

Original Research Article

Mitigation Options for Greenhouse Gas Emission from Wetland Rice Cultivation.

ABSTRACT

The study on the effect of soil amendments and fertilizers on the mitigation of CH₄ and N₂O emission from a rice field was conducted in the Wetland farm of Tamil Nadu Agricultural University farm, Coimbatore, Tamil Nadu, India during *rabi* season. The results showed ~~did reveal~~ that the use of gypsum and fly ash along with recommended dose of fertilizer reduced the emission of CH₄ methane whereas urea with neem treatment had reduced the N₂O emission from the conventional water logged rice field. Methane emission was found to peak during the panicle initiation stage while N₂O nitrous oxide emission was noted only during the maturity stage. The application of fly ash along with gypsum reduced ~~had cut down~~ the CH₄ methane emission by...% 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.

1. INTRODUCTION:

The most predominant form of carbon reserves is the soils and the soil carbon content which plays a major role in the fertility of the soil (Reference needed). In case of paddy cultivation, the soil is ~~has been~~ kept under submergence, leading to anaerobic condition which contributes towards higher methane emission and to a lesser extent nitrous oxide emission (Tiwari et al.,

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2020). But the untimely application and ~~incorrect faulty~~ methods of nitrogenous fertilizer application ~~can leads~~ to N₂O emission. Rice being the staple food of ~~the majority of the major~~ Asian population, the ~~increasing rising~~ demand for food commodities has caused ~~increasing~~ pressure on paddy cultivation. Paddy field emits approximately 11 ~~%per-cent~~ and 30 ~~%per-cent~~ of global agricultural ~~N₂O Nitrous oxide~~ and ~~mMethane (CH₄)~~ emission, respectively (Gupta et al., 2021). It is therefore ~~imperative -pertinent~~ to develop technologies to reduce ~~greenhouse gas (GHG) emission of GHGs~~ from rice field.

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Fly ash, an amorphous mixture contains high ~~quantities amount~~ of silica, iron, manganese oxides, zinc and copper, which could act as a ~~good~~ 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 ~~very~~ high concentration of electron acceptor like SO₄²⁻; its application might be effective on reducing CH₄ 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 N₂O as well as ~~CH₄ methane~~ from soil by 10-15 ~~%per-cent~~ (Singh et al., 2019).

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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 -and the~~ experiment was laid out in ~~a complete~~ randomized ~~complete~~-block design and replicated thrice.

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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 another 24 hours. Twenty days old seedlings were transplanted at with a spacing of 20 x 10 cm in the 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.

2.2 Treatments:

The eight treatments studied were as follows:

T₁ : Urea + Murate of Potash (MOP) + Single Super Phosphate (SSP) (150:50:50)

T₂ : Neem Treated Urea (NTU) + MOP + SSP

T₃ : Urea + MOP + SSP + Gypsum (500 kg ha⁻¹)

T₄ : NTU+ MOP + SSP + Gypsum (500 kg ha⁻¹)

T₅ : Urea + MOP + SSP + Fly Ash (20 tonnes ha⁻¹)

T₆ : NTU + MOP + SSP + Fly Ash (20 tonnes ha⁻¹)

T₇ : Urea + MOP + SSP + Gypsum (500 kg ha⁻¹) + Fly Ash (20 tonnes ha⁻¹)

T₈ : 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. Neem cake used was powdered neem cake to pass through 2 mm sieve before mixing with urea and kept overnight before use. Phosphorus, Gypsum and Fly Ash

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were ~~was~~ applied as ~~basal~~, ~~and~~ ~~p~~Potassium and ~~n~~Nitrogen were applied in four equal quantities ~~splits~~ as per ~~the~~ treatment, at ~~basal~~, active tillering, panicle initiation and ~~at~~ 50% ~~per cent~~ flowering stages.

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2.3 Gas collection:

Gas samples were collected from the field using ~~a~~ static closed chamber technique. The gas chambers were fabricated as per the recommendations made from several studies (Denmead, 2008). Open-bottom perplech 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.

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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. ~~S and~~ subsequent sampling was done at an interval of 15 minutes using ~~a~~ 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 evening~~ fluxes were used as the flux value for the day.

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2.5 Gas estimation:

The CH₄ and N₂O were estimated ~~using in~~ 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

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1 mg/Lppm, 2.3 mg/Lppm and 5 mg/Lppm 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 h⁻¹ using the equation given by Lantin et al., (1995). The obtained CH₄ and N₂O concentrations were determined by peak area and flux was calculated based on the equation proposed by Rolston (1986) to estimate CH₄ and N₂O concentrations, methane and nitrous oxide.

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

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 strategies were quantified for the four growth stages (active tillering, panicle initiation, 50 % per cent flowering and harvest stages). Data and data are presented in figure 1. 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 did record lower CH₄ emissions, as compared to the rest of the other treatments. Though application of gypsum and fly ash along with RDF (T₈) did reduce the CH₄ methane emission significantly, from the results it was truly observed that recommended fertilizer and gypsum (T₃) alone stood next to the treatments with NPK alone (T₁) on the higher emission of methane. The reduction of CH₄ methane with the application of fly ash and gypsum along with NTU, MOP and SSP (T₈), compared to the over control (T₁)

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was about 31.53, 24.46, 442 and 3.93 ~~%per-cent~~ at active tillering, and panicle initiation, 50 ~~%per-cent~~ at flowering and maturity stages, respectively.

The application of fly ash reduced the methanogens population with the lowest number in the treatments T₅, T₆, T₇ and T₈ at all three stages (Figure ?). The methanogen population at the active tillering stage in the treatments T₁ to T₄, i.e. the treatments without fly ash, in the ranged between 11 to 12 x 10³ CFU per g of soil, whereas it was 7 to 8 x 10³ CFU per g of soil was recorded for in the 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 aAsh 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 in turn the methane emission with the increased sulfatesulphate concentration, iron and manganese might have resulted into proliferation of other reducing bacteria, like sSulphate 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 fFerrous iron leading to suppression of mMethanogenesis (Gabriel et al., 2020). This might also be result due to

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shifting of electron flow from methanogenesis to ~~sulfate~~sulphate reduction under anaerobic soil conditions (Conrad ~~ard~~ et al., 2020).

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Either, ~~g~~Gypsum or fly ash when applied alone had lesser impact when compared with the treatments where both are applied in combination. ~~Eventhough~~Even though 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 CH₄ emission was due to the increased concentrations

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of active ~~sulfate~~sulphate 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 ~~CH₄~~ 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 (Sapkota et al., 2020).

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Application of NTU ~~urea~~ had no ~~effect~~ influence on ~~CH₄~~ methane emission from rice fields. The reduction in ~~CH₄~~ methane emission during the later stages was prominent ~~as well as 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.

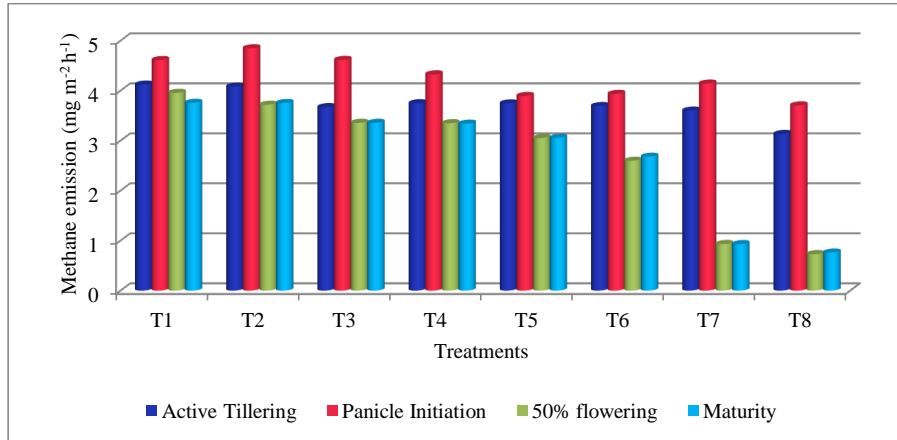


Figure. 1. Influence of different treatments on methane emission ($\text{mg m}^{-2} \text{hr}^{-1}$)

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3.2 Nitrous oxide emission rate

In respect of N_2O nitrous oxide, upto up to 50 %per cent of flowering, the N_2O nitrous oxide emission was below detectable level ($50 \mu\text{Lppb}$) and was recorded only at the harvest stage since watering was stopped 15 days before harvest (Figure. 2). Once the soil was brought to aerobic condition the N_2O nitrous oxide-emission was found in the present investigation. At this stage, the data were found to be significant, wherein significantly higher N_2O nitrous oxide-emission was noted in treatments T7 and T1.

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In the treatments in which NTU was applied instead of urea only, showed a decline in N_2O emission as reported by Davamani et al., (2021). The lowest N_2O nitrous oxide-emission was noted with the treatment T2 in which NTU was used as a slow nitrogen release fertilizer.

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The mean N_2O nitrous oxide-emission recorded during the maturity stage-recorded was $0.5008 \text{ mg m}^{-2} \text{ hr}^{-1}$. The high pitched- N_2O nitrous oxide-emission rate of $0.5940 \text{ mg m}^{-2} \text{ hr}^{-1}$ was with

T1 (control) followed by T5 and the lowest, i.e. most modest value of 0.3996 mg m⁻² hr⁻¹ was recorded for with the treatment T2. The decrease reduction was about 32 %.

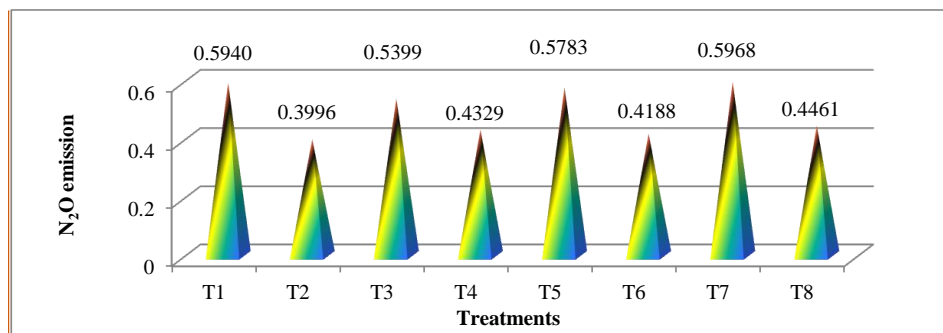


Figure. 2. Effect Influence of different treatments on nitrous oxide emission at maturity stage (mg m⁻²hr⁻¹)

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 an good impact on emission of the two major GHG (i.e. CH₄ and N₂O) from the rice field.

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