignificant difference on formation of grains per ear head (Table 4).

Thousand kernel weight

Non – significant effect of stage of biogas slurry was observed on thousand kernel weight of wheat in 2016 -2017 and in pooled analysis (Table 4). However, significant ($p < 0.01$) difference on thousand kernel weight of wheat due to different stages of biogas slurry was recorded in 2017 -2018. Slightly higher weight was recorded under the use of biogas slurry of 5 days' stage.

Thousand kernel weight of wheat was significantly ($p < 0.01$) influenced by different doses of biogas slurry in 2016 – 2017, 2017 – 2018 and in pooled analysis (Table 4). Thousand kernel weight of wheat was slightly higher with the dose of biogas slurry of 5, 10 and 15 t ha^{-1} than the check.

Interaction effect of stage and dose of biogas slurry on thousand kernel weight of wheat

Biogas slurry of 5 days produced significantly ($p < 0.05$) higher thousand kernel weight than 90 days with the dose of 5 t ha^{-1} in 2017 - 2018. Biogas slurry of 180 days produced significantly higher thousand kernel weight than 90 days with the dose of 5 t ha^{-1} (Table 6).

Biogas slurry of 5 days produced significantly higher thousand kernel weight than 90 days with the dose of 10 t ha^{-1}. Likewise, biogas slurry of 180 days produced significantly higher thousand kernel weight than 90 days with the dose of 10 t ha^{-1} (Table 6).

Biogas slurry of 5 days produced significantly higher thousand kernel weight than 90 days with the dose of 15 t ha^{-1}. Biogas slurry of 180 days produced significantly higher thousand kernel weight than 90 days with the dose of 15 t ha^{-1} (Table 6).

Table 6. Interaction effect of stage and dose of biogas slurry on thousand kernel weight of wheat at NWRP, Bhairahawa, Rupandehi; 2017 - 2018

Treatments	1000 kernel weight (g)			
	Dose of biogas slurry			
	0 t ha^{-1}	5 t ha^{-1}	10 t ha^{-1}	15 t ha^{-1}
Stages of biogas slurry				
5 days	50	51	52	52
90 days	50	50	51	51
180 days	50	51	52	52
F test	*		LSD	0.39
			CV (%)	0.5

* indicate significant F values at $P < 0.05$.

Grain yield

The mean grain yield in the experiment was 2.1 t ha^{-1} (Table 4). This yield of wheat is obtained without the use of chemical fertilizers. Significant ($P < 0.01$) effect due to the use of different age and dose of biogas slurry on grain yield was noticed in 2016 – 2017 (Table 3), 2017 – 2018 (Table 5) and in pooled analysis (Table 7). Similar and highest yield was recorded with 5 and 180 days age of biogas slurry in 2016 - 2017 and averaged across two years. However, highest yield was recorded with 5 days age of biogas slurry in 2017 – 2018. This might be due to supplementation of higher (2.54 %) nitrogen percentage found in biogas slurry of 5 days age. Similarly, the contribution of higher (70.37%) organic matter may also be counted for higher grain yield (Table 2). The biogas slurry is a good source of plant nutrients and can improve crop yield and soil properties (Smith & Elliot, 1990; Prasad & Power, 1991; Pathak et al., 1992).

The response of dose of biogas slurry regarding yield of wheat was observed up to the use of dose of biogas slurry of 10 t ha^{-1}. Similar yield was obtained due to the application of biogas slurry of dose of 10 and 15 t ha^{-1} in 2016 – 2017, 2017 – 2018 and averaged across two years. The lowest yield was recorded of check and highest yield is obtained due to the dose of 10 and 15 t ha^{-1}, of biogas slurry; in 2016 – 2017, 2017 – 2018 and in pooled analysis. Significantly higher grain yield was recorded in first year than second year, in pooled analysis (Table 4). Application of biogas slurry to the farmland can effectively improve the physical and chemical properties of soil and increase crop yield and grain quality (Du et al., 2016; Islam et al., 2010).

Interaction effect of age and dose of biogas slurry on length of ear – head (spike length) of wheat (pooled analysis)

Biogas slurry of 5 days produced significantly longer length of ear - head than 90 days with the dose of 5 t ha^{-1}. Biogas slurry of 180 days produced significantly longer length of ear – head than 90 days with the dose of 5 t ha^{-1} (Table 7).

Biogas slurry of 5 days produced significantly longer length of ear – head than 90 days with the dose of 15 t ha^{-1}. Biogas slurry of 180 days produced significantly longer length of ear - head than 90 days with the dose of 15 t ha^{-1} (Table 7).

Table 7. Interaction effect of stage and dose of biogas slurry on length of ear – head (spike length) of wheat at NWRP, Bhairahawa, Rupandehi; average (pooled analysis)

Treatments	Length of ear-head (cm)			
	Dose of biogas slurry			
	No use (check)	**5 t ha^{-1}**	**10 t ha^{-1}**	**15 t ha^{-1}**
Stages of biogas slurry				
5 days	9	9.8	10	11
90 days	9	9	10	10
180 days	9	10	10	10.4
F test	*		LSD	0.36
			CV (%)	3.2

* indicate significant F values at $p < 0.05$.

CONCLUSION

Grain yield of wheat obtained due to the application of biogas slurry of 5 days stage was significantly higher than that of 180 days in second year of field experiment. However, the grain yield due to 5 and 180 days stage of biogas slurry was equal in value in first year and in averaged across two years. Grain yield increased significantly up to the dose of 10 t ha^{-1} as compared to that of no use (check) and became saturated, in 2016 – 2017, 2017 – 2018, and in pooled analysis. Thus, the use of biogas slurry of 5 days stage with the dose of 10 t ha^{-1} with higher grain yield is edaphically and economically viable option for wheat production without use of chemical fertilizers.

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REFERENCES

AICC. (2075). Government of Nepal; Ministry of Agriculture, land management and co-operatives. Agriculture information and communication centre. Nepal. 2p.

Bharde, N. M., Shivay, Y. S. & Singh, S. (2003). Effect of biogas slurry and neem oil-treated urea sources on rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy*, *48*(*2*), 73-77.

Bista, P., Ghimire, R., Chandra Shah, S., & Raj Pande, K. (2010, September). Assessment of soil fertility management practices and their constraints in different geographic locations of Nepal. *Forum geographic*, *9*, 41 - 48.

Du, Z., Chen, X., Qi, X., Li, Z., Nan, J., & Deng, J. (2016). The effects of biochar and hoggery biogas slurry on fluvo-aquic soil physical and hydraulic properties: a field study of four consecutive wheat–maize rotations. *Journal of soils and sediments*, *16*(*8*), 2050-2058.

Gopal, S., Somani, L. L., & Totawat, K. L. (2000). Effect of integrated nitrogen management on yield attributing characters and yield of wheat. *Research on Crops*, *1*(*2*), 123-127.

Gurung, J. B. (1997). Review of literature on effects of slurry use on crop production. *Biogas Support Programme*, *102*.

Hartemink, A. E., Veldkamp, T., & Bai, Z. (2008). Land cover change and soil fertility decline in tropical regions. *Turkish Journal of Agriculture and Forestry*, *32*(*3*), 195-213.

Holm-Nielsen, J. B., Al Seadi, T., & Oleskowicz-Popiel, P. (2009). The future of anaerobic digestion and biogas utilization. *Bioresource technology*, *100*(*22*), 5478-5484.

Islam, M. R., Rahman, S. M. E., Rahman, M. M., Oh, D. H., & Ra, C. S. (2010). The effects of biogas slurry on the production and quality of maize fodder. *Turkish Journal of Agriculture and Forestry*, *34*(*1*), 91-99.

Jacinthe, P. A., Lal, R., Owens, L. B., & Hothem, D. L. (2004). Transport of labile carbon in runoff as affected by land use and rainfall characteristics. *Soil and Tillage Research*, *77*(*2*), 111-123.

Khadka, D., Lamichhane, S., Thapa, B., Rawal, N., Chalise, D. R., Vista, S. P. & Lakhe, L. (2015). Assessment of Soil Fertility Status and Preparation of Their Maps of National Wheat Research Program (NWRP), Bhairahawa, Nepal. *Proceedings of the workshop, 24-25 March 2015.*

Makádi, M., Tomócsik, A., & Orosz, V. (2012). Digestate: a new nutrient source–review. *Biogas*, 295-310.

Pathak, H., Kushwaha, J. S., & Jain, M. C. (1992). Eyahiation of manurial value of Biogas spent slurry composted with dry mango leaves, wheat straw and rock phosphate on wheat crop. *Journal of the Indian society of soil science*, *40*(*4)*, 753-757.

Prasad, R., & Power, J. F. (1991). Crop residue management. In *Advances in Soil Science* (pp. 205-251). Springer, New York, NY.

Shewry, P. R. (2009). Wheat. *Journal of experimental botany*, *60*(6), 1537-1553.

Smith, J. L., & Elliott, L. F. (1990). Tillage and residue management effects on soil organic matter dynamics in semiarid regions. In *Advances in soil science* (pp. 69-88). Springer, New York, NY.

USDA. (2017). Grain: world markets and trade. Retrieved from: Xldata/world/all wheat/prod/exports/stocks. (13 April, 2017).

Surendra, K. C., Takara, D., Hashimoto, A. G., & Khanal, S. K. (2014). Biogas as a sustainable energy source for developing countries: Opportunities and challenges. *Renewable and Sustainable Energy Reviews*, *31*, 846-859.

Xu, M., Xian, Y., Wu, J., Gu, Y., Yang, G., Zhang, X., Peng, H., Yu, X., Xiao,Y. & Li, L. (2019). Effect of biogas slurry addition on soil properties, yields, and bacterial composition in the rice-rape rotation ecosystem over 3 years. *Journal of Soils and Sediments*, *19*(*5*), 2534-2542.