



Mitigation Option for GHG Emission from Wetland Rice Cultivation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study on the effect of soil amendments and fertilizers on the mitigation of CH₄ and N₂O 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 N₂O 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).

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1. INTRODUCTION

The most predominant form of carbon reserves the soil carbon content which plays a major role in the fertility of the soil [1]. 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 [2]. But the untimely application and incorrect methods of nitrogenous fertilizer application can lead to N₂O emission. Rice being the staple 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 [3]. 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 [4]. These elements enact to enhance the electron acceptors leading to depression in methanogenesis. "Gypsum has high concentration of electron acceptor like SO₄²⁻; its application might be effective on reducing CH₄ emission during rice cultivation" [5]. Nitrification inhibitors such as neem coated urea could slow down the process of nitrification in soil which

could reduce emission of N₂O as well as methane from soil by 10-15 per cent [6].

The research was done with the objective of developing a mitigation strategy to reduce the emission of CH₄ and N₂O from the rice fields with selected soil amendments like fly ash, gypsum and Neem Treated Urea (NTU).

2. 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 Fig. 1. The Soil characteristics are given in the Table 1.

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.

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

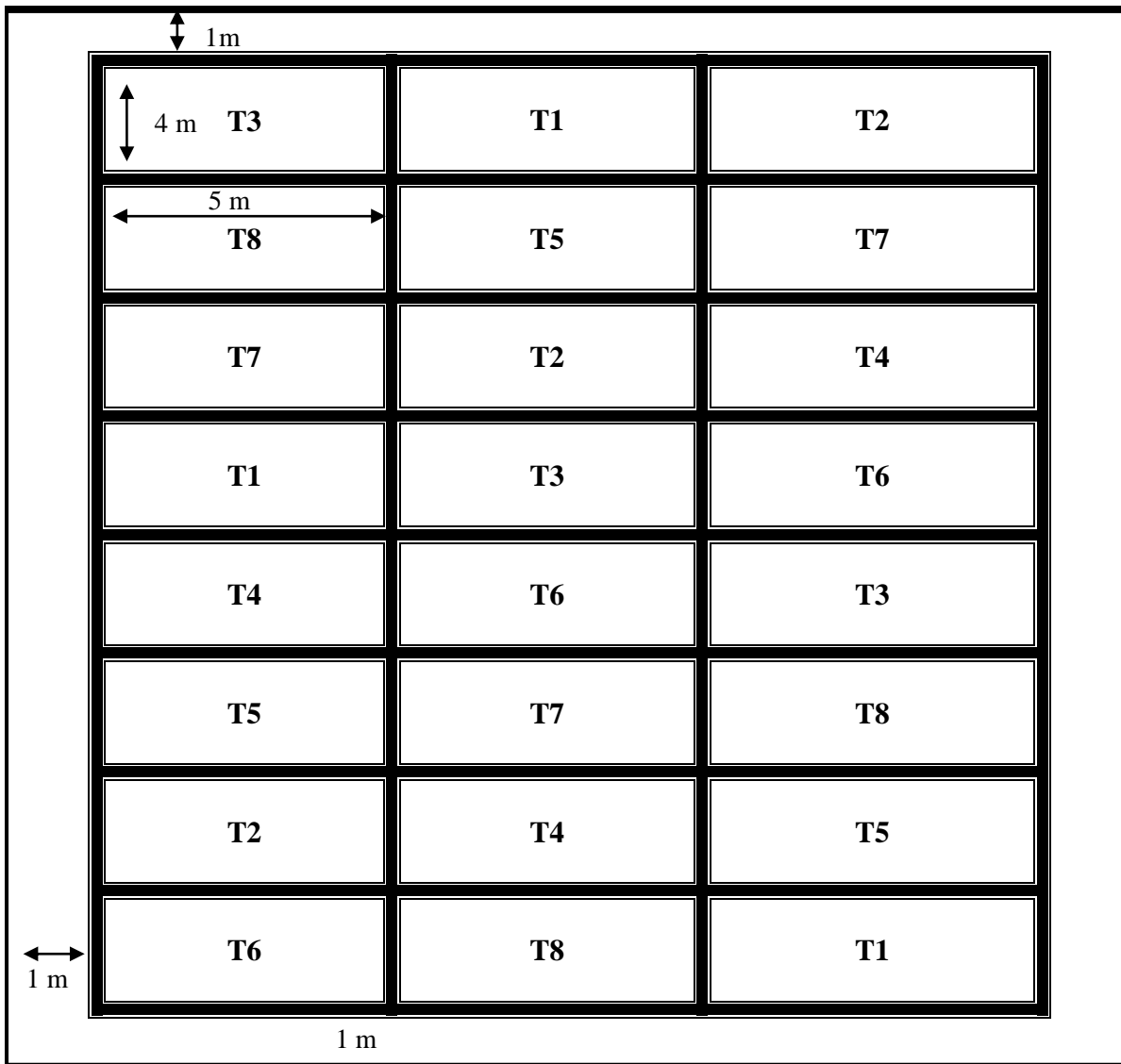


Fig. 1. Layout of the field experiment

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

2 mm 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” [7]. 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* [8] “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* [9] “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”.

2.4 Gas Estimation

“The CH₄ and N₂O 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. CH₄ and N₂O concentration were expressed as mg m⁻² hr⁻¹ using the equation” given by Lantin *et al* [10] The obtained CH₄ and N₂O concentrations were determined by peak area and flux was calculated based the equation proposed by Rolston [11] 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 (m³), A is equal to cross-section of chamber (m²), 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 (T₁ & T₂) at all the four stages. In the present investigation the treatment in which fly ash and gypsum were used along with RDF (T₈) had lower CH₄ emissions, compared to the rest of the treatments. Though application of gypsum and fly ash with RDF (T₈) reduced methane emission significantly, the application of recommended fertilizer and gypsum (T₃) alone stood next to the treatments with NPK alone (T₁) on the higher emission of methane. The reduction of methane with the application of fly ash and gypsum with NTU, MOP and SSP (T₈) compared to the control (T₁) 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 T₅, T₆, T₇ and T₈ at all three stages. The methanogen population at the active tillering stage in treatments T₁ to T₄ i.e. treatments without fly ash ranged between 11 to 12 x 10³ CFU per g of soil whereas 7 to 8 x 10³ 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 10³ CFU per g of soil in non fly ash applied treatments and 12 or 13 x 10³ 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 T₂ (NTU+SSP+MOP+Gypsum), but was not statistically significant over other treatments. The range was between 12 to 15 x 10³ CFU per g of soil in treatments without fly ash and 8 to 10 x 10³ CFU per g of soil in treatments with fly ash. The study on methanogen population revealed that the population was lowest in the treatments T₅, T₆, T₇ and T₈ in which Fly Ash was a component at the three stages (active tillering, panicle initiation and 50 per cent flowering) [12] 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 turn 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” [13]. Also increase ferric iron concentration increases the microbial ferric iron reduction to Ferrous iron leading to suppression of Methanogenesis” [14]. “This might also be result due to shifting of electron flow from methanogenesis to sulfate reduction under anaerobic soil conditions” [15].

“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” [12] inturn the methane emission. “The suppression of CH₄ 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” [16] 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 CH₄ production as well as CH₄ emission during rice cultivation” [17]. 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.

3.2 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 (Fig. 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 T₇ and T₁.

“In the treatments in which NTU was applied instead of urea showed a decline in N₂O emission as reported” by Davamani et al [18]. The lowest nitrous oxide emission was noted with the treatment T₂ 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 T₁ (control) followed by T₅ and the most modest value of 0.3996 mg m⁻² hr⁻¹ was recorded with the treatment T₂. 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 [19,20]. Similarly, neem treated urea also has nitrification inhibition properties [21,22].

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

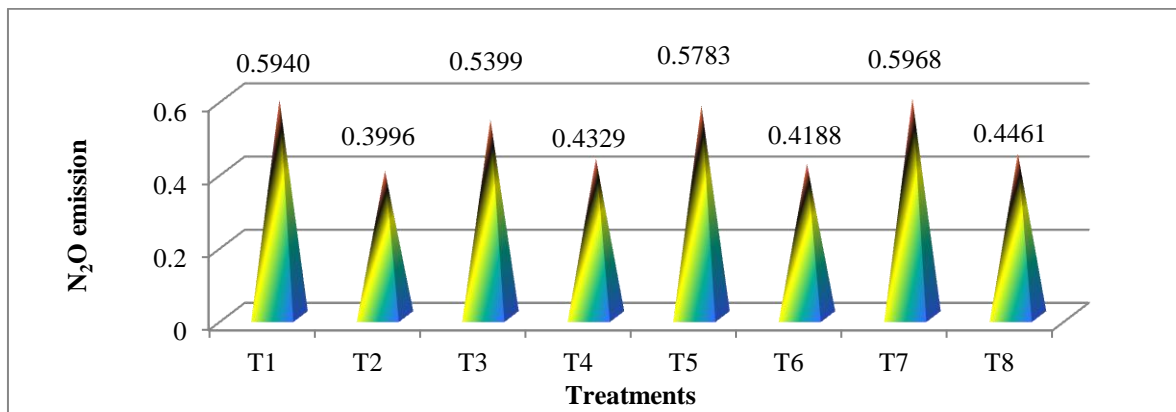


Fig. 2. Influence of different treatments on nitrous oxide emission at maturity stage (mg m⁻²hr⁻¹)

4. CONCLUSION

Based on the results it is concluded that fly ash or/and gypsum along with RDF reduces the emission of CH₄ by providing alternate electron acceptors whereas NTU, did reduce the N₂O emission by inhibiting nitrification. The amendments in combination can have a good impact on emission of the two major GHG (i.e. CH₄ & N₂O) from the rice field.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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