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Research Article

Effect of Digestate on growth and production of rice under rice – wheat cropping system

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ABSTRACT

Field experiments were conducted during rainy seasons of 2017 and 2018 at National Wheat Research Program (NWRP), Bhairahawa to identify the suitable age and appropriate dose of digestate/biogas slurry regarding yield maximization of rice (*cv.* Ram dhan). The experiment compared the effect of different age [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 rice yield. The experiment was laid out in Randomized Complete Block design (RCBD) with three replications. Grain yield of rice was significantly higher (4.5 t ha^{-1}) with the application of biogas slurry of 5 days than 90 days (4.3 t ha^{-1}) age, in 2017 A. D. Similarly, yield was significantly higher (4.6 t ha^{-1}) with the application of biogas slurry 5 days than of 90 days (4.5 t ha^{-1}) age, in 2018. Yield due to the application of biogas slurry of 5 days was equal to the yield resulted from the use of biogas slurry of 180 days in 2017 and 2018. The pooled analysis showed that the yield with the application of biogas slurry of 5 days age was significantly higher (4.6 t ha-^{1}) than the yield due to the application of biogas slurry of 90 (4. 4 t ha^{-1}) and 180 days (4.5 t ha^{-1}) age. The yield of rice has been found increasing significantly as the dose of biogas slurry was incremented from 0 t ha^{-1} to 15 t ha^{-1} in 2017, 2018 and in pooled analysis. The yield of rice was significantly higher (4.6 t ha^{-1}) in 2018 than in 2017 (4.4 t ha^{-1}), in pooled analysis. Thus, the use of biogas slurry of the age of 5 days with the dose of 15 t ha^{-1} produced the higher grain yield of rice.

Keywords: Anaerobic digestion, Oryza sativa, crop productivity and grain yield

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops in the world serving as the principle food source for more than half of the world's population (Singh & Khush, 2000). Asia produces and consumes about 90% of the rice on earth (Childs and Burdett, 2000). Rice is a source of staple food for the majority of the 1.7 billion population of South Asia and a source of livelihood for more than 50 million households. The region cultivated rice on 6, 02, 25, 784 ha and produced 23, 29, 94, 388 metric tons of paddy in 2016 A. D. (FAOSTAT, 2016). It accounts for more than 50% of the total calories of Nepalese people (Kharel et al., 2018: Gadal et al, 2019). To feed ever increasing population, rice production in Nepal has to be increased over 6.0 million tons by 2020 to meet the growing demand of ever increasing population (Kharel et al., 2018). Rice was cultivated in largest area i. e. in 15, 52, 469 hectare with production of 52, 30, 327 metric tons, during the fiscal year 2073/2074 B. S. (2016/2017 A. D.) (Krishi Diary, 2075). The productivity of rice was 3.37 t/ha in the fiscal year 2073/2074 B. S. (Krishi Diary, 2075).

The solid and/or liquid material remaining after undergoing anaerobic digestion of organic waste; often still high in nutrient content is called biogas slurry (Vogeli *et al.*, 2014). Biogas slurry is a valuable source of crop nutrients and organic matter and improves soil physical conditions (Ghoneim *et al.*, 2008). There are indications of stagnation or even decline in the productivity of rice-wheat cropping system due to decline in the soil organic matter, overmining and losses of nutrients from soil and non-availability of cost effective fertilizers. Therefore, we need the fertilizers which are not only cost effective but also maintain soil health favourably. Biogas generators or digesters yield two products: the biogas itself and a semisolid by-product called effluent or slurry that can be used as a high – quality fertilizer. As a liquid by-product in anaerobic digestion of organic waste, anaerobically digested slurry (ADS), is rich in N and offers a beneficial N source for crop cultivation (Arthurson, 2009). Field application of ADS may reduce greenhouse gas emissions (Amon *et al.*, 2006; Meijide *et al.*, 2007) and mitigate water pollution from direct discharge of ADS (Cho *et al.*, 2000; Lu *et al.*, 2012) to surface waters. In contrast to composting and direct burning, anaerobic digestion provides both fuel and fertilizer, rather than simply one or the other. The spent digested slurry 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.

Biogas slurry (BS) originating from anaerobically digested animal waste is a good source of plant nutrients and is thus considered a nutrient-enriched organic fertilizer for crop production (Abubaker *et al.*, 2013; Ozores-Hampton *et al.*, 2011; Win *et al.*, 2014). BS is used extensively to maintain sustainability in agricultural soils because (1) more nutrients are available during the period after its addition (Zirkler *et al.*, 2014); (2) soil C and N are mineralized (Galvez et al. 2012); (3) greenhouse gas emissions are reduced (Terhoeven-Urselmans *et al.*, 2009); and (4) nitrogen use efficiency (Sieling *et al.*, 2013) and crop yield (Abubaker *et al.*, 2012) are improved. Applying BS improves soil properties by increasing the nutrient content and bioactive substances, such as humic acids, consequently increasing plant productivity. Therefore, BS has attracted considerable attention for effectively improving soil fertility and ecological functions (Xu *et. al.*, 2019).

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

MATERIALS AND METHODS

Study site

Field experiments during 2017 and 2018 were conducted at research farm of National Wheat Research Program (NWRP) (27°31′49″ N, 83°27′36″ E and 82 m above sea level). 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 Randomized Complete Block design (RCBD) with three replications. The first factor was age 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}]. Each treatment was replicated thrice. The plot size was 16 m^2 (4 m × 4 m).

The rice variety used in the experiment was Ram dhan. Ram dhan was released in 2063 B.S. (2006 A. D.) recommended for Terai and Inner Terai region of Nepal. Foundation seed of Ram dhan was used in the experiment. The plots were irrigated 3 - 4 times in each study year. In each irrigation event, all plots were flooded with water till the water height reaches up to 5 – 7 cm from the soil surface. Chemical fertilizers were not applied in the research plots. Two hand weedings were done in each study year. Main characteristics of biogas slurry used in the field experiment is presented in Table 1.

Measurement of plant growth and yield

Plant growth was recorded on 50 marked plants in the second outer row in each plot. A particular stage was supposed to be completed when 75 % plants showed the characteristics of that phase, and number of days were counted from the date of soaking the seed in water, of rice, for sprouting. Plant height and panicle length were measured from randomly selected 10 plants per plot at physiological maturity stage. Panicles from the 10 plants were sampled to count grains per panicle. 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 14% moisture since the grain was sun dried instead of oven drying. Thousand grain weight were determined by weighing 1000 grains resulted from each plot.

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$$\text{Gain yield (kg ha}^{-1}\text{) at 14 \% moisture} = \frac{(100\text{-MC}) \times \text{plot yield (kg)} \times 10000\ (\text{m}^2)}{(100\text{-}14) \times \text{net plot area (m}^2)}$$

where, MC is the moisture content in percentage of the grains.

Statistical analysis

The experimental data were processed by using Excel 2010 and analyzed by using Genestat 13.2. The treatment means were compared by the Least Significant Difference (LSD) test at 5% level (Gomez & Gomez, 1984; Baral et al., 2016; Shrestha, 2019; Kandel & Shrestha, 2019).

RESULTS AND DISCUSSION

Plant height and tiller numbers

Plant height was significantly affected by different age and dose of biogas slurry in 2017 (Table 2) and pooled analysis (Table 7). Different dose of biogas slurry significantly affected plant height in 2018 (Table 4). Plant height was 1 cm taller due to the application of biogas slurry of 5 and 180 days than that of 90 days in 2017. Plant height due to the application of biogas slurry of 5 days was 2 cm taller than plant height resulted from 90 days biogas slurry and 1 cm taller than plant height resulted from 180 days biogas slurry, in pooled analysis. This might be due to supplementation of higher (2.39 %) nitrogen percentage found in biogas slurry of 5 days age (Table 1). Plant height was found increasing as the dose of biogas slurry was increased in 2017, 2018 and in pooled analysis. There was no significant difference in the mean plant height between the Chemical fertilizer (CF) and Biogas slurry (BS) amendments (Ghoneim *et al.,* 2008).

Significant difference was observed on formation of effective tillers due to the use of biogas slurry of different age and dose in 2017 (Table 2) and in pooled analysis (Table 7). Different dose of biogas slurry significantly ($P < 0.01$) affected the formation of effective tillers in 2018 (Table 4).

A perusal of data (Table 2) revealed that the application of biogas slurry of 5 days age significantly produced higher number of effective tillers per square meter than due to the application biogas slurry of 90 and 180 days old, in 2017. Application of biogas slurry of 5 days age resulted significantly more number of effective tillers than 90 days in pooled analysis (Table 7). There was significant difference in the number of tillers between the Chemical fertilizer (CF) and Biogas slurry (BS) amendments (Ghoneim *et al.,* 2008).

Tillers per square meter increased as the dose of biogas slurry was incremented in 2017 (Table 2), 2018 (Table 4) and in pooled analysis (Table 7). The formation of effective tillers due to the use of biogas slurry of 10 and 15 t ha^{-1} was significantly higher than the use of biogas slurry of 0 and 5 t ha^{-1} in 2017 (Table 2) and in pooled analysis (Table 7). In 2017 and in pooled analysis, the use of biogas slurry of 15 t ha^{-1} produced significantly higher number of effective tillers than that of 10 t ha^{-1}. In 2018, the use of biogas slurry of 10 and 15 t ha^{-1}

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resulted significantly higher number of effective tillers than the use of biogas slurry of 0 t ha^{-1} (Check). Similarly, the application of biogas slurry of 15 t ha^{-1} produced significantly higher number of effective tillers than the use of biogas slurry of 5 t ha^{-1} and 10 t ha^{-1}.

Non – significant difference was observed in producing effective tillers between the years, in pooled analysis (Table 7).

Interaction effect of age and dose of biogas slurry on effective tillers of rice (in 2017)

A significant difference was observed on formation of effective tiller numbers of rice between the use of biogas slurry of 5 and 90 days with dose of 10 t ha^{-1}. Biogas slurry of 5 days produced significantly ($P < 0.01$) higher (274) effective tillers than 90 days (261) with the dose of 10 t ha^{-1} (Table 3).

There was significant difference on formation of effective tiller numbers of rice between the use of biogas slurry of 5 and 90 days with dose of 15 t ha^{-1}. A significant difference was observed on formation of effective tiller numbers of rice between the use of biogas slurry of 5 and 180 days with the dose of 15 t ha^{-1}. Similarly, there was significant difference on formation of effective tiller numbers of rice between the use of biogas slurry of 90 and 180 days with dose of 15 t ha^{-1}. Biogas slurry of 5 days produced significantly ($P < 0.01$) higher (307) effective tillers than 90 days (274) with the dose of 15 t ha^{-1}. Biogas slurry of 5 days produced significantly ($P < 0.01$) higher (307) effective tillers than 180 days (287) with the dose of 15 t ha^{-1}. Likewise, biogas slurry of 180 days produced significantly higher (287) effective tillers than 90 days (274) with the dose of 15 t ha^{-1} (Table 3).

Days to heading and physiological maturity

Days to heading and physiological maturity were non-significantly affected by different age of biogas slurry in 2017 (Table 2). On the other hand, days to heading and physiological maturity were significantly affected by different age of biogas slurry in 2018. Heading was 1 day earlier due to the use of biogas slurry of 5 days age than 90 and 180 days. Similarly, attainment of physiological maturity was 1 day earlier due to the application of biogas slurry 5 and 180 days than that of 90 days (Table 4). Biogas slurry, rich in nutrients and organic carbon, can also improve soil quality (Zheng *et al.*, 2016). Non – significant difference was observed on occurrence of heading and physiological maturity due to the application of different age of biogas slurry, in pooled analysis (Table 7).

Occurrence of heading and attainment of physiological maturity were significantly affected by the use of different dose of biogas slurry in 2017 (Table 2), 2018 (Table 4) and in pooled analysis (Table 7). Heading of check (dose) was 1 day later than the use of dose of biogas slurry of 5 t ha^{-1}, 2 days later than the use of dose of biogas slurry of 10 t ha^{-1} and 3 days later than the use of dose of biogas slurry of 15 t ha^{-1} , in 2017 (Table 2). Heading of check (dose) was 1 day later than the use of dose of biogas slurry of 5 t ha^{-1}, 2 days later than the use of dose of biogas slurry of 10 t ha^{-1} and 15 t ha^{-1}, in 2018 (Table 4). Heading of check (dose) was 1 day later than the use of dose of biogas slurry of 5 t ha^{-1}, 2 days later than the use of dose of biogas slurry of 10 t ha^{-1} and 15 t ha^{-1}, in pooled analysis (Table 7).

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Attainment of physiological maturity of check (dose) was 1 day later than the use of dose of biogas slurry of 5, 10 and 15 t ha^{-1}, in 2017 (Table 2). Attainment of physiological maturity of check was 1 day later than the use of dose of biogas slurry of 10 t ha^{-1} and 2 days later than the use of dose of biogas slurry of 15 t ha^{-1}, in 2018 (Table 4). Similarly, attainment of physiological maturity of check was 1 day later than the use of dose of biogas slurry of 10 t ha^{-1} and 2 days later than the use of dose of biogas slurry of 15 t ha^{-1}, in pooled analysis (Table 7).

Heading and attainment of physiological maturity in Year -1 were significantly ($P < 0.01$) earlier than Year – 2, in pooled analysis (Table 7).

Interaction effect of age and dose of biogas slurry on days to heading of rice (in 2018)

A significant difference was observed on occurrence of heading of rice between the use of biogas slurry of 5 and 90 days with dose of 5 t ha^{-1}. Heading due to 5 days age of biogas slurry was significantly ($P < 0.01$) earlier (120 days) than 90 days (121 days) with the dose of 5 t ha^{-1}. Similarly, heading due to 180 days age of biogas slurry was significantly ($P < 0.01$) earlier (120 days) than 90 days (121 days) with the dose of 5 t ha^{-1} (Table 5).

There was significant difference on occurrence of heading of rice between the use of biogas slurry of 5 and 90 days with dose of 10 t ha^{-1}. Heading due to 5 days age of biogas slurry was significantly ($P < 0.01$) earlier (119 days) than 90 days (120 days) with the dose of 10 t ha^{-1}. Similarly, heading due to 5 days age of biogas slurry was significantly ($p < 0.01$) earlier (119 days) than 180 days (120 days) with the dose of 10 t ha^{-1} (Table 5).

There was significant difference on occurrence of heading of rice between the use of biogas slurry of 5 and 90 days with dose of 15 t ha^{-1}. Heading due to 5 days age of biogas slurry was significantly ($p < 0.01$) earlier (118 days) than 90 days (119 days) with the dose of 15 t ha^{-1}. Similarly, heading due to 5 days age of biogas slurry was significantly ($p < 0.01$) earlier (118 days) than 180 days (119 days) with the dose of 15 t ha^{-1} (Table 5).

Interaction effect of age and dose of biogas slurry on days to physiological maturity of rice (in 2018)

There was significant difference on attainment of physiological maturity of rice between the use of biogas slurry of 5 and 90 days with dose of 10 t ha^{-1}. Attainment of physiological maturity due to 5 days age of biogas slurry was 1 day earlier than 90 and 180 days with the dose of 10 t ha^{-1}. Similarly, attainment of physiological maturity due to 5 and 180 days age of biogas slurry was 1 day earlier than 90 days age of biogas slurry with the dose of 15 t ha^{-1} (Table 6).

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Interaction effect of age and dose of biogas slurry on days to heading of rice (pooled analysis)

A significant difference was observed on occurrence of heading of rice between the use of biogas slurry of 5 and 90 days with the dose of 5 t ha^{-1}. Heading due to the use of biogas slurry of 5 and 180 days was 1 day earlier than the of biogas slurry of 90 days with the dose of 5 t ha^{-1} . Similarly, occurrence of heading due to the use of biogas slurry of 5 days was 1 day earlier than the use of biogas slurry of 90 and 180 days with the dose of 10 t ha^{-1}. Likewise, occurrence of heading due to the use of biogas slurry of 5 days was 1 day earlier than the use of biogas slurry of 90 and 180 days with the dose of 15 t ha^{-1} (Table 6).

Interaction effect of age and dose of biogas slurry on days to physiological maturity of rice (in pooled analysis)

There was significant difference on attainment of physiological maturity of rice between the use of biogas slurry of 5 and 90 days with dose of 10 t ha^{-1}. Attainment of physiological maturity due to 5 days age of biogas slurry was 1 day earlier than 90 and 180 days with the dose of 10 t ha^{-1}. Similarly, attainment of physiological maturity of rice due to the use of biogas slurry of 5 and 180 days was 1 day earlier than the use of biogas slurry of 90 days with the dose of 15 t ha^{-1} (Table 9).

Yield attributing traits

Panicle length

Panicle length of rice due to the application of biogas slurry of 5 days was significantly longer than the use biogas slurry of 180 days in 2017 (Table 2), 2018 (Table 4) and in pooled analysis (Table 7). Similarly, panicle length due to the application of biogas slurry of 180 days was significantly longer than the use biogas slurry of 90 days in 2017, 2018 and in pooled analysis.

Panicle length was found increasing as the dose of biogas slurry was incremented in 2017 (Table 2), 2018 (Table 4) and in pooled analysis (Table 7). Panicle length of rice was significantly longer in Year – 2 than Year – 1 in pooled analysis (Table 7).

Grains per panicle

Biogas slurry of 5 days age resulted significantly higher number of grains per panicle than 180 and 90 days age in 2017 (Table 2) and 2018 (Table 4). In pooled analysis (Table 7), application of biogas slurry of 5 days age resulted significantly higher number of grains per panicle than that of 90 days age. Similarly, the use of biogas slurry of the age of 180 days resulted significantly higher number of grains per panicle than that of 90 days age in 2017, 2018 and in pooled analysis.

The number of grains per panicle of rice increased significantly as the dose of biogas slurry was incremented in 2017, 2018 and in pooled analysis. Significantly ($P < 0.01$) higher number of grains per panicle was observed in Year – 2 than Year – 1, in pooled analysis.

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Thousand grain weight (TGW)

Biogas slurry of 5 days age produced significantly higher TGW than 90 and 180 days in 2017 (Table 2) and 2018 (Table 4). In pooled analysis (Table 7), TGW resulted from the use of biogas slurry of 5 days age was at par with 180 days and significantly higher than that of 90 days.

TGW of rice increased significantly as the dose of biogas slurry was incremented in 2017. TGW of rice resulted from the dose of biogas slurry of 15 t ha^{-1} was significantly higher than that of check, 5 and 10 t ha^{-1} in 2018 and in pooled analysis. TGW of rice in Year - 2 was significantly higher than Year – 1, in pooled analysis.

Grain yield

The mean grain yield in the experiment was 4.4, 4.6 and 4.5 in 2017 (Table 2), 2018 (Table 4) and in pooled analysis (Table 7), respectively. Grain yield of rice was significantly higher with the use of biogas slurry 5 days age than 90 days in 2017, 2018 and in pooled analysis. This might be due to supplementation of higher (2.39 %) nitrogen percentage found in biogas slurry of 5 days age (Table 1). There was non-significant difference between the use of biogas slurry of 5 and 180 days in respect of grain yield of rice in 2017 and 2018. However, significant difference was observed between the use of biogas slurry of 5 and 180 days age in respect of grain yield of rice, in pooled analysis. Biogas slurry application significantly ($P < 0.05$) increased soil properties and crop yields compared with the untreated soil (Xu *et. al.*, 2019). Lu *et al.* (2012) demonstrated that the application of biogas slurry increased the rice yield by 24.0 and 4.9% when compared to no fertilization and conventional fertilization treatments, respectively. Rice yields can increase by 7% when slurry is applied (Wikipedia, 2013).

Grain yield of rice was found to be increasing significantly as the dose of biogas slurry as incremented up to 15 t ha^{-1} in 2017, 2018 and in pooled analysis. Compared with the control the rice yields increased by 39.9 - 69.8%, after adding biogas slurry (BS) (BS1–BS10 i. e. 59.9 t ha^{-1} to 264.4 t ha^{-1}) (Xu *et. al.*, 2019). The biogas slurry application rates at 480 m^3 ha^{-1} for rice and 9.00–11.25 m^3 ha^{-1} for wheat resulted in significantly higher yields than those from both no fertilization and conventional fertilization (Tang *et al.*, 2019).

CONCLUSION

Grain yield of rice (Ram dhan) due to the use of biogas slurry of 5 days was equal with the yield due to the use of biogas slurry of 180 days in 2017, 2018. However, grain yield of rice due to the use of biogas slurry of 5 and 180 days was significantly higher than 90 days in 2017 and 2018. In pooled analysis, 5 days age of biogas slurry produced significantly higher grain yield than the use of biogas slurry of 90 and 180 days. Similarly, use of biogas slurry of 180 days produced significantly higher grain yield than 90 days age of biogas slurry; in pooled analysis. The yield of rice has been found increasing significantly as the dose of biogas slurry was incremented from 0 t ha^{-1} to 15 t ha^{-1} in 2017, 2018 and in pooled analysis. Hence, it can be concluded that the use of biogas slurry of the age of 5 days with the dose of 15 t ha^{-1} is better option for higher yield of rice lacking the use of chemical fertilizers.

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Authors contribution

Bisheshwor Prasad Pandey	Conducted experiment, recorded data, and wrote the manuscript
Khem Raj Pant	Helped in experiment and recording data
Mathura Yadav	Helped in data analysis
Narayan Khatri	Helped in experiment and recording data

Conflict of interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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Table 1. Main characteristics of biogas slurry originating from anaerobically digested buffalo waste, used in the field experiment

S. N.	Parameters	Test Method	Observed Values		
			Fresh	3 Months	6 Months
1.	pH (1:5 Extration)	pH Metric	8.24	7.78	7.9
2.	Moisture, %	Gravimetric	83.42	63.67	63.65
3.	Dry Matter, (%)	Gravimetric	16.58	36.33	36.35
4.	Nitrogen, % (Oven dry basis)	Kjeldal Digestion	2.39	0.70	0.96
5.	Potassium as K_2O, % (Oven dry basis)	AAS	1.04	0.65	0.69
6.	Phosphorous as P_2O_5, % (Oven dry basis)	Spectrophotometer	2.51	2.76	2.98
7.	Organic Matter, % (Oven dry basis)	Walkey and Black	57.02	59.45	66.29

Table 2. Summary of means of variables evaluated at NWRP, Bhairahawa, Rupandehi, 2017

Treatments	DH	DM	PH	Pan. L	Grains per panicle	Tm^{-2}	TGW	GY
Age of biogas slurry (days)								
5	112	144	102	22.9	101	264	21.4	4.5
90	112	144	101	22.4	98	253	20.7	4.3
180	112	144	102	22.6	100	257	21.1	4.5
F test	ns	ns	**	**	**	**	**	**
$LSD_{0.05}$	0.14	0.32	0.43	0.09	0.27	5.56	0.20	0.05
Dose of biogas slurry (t ha^{-1})								
0	113	145	99	21.9	90	237	19.8	4.2
5	112	144	101	22.2	98	240	20.3	4.4
10	111	144	102	22.8	104	266	21.4	4.5
15	110	144	104	23.4	107	290	22.7	4.7
F test	**	**	**	**	**	**	**	**
$LSD_{0.05}$	0.16	0.37	0.49	0.10	0.32	6.42	0.23	0.06
Interaction								
F test	ns	ns	ns	ns	Ns	**	ns	ns
Grand mean	112	144	102	22.6	100	258	21.1	4.4
CV (%)	0.1	0.3	0.5	0.5	0.3	2.5	1.2	1.5

*** indicate significant F values at $P < 0.01$. ns indicate non-significant at $P < 0.05$. DH= days to heading, DM = Days to maturity, PH = Plant height, Pan. L= Panicle length, Tm^{-2} = Tillers per square meter, TGW = Thousand grain weight and GY = Grain yield*

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Table 3. Interaction effect of age and dose of biogas slurry on effective tillers of rice at NWRP, Bhairahawa, Rupandehi; 2017

Treatments	Effective tillers			
	Dose of biogas slurry (t ha^{-1})			
	0	5	10	15
Age of biogas slurry (days)				
5	234	241	274	307
90	237	238	261	274
180	238	240	263	287
F test	**			
$LSD_{0.05}$	11.11			
CV (%)	2.5			

*** indicate significant F values at P < 0.01*

Table 4. Summary of means of variables evaluated at NWRP, Bhairahawa, Rupandehi; 2018

Treatments	**DH**	**DM**	**PH**	**Pan. L**	**Grains per panicle**	**Tm^{-2}**	**TGW**	**GY**
Age of biogas slurry (days)								
5	119	148	95	26	107	259	23	4.6
90	120	149	93	25.5	102	253	22	4.5
180	120	148	94	25.7	105	256	22	4.6
F test	**	**	ns	**	**	ns	*	**
$LSD_{0.05}$	0.36	0.22	2.56	0.14	1.62	7.09	0.29	0.07
Dose of biogas slurry (t ha^{-1})								
0	121	149	90	24.3	97	243	22	4.1
5	120	149	93	25.5	102	250	22	4.4
10	119	148	96	26.2	108	256	22	4.7
15	119	147	99	26.8	113	275	23	5.1
F test	**	**	**	**	**	**	**	**
$LSD_{0.05}$	0.41	0.26	2.96	0.17	1.87	8.19	0.33	0.09
Interaction								
F test	**	**	ns	ns	ns	ns	ns	ns
Grand mean	120	148	94	25.7	105	256	22	4.6
CV (%)	0.4	0.2	3.2	0.7	1.8	3.3	1.5	2

** and ** indicate significant F values at P < 0.05 and 0.01, respectively. ns indicate non-significant at P < 0.05. DH= days to heading, DM = Days to maturity, PH = Plant height, Pan. L= Panicle length, Tm^{-2} = Tillers per square meter, TGW = Thousand grain weight and GY = Grain yield*

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Table 5. Interaction effect of age and dose of biogas slurry on days to heading of rice at NWRP, Bhairahawa, Rupandehi; 2018

Treatments	Days to heading			
	Dose of biogas slurry (t ha^{-1})			
	0	5	10	15
Age of biogas slurry (days)				
5	121	120	119	118
90	121	121	120	119
180	121	120	120	119
F test	**			
$LSD_{0.05}$	0.72			
CV (%)	0.4			

*** indicate significant F values at P < 0.01*

Table 6. Interaction effect of age and dose of biogas slurry on days to physiological maturity of rice at NWRP, Bhairahawa, Rupandehi; 2018

Treatments	Days to maturity			
	Dose of biogas slurry (t ha^{-1})			
	0	5	10	15
Age of biogas slurry (days)				
5	149	149	147	147
90	149	149	148	148
180	149	149	148	147
F test	**			
$LSD_{0.05}$	0.45			
CV (%)	0.2			

*** indicate significant F values at P < 0.01*

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Table 7. Summary of means of variables evaluated at NWRP, Bhairahawa, Rupandehi (Pooled analysis)

Treatments	DH	DM	PH	Pan. L	Grains/ panicle	Tm^{-2}	TGW	GY
Age of biogas slurry (days)								
5	116	146	99	24.4	104	261	22	4.6
90	116	146	97	23.9	100	253	21	4.4
180	116	146	98	24.2	103	257	22	4.5
F test	ns	ns	*	**	**	**	**	**
$LSD_{0.05}$	0.19	0.18	1.38	0.09	1.33	5.11	0.19	0.05
Dose of biogas slurry (t ha^{-1})								
0	117	147	95	23.1	94	240	21	4.1
5	116	147	97	23.9	100	245	21	4.4
10	115	146	99	24.5	106	261	22	4.6
15	115	145	101	25.1	110	282	23	4.9
F test	**	**	**	**	**	**	**	**
$LSD_{0.05}$	0.22	0.21	1.59	0.11	1.54	5.91	0.22	0.06
Year								
Year - 1	112	144	102	22.6	100	258	21	4.4
Year - 2	120	148	94	25.7	105	256	22	4.6
F test	**	**	**	**	**	ns	**	**
$LSD_{0.05}$	0.15	0.15	1.13	0.07	1.09	4.18	0.16	0.04
Interaction								
F test	**	**	ns	ns	ns	ns	ns	ns
Grand mean	116	146	98	24.2	102	257	22	4.5
CV (%)	0.3	0.2	2.4	0.7	2.3	3.4	1.6	2

** and ** indicate significant F values at P < 0.05 and 0.01, respectively. ns indicate non-significant at P < 0.05*

Table 8. Interaction effect of age and dose of biogas slurry on days to heading of rice at NWRP, Bhairahawa, Rupandehi (Pooled analysis)

Treatments	Days to heading			
	Dose of biogas slurry (t ha^{-1})			
	0	5	10	15
Age of biogas slurry (days)				
5	117	116	115	114
90	117	117	116	115
180	117	116	116	115
F test	**			
$LSD_{0.05}$	0.38			
CV (%)	0.3			

*** indicate significant F values at P < 0.01*

Table 9. Interaction effect of age and dose of biogas slurry on days to maturity of rice at NWRP, Bhairahawa, Rupandehi (Pooled analysis)

Treatments	Days to maturity			
	Dose of biogas slurry (t ha^{-1})			
	0	5	10	15
Age of biogas slurry (days)				
5	147	147	145	145
90	147	147	146	146
180	147	147	146	145
F test	**			
$LSD_{0.05}$	0.37			
CV (%)	0.2			

*** indicate significant F values at P < 0.01*