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Methane emission from transplanted rice cultivation through irrigation and fertilizer management practices

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Abstract
The experiment was conducted at Jorhat in Assam of India during *autumn* season of 2017 and 2018 to investigate the methane emission from transplanted rice through irrigation and fertilizer management practices. The treatment consisted of four irrigation schedules *viz.,* continuous submergence, 5 cm irrigation at 3 days after disappearance of ponded water (DADPW), 5 cm irrigation at 5 DADPW, 5 cm irrigation at 7 DADPW and four fertilizers management practices *viz.,* control, compost @ 5 t/ha, integrated nutrient management (INM) and recommended dose of fertilizers (RDF). Results revealed that highest methane emission and cumulative methane flux (CMF) were recorded in continuous submergence plot. Amongst the fertilizers management practices, application of RDF recorded the highest methane emission and CMF. Application of 5 cm irrigation at 3 DADPW with RDF recorded the highest grain and straw yield in both the years. The treatment receiving continuous submergence with RDF recorded the highest seasonal methane flux.

Keywords: Methane emission, cumulative methane flux, fertilizers, irrigation, autumn rice

Introduction
More than 75% of the rice consumed worldwide is produced under irrigation, mainly in Asia. This is because rice grows better than other crops in environments with plenty of water. However, it has been determined that this kind of rice fields with lots of water are the primary source of methane production, accounting for around 10-15% of the world's methane emissions (Pittelkow *et al.*, 2013) [12]. In the course of the anaerobic breakdown of organic matter, soil-dwelling bacteria release methane. Because of their anaerobic conditions, high levels of moisture, and abundance of organic substrate, rice fields offer the perfect environment for methane synthesis. This promotes the activity of methanogenic bacteria. By diffusion and through the rice plant, it leaves the soil and enters the atmosphere. Methane has been reported to make up 78% of all CO_2-equivalent emissions when taking global warming into consideration. Methane concentration in the atmosphere have increased globally, rising from 715 parts per billion (ppb) before industrialization to 1774 ppb in 2005 (IPCC, 2007) [7]. According to IPCC 2007, of the total yearly global methane emissions, more than 50% are attributable to human activity, with rice farming in wetlands contributing 14% of the overall methane emission. Methane emissions from rice fields are influenced by a number of variables, including climate, water level, water management, soil qualities, irrigation schedule, drainage, organic matter, chemical fertilisers, rice type, and rice straw management. One of the vital aspects in mitigating methane emission from rice fields is water management (Tang *et. al.*, 2018) [14] and fertilizer management (Bhattacharyya *et al.*, 2012; Anitha and Bindu, 2016) [3, 2]. The choice of fertilizer can affect production and emission of methane from rice field by influencing various factors *viz.*, availability of carbon sources in soil, rate of growth of rice plants, activity of methanogenic microbes in the soil, and the amount and composition of root exudates from growing rice plants. In perception of the above, a field experiment was conducted to assess both the direct and indirect effects of irrigation and nutrient sources on rice yields and methane emissions.

Material and Methods

The experiment was conducted at Assam Agricultural University, Jorhat, Assam during *autumn* season of 2017 and 2018. Geographically, the area is situated at northern latitude 26°44' and eastern longitude 94°10' at an altitude of 91.0 m above the mean sea level (msl). The weekly average maximum temperature ranged from 25.6 °C to 32.9 °C during 2017 and 23.73 °C to 34.51 °C during 2018 and minimum temperature ranged from 11 °C to 25.30 °C during 2017 and 11.57 °C to 25.06 °C during 2018. The total rainfall received were 767.20 mm and 536.60 mm during 2017 and 2018, respectively. The soil of the experimental field was sandy clay loam with pH of 5.80 and 5.82, organic carbon of 0.68 and 0.70%, medium available N (316.53 and 348.43 kg/ha) and P content (25.70 and 27.31 kg/ha) and K (137.64 and 139.56 kg/ha) for 2017 and 2018, respectively. The experiment was arranged in split plot design with three replications. The treatments comprised four irrigation schedules (I_1: continuous submergence, I_2: 5 cm irrigation at 3 DADPW,I_3: 5 DADPW, and I_4: 5 DADPW) in main plots and four fertilizers management practice (F_1:Control; F_2: Compost @ 5 t/ha; F_3:INM package i.e. compost @ 1 t/ha + mixture of *Azospirillum amazonense* A-10 and *Bacillus megaterium* P-5 @ 4 kg/ha each + rock phosphate @ 56 kg/ha + MOP @ 67 kg/ha + 10 kg/ha); and F_4: Recommended fertilizer dose i.e. compost @ 5 t/ha + N:P_2O_5:K_2O @ 40:20:20 kg/ha) in sub plots. Seeds of rice variety "Disang" was sown @ 45 kg/ha in nursery bed on 27th February 2017 and 24th February 2018 and transplanting was done on 23rd March in 2017 and 21st March in 2018.Other agronomic practices and plant protection measures were followed as per recommendation. Observations on yields were noted following standard procedure.

Methane emission from the soil using closed-chambers was determined by collecting gas samples periodically from the chambers and measuring the change in concentration of a gas with time during the period of linear concentration change (Ali *et al*., 2008). The chamber used in the present experiment was made with 6 mm Perspex sheets, fabricated locally. The dimensions of the chamber used in the experiment was 50 cm × 30cm × 70- 100 cm. Head space volume and temperature inside the chamber was recorded, which is used to calculate flux of gas. Gas samples were drawn with 20-50 mL syringe with the help of 24 gauge hypodermic needle at an interval of at 0, 1/4, 1/2 and 3/4 hrs. After drawing sample, the syringe was made air tight with three way stop cock. The gas samples were analyzed immediately in the gas chromatograph (GC) to prevent the diffusion losses. Emissions were calculated from the increase or decrease of gas concentration in the gas sampling chamber over time using the following equation:

$$\text{Methane emission } (mg/m^2/hr) = \rho \times V/A \times \Delta c/\Delta t \times 273/T \times \alpha$$

Where,

ρ : Density of gas at the standard condition (CH_4 = 0.716 kg/m^3)

V(m_3) : Volume of the chamber

A(m_2) : Bottom area of the chamber

$\Delta c/\Delta t$: Gas concentration change in the chamber during a given period

T : Absolute temperature(K) and

α : Conversion factor for CH_4 to C (12/16).

Total methane emission during the cropping season was calculated by successive linear interpolation of average gas emissions on the sampling days, assuming that gas emissions followed a linear trend during the periods when no sample was taken.

$$\text{Cumulative methane flux (CMF)} = \sum_{i-1}^{n-1} \text{Ri} \times \text{Di}$$

Where, *Ri* is the mean gas emission (mg/m^2/day) of the two sampling times, *Di* is the number of days in the sampling interval and *n* is the number of sampling times. All the data were statistically analysed following the standard method described by Rangaswamy (1995) [13].

Results and Discussion

The grain and straw yield of rice were significantly influenced by different irrigation schedules and nutrient management practices in both the years (Table 1). Rice crop irrigated with 5 cm at 3 DADPW (I_2) resulted in significantly higher grain and straw yield in both the years compared to other irrigation schedules. The higher grain yield under 5 cm irrigation at 3 DADPW (I_2) might be due to a greater number of effective tillers/hill, number of grains/panicle and 1000-grain weight. Alternate wetting and drying could perhaps optimally maintained soil hydrological situation to enhance the sink strength by regulating the key enzyme involved in the sucrose-to- starch pathway in the grains of rice and subsequently increased the grain filling rate and grain weight of inferior spikelets. Such beneficial effects of alternate wetting and drying with particular duration on yield attributes and grain yield of rice were also reported by Djaman *et al*. (2018) [4]. Application of RDF (F_4) being at par with INM treatment (F_4) resulted in significantly higher grain and straw yield as compared to other nutrient management practices. The increased yield parameter in the treatment receiving organic fertilizer along with chemical fertilizer might be due to enhanced availability of nutrients. The available nutrients might have helped in enhancing leaf area which increases the photosynthesis and more dry matter accumulation. The present results corroborate findings of Mangaraj *et al*. (2022) [11].

Table 2 shows the combined impact of fertilizer management practices (F) and irrigation schedules (I) on grain and straw yields. The treatment receiving RDF (F_4), which was statistically comparable to the INM treatment (F_3), had the highest grain and straw yields at the same level of irrigation schedules (I). Similar to this, at the same amount of fertilizers management practices (F), 5 cm irrigation with 3 DADPW (I_2) produced considerably greater grain and straw yields than the other irrigation treatments. This was true amongst all the nutrient management regimes. The highest grain and straw yield in I_2F_3 might be due to the presence of adequate soil moisture and nitrogen which increased the availability of NH_4+ and its uptake. Higher nitrogen uptake may correlate with absorption of phosphorus and potassium, increase in number of tillers and filled grains/panicle which eventually increases the grain and straw yield of rice. Elhabet (2018) [6] also reported similar results.

The temporal methane emission varied with different irrigation schedules and nutrient management practices in both the years (Figure 1 & Figure 2). Emission peaks were observed at 35 DAT (maximum tillering) and at 63 DAT (flowering stages), irrespective of irrigation schedules and nutrient management practices. In general, methane emission rate increases with increases in growth and development of rice plants until flowering, due to the good development of aerenchyma tissue, release of more root exudates, and fermentation of easily degradable soil organic matter in lowland rice cultivation (Islam *et al*. 2020; Islam *et al*. 2022; Malayan *et al*., 2016) [8, 9, 10]. In the present study, CH_4 emission peaks were observed at the tillering and flowering stages under different irrigation schedules and nutrient management practices. This might be explained by the microbial degradation of rhizodeposition, root exudates, algal biomass, and microbial biomass during the tillering stage (Malayan *et al*., 2016) [10]. Similarly, higher emission peaks at the flowering stage might be attributed to higher methanogenesis and soil labile organic carbon (Malayan *et al*., 2016) [10]. Our results are consistent with previous findings (Islam *et al*. 2020; Islam *et al*. 2022) [8, 9].

The cumulative flux of methane in both the years as affected by different irrigation schedules are shown in Table 3. The highest cumulative methane flux was observed under continuous flooding (I_1) and RDF (F_4) treatment. Urea hydrolysis and decrease in the redox potential under continuous flooding resulted in the increase in cumulative methane flux over the control. Dubey (2005) [5] also reported increase in cumulative methane flux because of these two processes. Moreover, more production of plant biomass under properly fertilized treatment acts as better source of carbon substrate for methanogenesis besides the higher root exudates acting as major carbon source for methane production (Islam *et al*. 2022) [9]. Combine effect of irrigation schedules and different nutrient management practices was significant on cumulative methane flux (Table 4) in both the years. At the same level of irrigation treatment, the highest CMF was recorded in F_4 (RDF) and at the same level of fertilizers (F), a significantly higher CMF was recorded under I_1 (continuous submergence) than that of other irrigation scheduling treatments. The increase in cumulative methane flux in the I_2F_4 treatment might be due to vigorous growth of the rice crop as observed from the plant biometric parameters due to adequate supply of nutrient to crop and prevailing anaerobic condition of soil which was favorable for methane production.

Table 1: Effect of irrigation schedules and nutrient management practices on grain and straw yield of transplanted autumn rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)	
	2017	**2018**	**2017**	**2018**
Irrigation schedules (I)				
I_1: Continuous submergence	2.99	2.83	4.99	5.37
I_2:5 cm at 3 DADPW	4.08	4.13	6.26	6.45
I_3:5 cm at 5 DADPW	3.20	3.10	4.81	4.60
I_4:5 cm at 7 DADPW	2.73	2.70	4.28	4.17
S.Em (±)	0.08	0.07	0.14	0.15
C.D(P=0.05)	0.26	0.26	0.49	0.53
Nutrient management practices (F)				
F_1: Control plot (No fertilizers)	2.61	2.47	4.06	4.02
F_2: Compost @ 5 t/ha	3.13	3.03	4.80	4.74
F_3: INM package	3.53	3.54	5.58	5.78
F_4: RDF	3.74	3.71	5.90	6.06
S.Em (±)	0.08	0.07	0.11	0.14
C.D (P=0.05)	0.23	0.21	0.32	0.42
Interaction(I×F)				
S.Em (±)	0.16	0.15	0.22	0.29
CD (P=0.05)	0.46	0.42	0.65	0.85

Table 2: Combine effect of irrigation schedules and nutrient management practices on grain and straw yield of transplanted autumn rice

Irrigation Schedules	Grain yield (t/ha)								Straw yield (t/ha)							
Nutrient management practices	2017				2018				2017				2018			
	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
F_1	2.47	3.27	2.73	1.97	2.00	3.23	2.70	1.93	3.33	5.62	4.18	3.11	3.58	5.60	4.00	2.88
F_2	3.03	3.90	3.30	2.30	2.93	4.00	2.93	2.27	4.62	6.02	5.05	3.52	4.61	6.22	4.56	3.56
F_3	3.17	4.47	3.33	3.13	3.17	4.47	3.27	3.27	5.42	6.68	5.00	5.22	6.30	6.91	4.88	5.04
F_4	3.30	4.70	3.43	3.53	3.20	4.80	3.50	3.33	6.58	6.71	5.02	5.29	6.99	7.07	4.96	5.20
	S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)		S.Em±		CD (P=0.05)	
F at the same level of I	0.16		0.46		0.15		0.42		0.22		0.65		0.29		0.85	
I at the same or different level of F	0.16		0.46		0.15		0.45		0.24		0.74		0.29		0.90	

Table 3: Cumulative methane flux as affected by different irrigation schedules and nutrient management practices

Treatment	CMF(mg/m2)	
	2017	2018
Irrigation Schedules (I)		
I_1: Continuous submergence	275.70	278.81
I_2:5 cm at 3 DADPW	263.99	268.12
I_3:5 cm at 5 DADPW	256.94	257.40
I_4:5 cm at7 DADPW	229.17	230.62
S.Em (±)	1.99	2.76
C.D(P=0.05)	6.90	9.56
Nutrient management practices(F)		
F_1: Control plot (No fertilizers)	202.15	203.02
F_2: Compost @ 5 t/ha	239.76	241.63
F_3: INM package	276.51	277.49
F_4: RDF	307.38	312.82
S.Em (±)	1.83	1.99
C.D(P=0.05)	5.34	5.80
Interaction (I x F)		
S.Em (±)	3.66	3.98
CD(P=0.05)	10.68	11.61

Table 4: Interaction effect of irrigation schedules and nutrient management practices on Cumulative methane flux (CMF)

Irrigation Schedules	CMF(mg/m2)							
	2017				2018			
Nutrient management practices	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
F_1	216.84	207.46	206.13	178.20	214.13	212.52	206.52	178.90
F_2	250.11	250.11	252.14	206.66	253.19	249.62	253.87	209.86
F_3	295.19	283.62	273.44	253.80	297.85	288.63	272.07	251.39
F_4	340.64	314.77	296.05	278.04	350.07	321.72	297.15	282.33
	S.Em (±)		CD (P=0.05)		S.Em (±)		CD (P=0.05)	
F at the same level of I	3.66		10.68		3.98		11.61	
I at the same or different level of F	3.74		11.51		4.41		13.82	

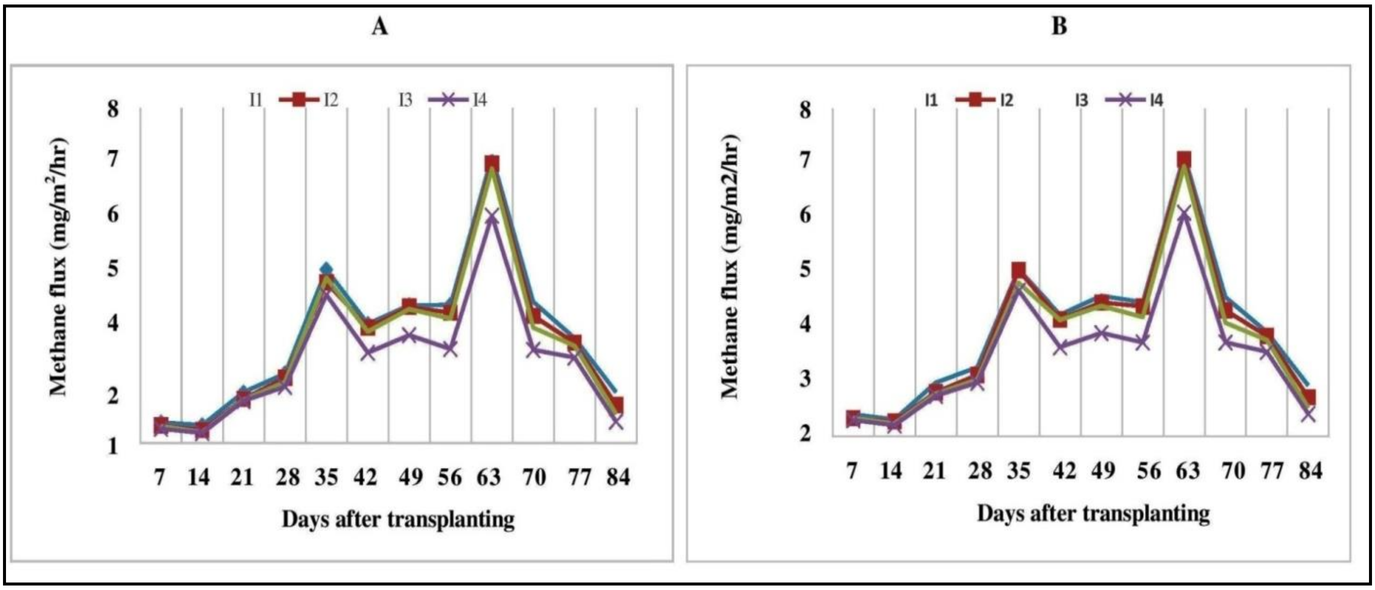

Fig 1: Methane emission from rice field as affected by different irrigation schedules during 2017(A) and 2018(B).
I_1: Continuous submergence, I_2:5cm irrigation at 3 DADPW, I_3:5cm irrigation at 5 DADPW, I_4: 5 cm irrigation at 7 DADPW

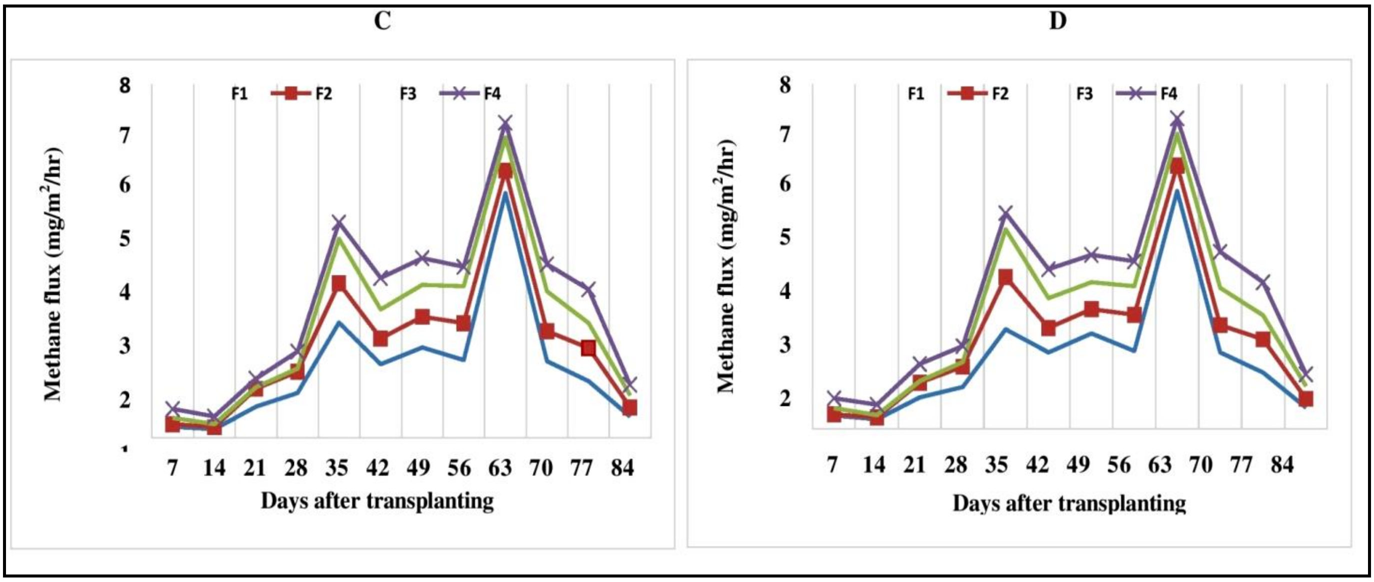

Fig 2: Methane emission from rice field as affected by different nutrient management practices during 2017(C) and 2018(D).
F1: Control, F2: Compost @ 5 t/ha, F3: INM, F4: R

Conclusion

Treatment combination I_2F_3, *i.e*., 5 cm irrigation at 3 DADPW (days after disappearance of ponded water) along with INM package was proved to be a better proposition for obtaining both economic and biological yields with minimum methane emission from the rice fields

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