Original Research Article

Mitigation Option for GHG Emission from Wetland Rice Cultivation.

ABSTRACT

The study on the effect of soil amendments and fertilizers on the mitigation of CH_4 and N_2O emission from rice field was conducted in the Wetland farm of Tamil Nadu Agricultural University farm, Coimbatore, Tamil Nadu, India during *rabi* season. The results showed that the use of Gypsum and Fly Ash along with recommended dose of fertilizer reduced the emission of methane whereas urea with neem treatment reduced the N_2O emission from the conventional water logged rice field. Methane emission was found to peak during the panicle initiation stage while nitrous oxide emission was noted only during the maturity stage. The application of Fly Ash along with gypsum had cut down the methane emission to a greater extent at all the stages. Nitrous oxide emission was reduced with the application of slow release N fertilizer (neem treated urea).

Key words: Fly ash, Neem, Gypsum, GHG, Methane and Nitrous oxide.

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INTRODUCTION:

The most predominant form of carbon reserves the soil carbon content which plays a major role in the fertility of the soil (Galaktionova *et al.*, 2020). In case of paddy cultivation, the soil is kept under submergence leading to anaerobic condition which contributes towards higher methane emission and to a lesser extent nitrous oxide emission (Tiwari *et al.,* 2020). But the untimely application and incorrect methods of nitrogenous fertilizer application can lead to N_2O emission. Rice being the stable food of the majority of the Asian population, the increasing demand for food commodities has caused pressure on paddy cultivation. Paddy field emits approximately 11 per cent and 30 per cent of global agricultural Nitrous oxide and Methane emission, respectively (Gupta *et al.*, 2021). It is therefore, imperative to develop technologies to reduce emission of GHGs from rice field.

Fly ash, an amorphous mixture contains high quantities of silica, iron, manganese oxides, zinc and copper which could act as a soil amendment to suppress methane emission (Yadav and Pandita, 2019). These elements enact to enhance the electron acceptors leading to depression in methanogenesis. "Gypsum has high concentration of electron acceptor like SO_4^{2-}; its application might be effective on reducing CH_4 emission during rice cultivation" (Thakur and Solanki, 2021). Nitrification inhibitors such as neem coated urea could slow down the process of nitrification in soil which could reduce emission of N_2O as well as methane from soil by 10-15 per cent (Singh *et al*., 2019).

The research was done with the objective of developing a mitigation strategy to reduce the emission of CH_4 and N_2O from the rice fields with selected soil amendments like fly ash, gypsum and Neem Treated Urea (NTU).

MATERIALS AND METHODS:

The field experiment was conducted at the wetland farm of the Tamil Nadu Agricultural University, Coimbatore during *rabi* with CO(R) 51, a short duration rice variety. The experiment was laid out in a complete randomized block design and replicated thrice. The layout of the field experiment is provided in the figure 1. The Soil characteristics are given in the table 1.

Table 1. Soil characteristics of the experimental field

I.	**Textural properties (Piper, 1966)**

	i. Clay (%)	39.5
	ii.Silt (%)	17.3
	iii. Fine sand (%)	23.4
	iv. Coarse sand (%)	19.2
	v. Textural class	Clay loam
II.	**Chemical properties**	
	i. pH (1:2 soil water suspension)	8.2
	ii. EC (ds m^{-1})	0.44
	iii. Organic carbon (%)	0.60
	iv. Available Nitrogen (kg ha^{-1})	221.02
	v. Available Phosphorus (kg ha^{-1})	28.6
	vi. Available Potassium (kg ha^{-1})	380
	vii. DTPA Zn (mg kg^{-1})	3.09
	viii. DTPA Cu (mg kg^{-1})	2.76
	ix. DTPA Mn (mg kg^{-1})	10.32
	x. DTPA Fe (mg kg^{-1})	6.12

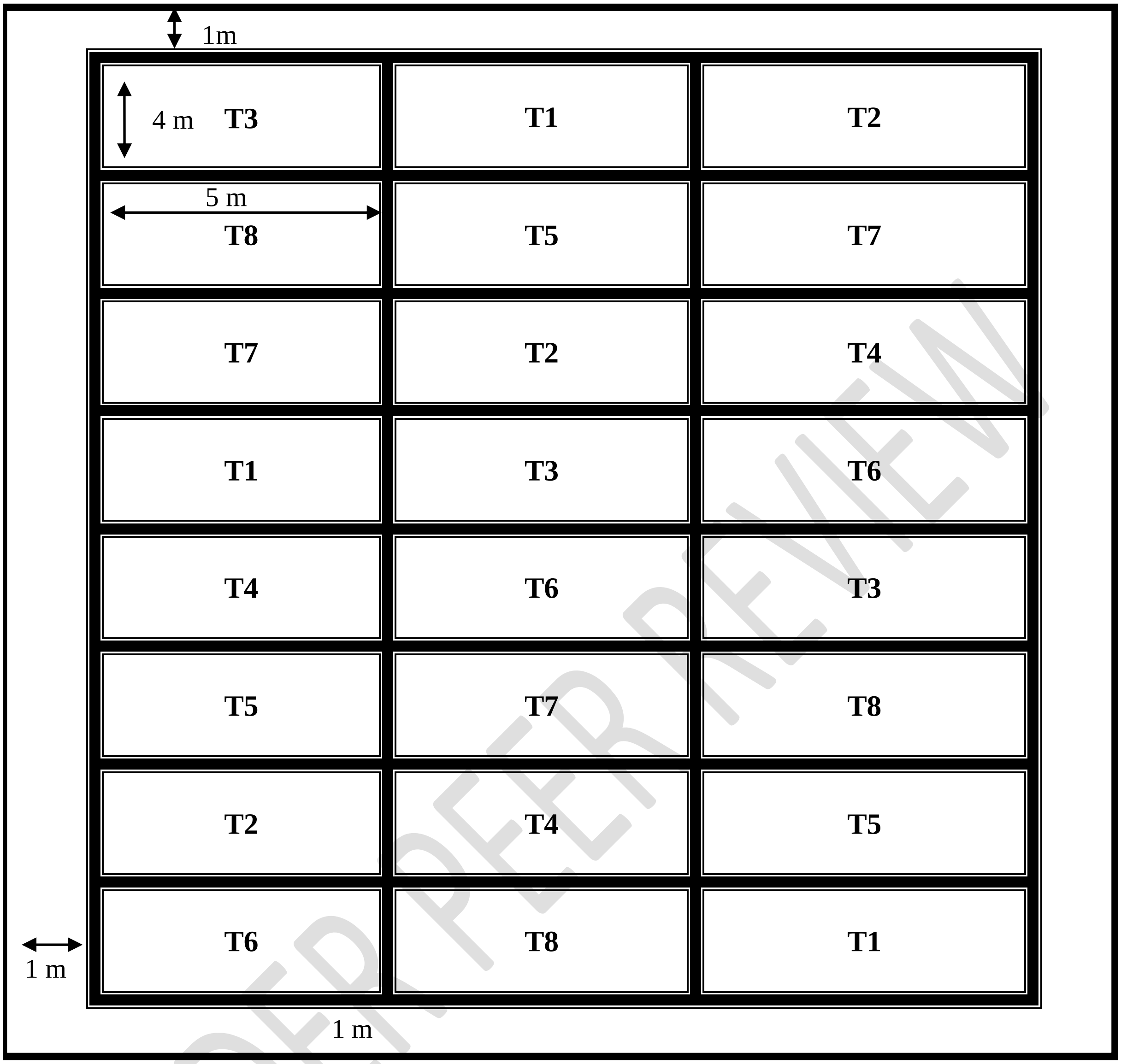

Figure 1. Layout of the field experiment

2.1 Crop husbandry

The nursery was raised with a seed rate of 40 kg ha^{-1}. The seeds were soaked for 12 hrs and treated with *Azospirillum* and *Pseudomonas* at the rate of 200 g and 100 g per 10 kg of seeds and kept in dark for an additional 24 hours. Twenty days old seedlings were transplanted at a spacing of 20 x 10 cm in plots that were treated with the selected soil amendments and fertilizers according to the treatments. Submergence in the main field was maintained till 15 days prior to harvest. The TNAU recommended dose of fertilizers (NPK - 150:50:50) was used for the experimentation purpose.

2.2 Treatments

The treatments were as follows:

T_1 : Urea + Murate of Potash (MOP) + Single Super Phosphate (SSP) (150:50:50)

T_2 : Neem Treated Urea (NTU) + MOP + SSP

T_3 : Urea + MOP + SSP + Gypsum (500 kg ha^{-1})

T_4 : NTU+ MOP + SSP + Gypsum (500 kg ha^{-1})

T_5 : Urea + MOP + SSP + Fly Ash (20 tonnes ha^{-1})

T_6 : NTU + MOP + SSP + Fly Ash (20 tonnes ha^{-1})

T_7 : Urea + MOP + SSP + Gypsum (500 kg ha^{-1}) + Fly Ash (20 tonnes ha^{-1})

T_8 : NTU + MOP + SSP + Gypsum (500 kg ha^{-1}) + Fly Ash (20 tonnes ha^{-1})

Neem treated urea was prepared by blending urea with crushed neem seed or neem cake 20% by weight. Powdered neem cake to pass through 2mm sieve before mixing with urea and kept overnight before use. Phosphorus, Gypsum and Fly Ash were applied as basal, potassium and nitrogen were applied in four equal quantities as per treatment at basal, active tillering, panicle initiation and at 50 per cent flowering stages.

2.3 Gas collection:

“Gas samples were collected from the field using static closed chamber technique. The gas chambers were fabricated as per the recommendations made from several studies” (Denmead, 2008). Open-bottom perplex chambers using 4 mm acrylic sheets with a dimension of 50 cm x 50 cm x 100 cm were fabricated. A battery (12V) operated fan was fixed for air circulation (to avoid plant suffocation) to mix the air inside the chamber.

As described by Khosa *et al.*, (2010) “each chamber was placed on the soil surface with 4-5 cm inserted into the soil. Care was taken not to disturb the vegetation during the whole measurement programme. After covering the plants with the chamber, four air samples were collected in Tedlar bags starting with zero time. Subsequent sampling was done at an interval of 15 minutes using one way valve pump”. As described by Jayadeva *et al.* (2009), “the air samples were collected in the morning (09:00-10:00 hours) and in the evening (14:00-15:00 hours) and the average of morning and afternoon fluxes were used as the flux value for the day”.

2.5 Gas estimation:

“The CH_4 and N_2O were estimated using a Shimadzu GC-2014 gas chromatograph equipped with FID and ECD. The gas samples were introduced into the analyzer by filling the fixed loop (1.0 ml) on the sampling valve. Samples were injected into the column system by starting the analyzer which automatically activated the valve and back flush the samples according to the time programmed. The GC was calibrated before and after each set of measurements using 1 mg/l, 2.3 mg/l and 5 mg/l of standards (Chemtron® Science Laboratories Pvt. Ltd., Mumbai) as primary standard curve linear over the concentration ranges used. CH_4 and N_2O concentration were expressed as mg m^{-2} hr^{-1} using the equation” given by Lantin *et al*., (1995). The obtained CH_4 and N_2O concentrations were determined by peak area and flux was calculated based the equation proposed by Rolston (1986) to estimate methane and nitrous oxide concentrations.

$$f = (V/A)\ (\Delta C/\ \Delta t)$$

Where f is equal to greenhouse gas emission rate (mg m^{-2} h^{-1}), V is equal to volume of chamber above soil (m^3), A is equal to cross-section of chamber (m^2), ΔC is equal to concentration difference between zero and t times (mg cm^{-3}), and Δt is equal to time duration between two sampling periods (h).

3. RESULTS AND DISCUSSION:

3.1 Methane emission

The emission data are presented in table 2. Significantly higher methane emission was recorded in treatment with NPK alone (T_1 & T_2) at all the four stages. In the present investigation the treatment in which fly ash and gypsum were used along with RDF (T_8) had lower CH4 emissions, compared to the rest of the treatments. Though application of gypsum and fly ash with RDF (T_8) reduced methane emission significantly, the application of recommended fertilizer and gypsum (T_3) alone stood next to the treatments with NPK alone (T_1) on the higher emission of methane. The reduction of methane with the application of fly ash and gypsum with NTU, MOP and SSP (T_8) compared to the control (T_1) was about 31.53, 24.46, 442 and 3.93 per cent at active tillering, panicle initiation, 50 per cent flowering and maturity stages respectively.

The application of fly ash reduced the methanogen population with the lowest number in the treatments $T_{5,}$ $T_{6,}$ T_7 and T_8 at all three stages. The methanogen population at the active tillering stage in treatments T_1 to T_4 i.e. treatments without fly ash ranged between 11 to 12 x 10^3 CFU per g of soil whereas 7 to 8 x 10^3 CFU per g of soil was recorded for treatments with fly ash as a component. In the panicle initiation stage the population was 18 or 19 x 10^3 CFU per g of soil in non fly ash applied treatments and 12 or 13 x 10^3 CFU per g of soil in fly ash treated fields. During the 50 per cent flowering stage, the population was found to be highest in T_2 (NTU+SSP+MOP+Gypsum), but was not statistically significant over other treatments. The range was between 12 to 15 x 10^3 CFU per g of soil in treatments without fly ash and 8 to 10 x 10^3 CFU per g of soil in treatments with fly ash. The study on methanogen population revealed that the population was lowest in the treatments T_5, T_6, T_7 and T_8 in which Fly Ash was a component at the three stages (active tillering, panicle initiation and 50 per cent flowering) (Pradipa *et al.,* 2016) and the lower emission was also noticed in the same treatments at all the four stages. The methanogen population was also in line with emission results.

"The reduction in methanogen population inturn the methane emission with the increased sulfate concentration, iron and manganese might have resulted into proliferation of other reducing bacteria like Sulphate reducing, that out-compete methanogens for substrates leading to reduction in population of methanogens" (Singh *et al*., 2018)*."*Also increase ferric iron concentration increases the microbial ferric iron reduction to Ferrous iron leading to suppression of Methanogenesis" (Gabriel *et al*., 2020). *"*This might also be result due to shifting of electron flow from methanogenesis to sulfate reduction under anaerobic soil conditions" (Conard *et al.,* 2020).

"Either, Gypsum or fly ash when applied alone had lesser impact when compared with the treatments where both are applied in combination. Eventhough gypsum is a good source of sulphate, the rate of application was only 500 kg per ha which might not be sufficient enough to suppress the activity of methanogens" (Pradipa *et al.,* 2016) inturn the methane emission.

"The suppression of CH_4 emission was due to the increased concentrations of active sulfate in the soil amended by gypsum and fly ash might have controlled methanogens activity by limiting substrates availability" (Malyan *et al.,* 2021) and hence resulted in reduced methane emission. "The increased supply of iron and manganese compounds from the fly ash might have acted as electron acceptors and thereby, suppressed CH_4 production as well as CH_4 emission during rice cultivation" (Sapkota *et al.,* 2020). Application of NTU urea has no influence on methane emission from rice fields. The reduction in methane emission during the later stages was prominent that too in the treatments with fly ash and gypsum in combination with RDF, since the antagonistic microbial mass might need time for its proliferation and active involvement in electron transport chain.

Table 2. Influence of different treatments on methane emission (mg m^{-2} hr^{-1})

Treatments	Active Tillering	Panicle Initiation	50 per cent flowering	Maturity
T1	4.1220	4.6126	3.9565	3.7569
T2	4.0806	4.8486	3.7190	3.7531
T3	3.6704	4.6156	3.3570	3.3560
T4	3.7482	4.3269	3.3495	3.3395
T5	3.7453	3.8938	3.0538	3.0564
T6	3.6927	3.9351	2.5974	2.6787
T7	3.6010	4.1418	0.9328	0.9310
T8	3.1338	3.7058	0.7299	0.7613
Mean	**3.7243**	**4.2600**	**2.7120**	**2.7041**
SEd	**0.0504**	**0.2559**	**0.1628**	**0.1164**
CD(0.05)	**0.1080**	**0.5490**	**0.3493**	**0.2496**

Nitrous oxide emission rate

In respect of nitrous oxide, upto 50 per cent of flowering the nitrous oxide emission was below detectable level (50 ppb) and was recorded only at the harvest stage since water was stopped 15 days before harvest (Figure. 2). Once the soil was brought to aerobic condition the nitrous oxide emission was found in the present investigation. At this stage, the data were found to be significant, wherein significantly higher nitrous oxide emission was noted in treatments T_7 and T_1.

"In the treatments in which NTU was applied instead of urea showed a decline in N_2O emission as reported" by Davamani *et al.,* (2021). The lowest nitrous oxide emission was noted with the treatment T_2 in which NTU was used as a slow nitrogen release fertilizer.

The mean nitrous oxide emission during the maturity stage recorded was 0.5008 mg m^{-2} hr^{-1}. The high pitched nitrous oxide emission rate of 0.5940 mg m^{-2} hr^{-1} was with T_1 (control) followed by T_5 and the most modest value of 0.3996 mg m^{-2} hr^{-1} was recorded with the treatment T_2. The reduction was about 32.72 per cent.

The naturally occurring allelochemicals in neem ((*Azadirachta indica*), mint (*Mentha* sp.) and mahua (*Madhuca longifolia*, L.) are reported to have Nitrification inhibition (Kumar *et al.*, 2016; Majumdar, 2008). Similarly, neem treated urea also has nitrification inhibition properties.

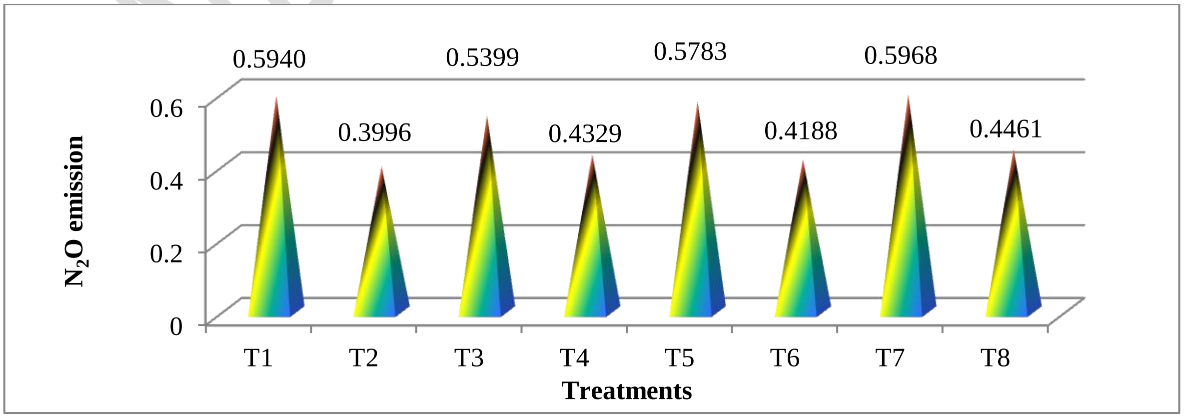

Figure. 2. Influence of different treatments on nitrous oxide emission at maturity stage (mg $m^{-2}hr^{-1}$)

CONCLUSION:

Based on the results it is concluded that fly ash or/and gypsum along with RDF reduces the emission of CH_4 by providing alternate electron acceptors whereas NTU, did reduce the N_2O emission by inhibiting nitrification. The amendments in combination ca have a good impact on emission of the two major GHG (i.e. CH_4 & N_2O) from the rice field.

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