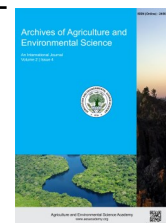




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ORIGINAL RESEARCH ARTICLE



Effect of standing water levels on methane gas emission and yield performance of transplanted *Aman* rice (*Oryza sativa* L. cv. BRRI dhan51)

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ABSTRACT

An experiment was conducted to investigate the effect of standing water levels on methane gas emission and yield of transplanted *Aman* rice (cv. BRRI dhan51) during July to December 2015 at medium low lying area of Mohangonj upazila under Netrokona district. The experiment comprised five standing water levels on surface paddy soil viz., 5 cm, 10 cm, 15 cm, 20 cm and 25 cm. Methane (CH₄) gas emission, yield components and yield of transplanted *Aman* rice were significantly affected by standing water levels on surface paddy soil. CH₄ emission was gradually increased with rising standing water levels and remained static condition at 20-25 cm water level. The highest CH₄ emission was observed at 20 cm standing water level and the lowest CH₄ emission was recorded at 5 cm water level. The highest CH₄ peak recorded at 85 days after transplanting (DAT). The highest CH₄ flux (36.59 mg/m²/h) was observed in treatment 20 cm water level whereas the lowest CH₄ flux (21.17 mg/m²/h) was observed in 5 cm water level. Finally the CH₄ emission dropped at 108 DAT. On and average, the CH₄ emission rate during rice cultivation followed 20 cm > 25 cm > 15 cm > 10 cm > 5 cm water level. Soil Eh gradually decreased with progress of time and plant growth and at 85 DAT highly reduced condition developed in all treatments. The maximum reduced condition was observed (-238.67 mV) in treatment 20 cm water level and minimum one (-214.667 mV) was found in 5 cm water level. The highest grain (5260 kg ha⁻¹) and straw (6725.0 kg ha⁻¹) yields were obtained at 10 cm standing water level while the lowest grain (4191.6 kg ha⁻¹) and straw (5050.0 kg ha⁻¹) yields were recorded in 5 cm and 15 cm water level, respectively. It may be concluded that 10 cm standing water level is beneficial for transplant *Aman* rice (cv. BRRI dhan51) cultivation in low lying area in respect of grain yield and environmental issues.

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INTRODUCTION

Global warming and climate change have become the main issue in Bangladesh. Climate change is strongly linked to increasing levels of specific greenhouse gases (GHGs) such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) that are responsible for global warming. Methane (CH₄) is an important greenhouse gas with both natural and anthropogenic sources (Wang *et al.*, 2005). CH₄ is considered as the second important

greenhouse gas next to CO₂ which has 25 times more global warming potential (GWP) than carbon dioxide contributing to 16% of the global warming. The global atmospheric concentration of CH₄ has increased steadily more concentrated in the air since the 18th century, more than doubling from around 750 parts per billion (ppb) to more than 1,850 ppb today. Like carbon dioxide, methane absorbs infrared radiation and warms the atmosphere. Atmospheric CH₄ originates from both natural and anthropogenic sources. Rice paddy is a large source of

methane emission (Zhang et al., 2020). More than 50% of the global annual CH₄ emissions are of anthropogenic origin, and the cultivation of irrigated rice may account for up to 12% of this flux (IPCC, 2007 and Smartt et al., 2016). Recent estimates of CH₄ from rice fields range between 39 and 112 Tg CH₄ per year (Denman et al., 2007). Rice paddies are major source of atmospheric CH₄. The total annual global emission of CH₄ is estimated at 500 Tg yr⁻¹, but the accuracy of this estimate is highly uncertain. Improving estimates of CH₄ emission at the regional and global scales requires process-based models, integrating the environmental and biological factors that determine the rate of CH₄ emission. A clear understanding of the interaction between climate change and rice production will provide a sound basis for future decisions and technology developments by policymakers, agriculturists, environmentalist, rice producers and consumers alike. The CH₄ plays a major role in global warming and climate change, and its reduced emission is essential without adversely affecting crop production. CH₄ emitted from rice fields under various cultural practices has been an area of research, as little information is presently available on this aspect (Yan et al., 2003).

Rice (*Oryza sativa* L.) is the most extensively cultivated food grain crop which contributes near about 95% of total food production in Bangladesh. Soil and climate conditions are very favorable for year round rice cultivation in Bangladesh. About 74.85% of cropped area of Bangladesh is used for rice production, where *Aus*, *Aman* and *Boro* rice covers 8.94%, 49.12% and 41.94%, respectively (BBS, 2018). The area and production of rice in Bangladesh is about 11.01 million hectares and 33.80 million tons, respectively (BBS, 2018). As a main food grain crop rice is produced at least twice in the same crop field in Bangladesh. In case of Rice Fallow-Rice cropping pattern, one rice crop is fully irrigated (*Boro* rice) and another is mostly rainfed (*T. Aman* rice). The flooded rice paddy has been identified as one of the most important sources of anthropogenic CH₄ emission (Jacobson, 2005). The farmers' of Bangladesh are poor and marginal and still depend on traditional agriculture. They use cow dung, poultry litter, compost, biogas slurry, municipal compost, and vermicompost in their land those produce or enhance CH₄ emission from rice fields. These organic fertilizers are available to farmers as they rear poultry, cattle in their own houses. The largest present anthropogenic sources of CH₄ are rice fields, cattle and biomass burning. Therefore, producing more rice with less water is a formidable challenge for achieving food and water security for these regions (Khalil and Shearer, 2000). Climate change is become a big challenge for agriculture sector. If the farmer wants to increase agriculture productions, the farmer has to follow adaption method to mitigate the effect of climate change. As extensive research works are necessary to find out the methane gas emission and grain yield in *Aman* rice at medium low lying area under standing water level. The present investigation was undertaken to assess CH₄ gas emission and grain yield in *Aman* rice under different levels of standing water.

MATERIALS AND METHODS

Experimental period, location and site

The experiment was carried out during July to December 2015 (T. *Aman* season). The experimental site was medium low lying area of Mohanganj Upazila (24.87 °N latitude and 90.97 °E longitude) under Netrokona District, Bangladesh. The soil of the experimental field belongs to the non-calcareous dark grey floodplain soil under the Old Brahmaputra Flood Plain (AEZ-9). The experimental area was under subtropical climate characterized by moderate high temperature, heavy rainfall, flash flood and high humidity during the T. *Aman* season (July-October, 2015) (Table 1).

Experimental treatments and design

The experimental treatments were: T₁: Standing water level from soil surface (5 cm), T₂: Standing water level from soil surface (10 cm), T₃: Standing water level from soil surface (15 cm), T₄: Standing water level from soil surface (20 cm), T₅: Standing water level from soil surface (25 cm). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experimental field was divided into three blocks. The area of each plot was 20 square meter (5.0 m × 4.0 m). The treatment combinations were randomly distributed to unit plots. BRRI dhan51 was used as the test crop.

Crop husbandry

Seeds were soaked in water in bucket for 24 hours and then taken out of water and kept thickly in gunny bags. During July the experimental field was ploughed and cross plough three times followed by laddering to obtain the desirable tilth. The land was cleaned by removing weeds, stubbles and crop residues. Nursery beds were made wet by application of water both in the morning and evening on the day before uprooting the seedlings. Seedlings were uprooted carefully early in the morning on 6 August 2015 and transplanting in row in the main field at the 2 seedlings per hill with 15 cm × 25 cm spacing. Thirty days old seedlings were uprooted from the seed bed and transplanted in the main field.

Five hills were selected at random from each unit plot excluding boarder rows to record the data on crop characters and yield components. The rice was harvested plot wise on 05 December 2015. The harvested crop of each plot was separately bundled, tagged and brought to the threshing floor. The grains were threshed, cleaned, sun dried and weighed to record the grain yield. The grain yield was adjusted to 14% moisture content. Straw was sun dried and weighed to record the straw yield. Finally grain and straw yields plot⁻¹ were recorded and converted to t ha⁻¹. Harvest index (%) was calculated with the following formula (Paul et al., 2020).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,

Economic yield = Grain yield, Biological yield = Grain yield + Straw yield

Gas samples collection

One chamber was installed in each experimental plot (Plate 1). Gas samples were collected at different growth stages of rice plant to get the trend of CH₄ emissions during the cropping season (Plate 2). Gas samples were collected by 50 ml gas-tight syringes at 0, 10 and 20 minutes intervals after chamber placement over the rice planted plot. The samples were analyzed for CH₄ by using gas chromatograph (GC-2014) equipped with an FID (flame ionization detector). The analysis column used a stainless steel column packed with Porapak NQ (Q 80-100 mesh). The collected samples were stored in an evacuated glass vials until its laboratory analysis. Sample collected before chamber closing was used to determine the background concentration of methane. The concentration difference between 0 min and 20 min gave the total emission occurred during 20 min when gas chamber was closed.

Gas sample analysis

Gas sample was analyzed in the Central Laboratory of Bangladesh Agricultural University (BAU), Mymensingh. Seasonal total emissions of CH₄ were calculated from the sum of daily emission rates. The data were processed with MS, Excel, and average value and standard deviation is calculated.

Analytical techniques

Gas samples were collected by using the closed-chamber method (Ali *et al.*, 2008) during the rice cultivation. The dimen-

sions of close chamber were 62 × 62 × 112 cm. One chamber was installed in each experimental plot. Gas samples were collected at two times (11.00 am- 2.00 pm) in three stages (vegetative, flowering and ripening stage) to get the average CH₄ emissions during the cropping season

Calculation of CH₄ flux

CH₄ flux was calculated by using the following formula (Rolston, 1986)

$$F = \rho \cdot (V/A) \cdot (\Delta c/\Delta t) \cdot 273/T$$

Where

F= methane flux (mg m⁻² hr⁻¹)

ρ= gas density (0.714 mg CH₄ m⁻³)

V=volume of the chamber (m³)

A=surface area of chamber (m²)

Δc/Δt=rate of increase of methane gas concentration in the chamber (mg m⁻³ hr⁻¹)

T= 273+ mean temperature in chamber (°c)

Statistical analysis

Data on the plant characteristics and CH₄ emission were analyzed using the analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C (Russell, 1986) and mean differences were adjusted by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Table 1. Meteorological parameters during study period.

Date	Air temperature		Relative* humidity (%)	Rainfall* (mm) (Total)
	Maximum	Minimum		
July, 2015	31.56	26.83	86.00	16.14
August, 2015	31.96	26.31	97.00	12.63
September, 2015	32.02	24.03	87.68	12.30
October, 2015	32.05	23.2	82.9	78
November, 2015	30.0	18.1	82.2	4.3
December, 2015	25.2	13.3	83.4	0.0

Source: Department of Irrigation and Water Management, BAU, Mymensingh-2202.



Plate 1. Site view of experimental plot.



Plate 2. Collection of gas sample from paddy field.



RESULTS AND DISCUSSION

Effect of standing water level on CH₄ emission

The CH₄ emission was significantly affected by standing water levels (Figure 1). It was found that the CH₄ emission was significantly varied from 6.3 to 13.11 mg m⁻² h⁻¹ at 24 DAT, where the treatment T₄ (Standing water 20 cm) level showed the highest CH₄ emission while the lowest was recorded in the treatment T₁ (Standing water 5cm) level. Similar trend of CH₄ emission was also recorded at 48 DAT. At 85 DAT, treatment T₄(Standing water 20cm) level showed the highest CH₄ emission (about 35 mg m⁻² h⁻¹) while the lowest CH₄ emission 17.9 mg m⁻² h⁻¹ was found from treatment T₁(Standing water 5cm) (Figure 1). This was supported by Ding *et al.* (2002) who reported that CH₄ emission increased as standing water depth incremented from 15 to 20 cm. The author noticed that standing water depth determined the type of marsh plants, which governed CH₄ transport, and the amount of plant litters, which resulted in the difference of labile organic C for methanogenesis among marshes. Zou *et al.* (2005) reported that water table depth could be used as a management option and control CH₄ emission from rice fields and CH₄ emission could be considerably reduced by lowering the water table. However, reduction of water table may trigger CH₄ emissions from soil pores (Bubier and Moore, 1994).

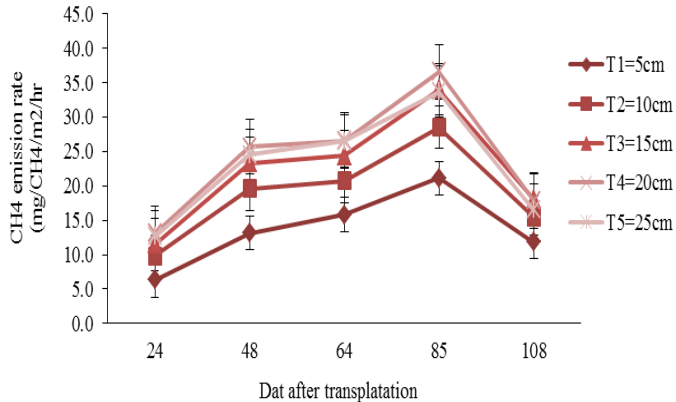


Figure 1. CH₄ emission rate at different growth stages of BRRI dhan51.

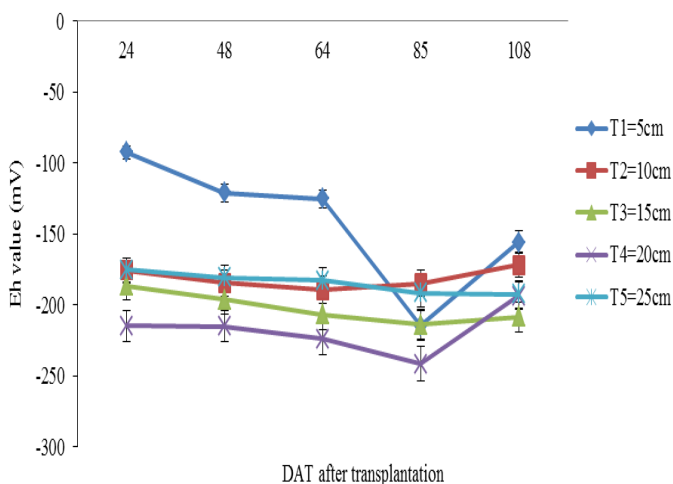


Figure 2. Changes in soil redox potential (Eh) with rice plant growth stages (BRRI dhan51).

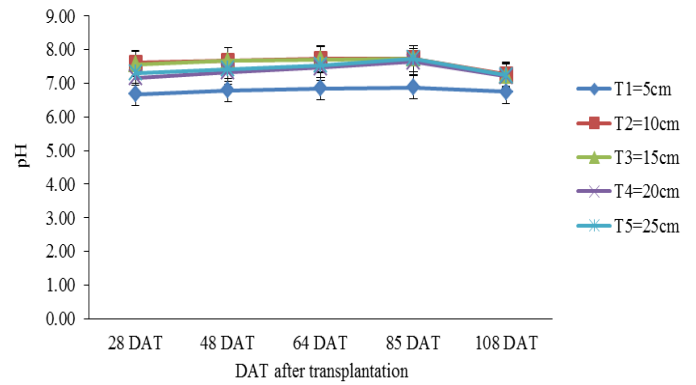


Figure 3. Soil pH at different growth stages of BRRI dhan51.

Effect of standing water level on soil properties

Soil redox potential (Eh): Soil redox potential (Eh) values were recorded at different rice growth stages. It was found that the reduction of soil redox status influenced significantly by the advancement of the growth stages. At 24 DAT, soil Eh ranged from -92.33 to -114.6 mV, -121 to -215 mV at 48 DAT (PS), -125 to -224 mV at 64 DAT (BS), -214.6 to -241.6 mV at 85 DAT (HS) and -155.6 to -193.6 mV at 108 DAT (RS). Among the treatment only T₁: (Standing water level 5cm) showed the less soil reduction potential of Eh (-92.33 mV) of 24 DAT, while treatment T₄ (Standing water level 20cm) showed the highest soil reduction potential reduction of Eh (-238.67 mV) at this stage. At 48 DAT, soil Eh value was observed (-121.3 mV) in treatment T₁ while treatment T₄ showed highly reduced end Eh value (-224 mV). Similarly at 64 DAT, treatment T₄ (Standing water level 20cm) showed the capability to reduce the most intense of soil redox reduction (-238.67 mV). Later on (85 DAT), the soil Eh value decreased towards -214.6 (T₁) to -241.6 mV(T₄). Finally at 108 DAT, soil redox status improved towards -155.6 mV (T₁) to -193.5 mV (T₄) (Figure 2).

Soil pH: The data of soil pH was recorded at 24, 48, 64, 85 and 108 DAT where all the data recording stages were statistically due to the effect of different standing water level. At 24 DAT, the highest pH content of soil (7.6) was recorded from the T₂ treatments (standing water level 10cm). At this stage (24 DAT), standing water level T₁ (standing water level 5cm) treated soil recorded the lowest pH content (6.79). At 64 DAT, the ranges of pH was 6.84 to 7.72 where the lowest was found from the treated soil of standing water level T₁ (standing water level 5cm) and the highest was observed from the treated soil of standing water level T₂ (standing water level 10cm). From the above result it was found that the highest and the lowest pH value of 85 DAT was found 7.73 in the treatment of T₂, T₃ and T₅ and the lowest value is 6.87 in the treatment T₁ (standing water level 5cm). Finally the pH value in 108 DAT highest and lowest value was found 7.27 and 6.74 respectively in the treatment of standing water level T₂ (standing water level 10cm) and T₁(standing water level 5cm) (Figure 3). Wang *et al.* (1993) observed that the CH₄ production rate in paddy soil peaked at a pH between 6.9 and 7.1. A pH of below 5.75 or above 8.75 completely suppressed CH₄ production.

Table 2. Effect of different levels of water on the yield contributing characters and yield of transplant Aman rice.

Treatments (Standing water level)	Plant height (cm)	Panicles hill ⁻¹ (no.)	Length of panicle (cm)	Number of filled grains hill ⁻¹	Weight of 1000-grain (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
T ₁ (5 cm)	98.00ab	17.33ab	29.00	2011.0b	23.47	4191.6c	5487.0b	42.62b
T ₂ (10 cm)	98.33a	23.33a	28.67	2660.0a	23.78	5260.0a	6725.0a	43.89a
T ₃ (15 cm)	96.00c	18.33ab	27.67	2116.0a	23.67	4506.0b	5050.0d	47.20a
T ₄ (20 cm)	97.33abc	17.33ab	28.00	1985.0b	22.27	4388.0bc	5992.0c	44.40a
T ₅ (25 cm)	96.33bc	16.67b	27.00	1896.0b	23.36	4333.4bc	5433.0c	43.3a
LSD _(0.05)	1.60	5.959	3.72	448.6	1.60	307.7	158.80	1.07
CV (%)	0.88	17.02	7.04	11.17	3.66	3.66	1.48	1.30
Level of significance	*		NS	*	NS	**	**	*

Table 3. Chemical properties of post-harvest soil under different treatments.

Treatments (Standing water level)	OC (%)	OM (%)	TN (%)	P (ppm)	K (meq/100g soil)	S (ppm)
T ₁ (5 cm)	1.27	2.450	0.13	40.53b	0.20	8.75
T ₂ (10 cm)	1.24	2.333	0.13	48.05a	0.19	9.68
T ₃ (15 cm)	1.28	2.083	0.11	32.79c	0.20	10.93
T ₄ (20 cm)	1.21	2.460	0.13	39.98b	0.21	10.14
T ₅ (25 cm)	1.28	2.060	0.14	37.60bc	0.19	9.39
LSD _(0.05)	0.15	0.43	0.05	4.70	0.084	3.93
CV%	3.90	3.84	17.32	1.77	24.05	20.84
Level of significance	NS	NS	NS	*	NS	NS

Effect of standing water level on crop characters, yield components and yield

Plant height, number of panicles hill⁻¹, number of filled grains hill⁻¹, grain yield, straw yield and harvest index were significantly influenced by standing water level (Table 2). The tallest plant (98.33 cm) was recorded in T₂ (standing water 10 cm) which was statistically identical with T₁ (standing water 5 cm) followed by T₄ (20 cm) and T₅ (standing water 25 cm) and the lowest one (96.00 cm) was recorded in T₃ (standing water 15 cm). This result was in conformity with Sarkar *et al.* (2017) who noticed that water management in rice influenced on plant height. The highest number of panicles hill⁻¹(23.33) was recorded in T₂ (standing water 10 cm) which was at par with T₁ (standing water 5 cm), T₃ (standing water 15 cm) and T₄ (standing water 20 cm) while the lowest number of panicles hill⁻¹was obtained in T₅ (standing water 25 cm). It means different water regime regulate the production of effective tillers and higher water level decreased in T₅ (standing water 25 cm). Length of panicle was not significantly influenced by standing water level (Table 2). Numerically the longest panicle length (29 cm) was recorded in T₁ (standing water 5 cm) where the shortest panicle (27.00 cm) was obtained at T₅ (standing water 25 cm). The highest number of filled grains hill⁻¹(2660.0) was recorded in T₂ (standing water 10 cm) which was as good as (2116.0) T₃ (standing water 15 cm) while the lowest number of filled grains hill⁻¹(1896.0) was recorded in T₅ (standing water 25 cm). Thousand-grain weight was not significantly influenced by standing water level (Table 2). Numerically the highest 1000-grain weight (23.78 g) was recorded in T₂ (standing water 10 cm) while the lowest value

(22.27 g) was recorded in T₄ (standing water 20 cm). The highest grain yield (5260.0 kg ha⁻¹) was recorded in T₂ (standing water 10 cm) followed by T₃ (standing water 15 cm) while the lowest grain yield (4191.6 kg ha⁻¹) was obtained in T₁ (standing water 5 cm). The highest number of panicles and number of filled grains hill⁻¹ are contributed the highest grain yield in T₂ (standing water 10 cm). The highest straw yield (6725.0 kg ha⁻¹) was obtained from T₂ (standing water 10 cm) and lowest straw yield (5050.0kg ha⁻¹) was recorded in T₃ (standing water 15 cm). The highest plant height in T₂ (standing water 10 cm) might be responsible for the highest straw yield. These results corroborate with the findings of Paul *et al.* (2019) who reported that crop characters, yield components, grain and straw yields varied due to variation of water management in rice. The highest harvest index (47.2%) was obtained in T₃ (standing water 15 cm) which was as good as T₂ (standing water 10 cm), T₄ (standing water 20 cm) and T₅ (standing water 25 cm) but the lowest harvest index (42.62%) was obtained at T₁ (standing water 5 cm).

Chemical properties of post-harvest soil under different levels of standing water

Percentage of organic carbon (OC): The organic carbon in post-harvest soil was not significant due to the effect of different levels of standing water (Table 3). Numerically, the highest organic carbon (1.28 %) was recorded in T₃(standing water 15 cm) and T₅ (standing water 25 cm) the lowest content of organic carbon (1.21%) studied postharvest soil in the water level T₄ (standing water 20 cm).

Percentage of organic matter (OM): The organic matter in post-harvest soil was not significant due to the effect of different levels of standing water (Table 3). Numerically, the highest total organic matter (2.46 %) was recorded in T₄ (standing water 20 cm) and lowest organic matter content (2.06 %) in postharvest soil was recorded in the water level T₅ (standing water 25 cm).

Total nitrogen (N): Total nitrogen was not significantly influenced by level of standing water in the rice field (Table 3). However, numerically, the highest N (0.14 ppm) was recorded in T₅ (standing water 25 cm) and the lowest content of N (0.11 ppm) in the water level T₃ (standing water 15 cm).

Available phosphorus: The phosphorus in post-harvest varied significantly due to the effect of standing water level (Table 3). The highest phosphorus value was found (48.05 ppm) in the treatment T₂ (standing water 10 cm) followed by T₁ (standing water 5 cm) which was at par with and the lowest content of phosphorus (32.79 ppm) studied postharvest soil in the water level and T₃ (standing water 15 cm).

Exchangeable potassium: The exchangeable potassium was not significant due to the effect of different levels of standing water (Table 3). The highest value of potassium was recorded (0.21 meq/100g soil) in T₄ (standing water 20 cm) while the lowest content of potassium (0.19 meq/100g soil) studied postharvest soil in the water level T₅ (standing water 20 cm).

Available sulphur: Sulphur content of post-harvest soil was not varied significantly due to effect of standing water level (Table 3). Numerically the highest value of sulphur found (10.93 ppm) in the T₃ (water level 15 cm) while the lowest value of sulfur (8.75 ppm) in the water level T₁ (standing water 5 cm).

Conclusion

CH₄ emission gradually increased with rising standing water levels and remained static condition at 20-25 cm water level. The highest CH₄ emission was observed at 20 cm standing water levels and the lowest CH₄ emission was recorded at 5 cm standing water level. The maximum CH₄ peak recorded at 85 DAT. In this study, the CH₄ flux during rice cultivation followed the sequence 20 cm > 25 cm > 15 cm > 10 cm > 5 cm. Soil Eh gradually decreased with progress of time and plant growth. The highest plant height, number of grains hill⁻¹, grain yield and straw yield were observed at 10 cm standing water level while the lowest grain yield and straw yield were recorded at 5 cm and 15 cm water level, respectively. The highest amount of available phosphorus was found at 10 cm standing water level followed by 5 cm standing water level while the lowest one was recorded at 15 cm water level. From this study it can be concluded that 10 cm standing water level is suitable for transplant *Aman* rice cultivation considering the higher grain yield and nutrients availability and lower methane emission compared to other standing water level.

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