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INM-A Potential Way of Farming in Reduction of CH_4 and CO_2 Emission in Rice-sunflower Sequential Cropping System

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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

Aim: To find out the CH_4 and CO_2 emission pattern and the considerable amount of SOC sequestered by using different organic sources in sandy clay loam soil.
Study Design: Randomized Block Design.
Place and Duration of the Study: The study was conducted in a farmer's field at Ayanathur, which is geographically located at 11°23'N latitude, 79°29'E longitude, and an altitude of +26 m MSL. Duration of the study confined to 2 years cycle from September 2016 to January 2018 I and II crops respectively.

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Methodology: Different sources of organic manures viz., Farm Yard Manure @ 12.5 t ha^{-1}, vermicompost, pressmud, poultry manure, and composted coirpith are each @ 5 t ha^{-1} were applied as basally and incorporated along with Azospirillum and phosphobacteria @ 2 kg ha^{-1} as a soil application at the time of last ploughing. Fertilizers were applied as per the treatment schedule of 150:50:50 kg N, P, and K ha^{-1} was followed throughout the period of study through urea, Di Ammonium phosphate and muriate of potash for rice crops. An open path LICOR analyzer 7700 and 7500 for CH_4 and CO_2 to find the CH_4 and CO_2 fluxes during the period of study through calibration of eddy covariance fluxes emissions were calculated.

Results: Combined application of a Recommended dose of fertilizers along with Farmyard manure @ 12.5 t ha^{-1} reduced the CH_4 emission by 13.6 and 15 % over other organic sources in rice whereas, the CO_2 emission by 54.4 and 53.8% and 61.5 and 53.9 % over other organic sources in rice and sunflower respectively. Concomitantly, the SOC increased by 6.8 and 7.5% in rice and 4,7 and 4.4% in sunflower over other organic sources.

Keywords: Carbon dioxide; GHG's; global warming; INM; methane; organic carbon.

1. INTRODUCTION

"Global warming is a part of climate change and one of the most predominant environmental issues across the world due to the wide range of GHG's emissions. Worldwide agricultural practices are identified as a potential mode of greenhouse gases (GHG's) like methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions, thereby contributing around 20-30% of the earth's global warming radiative force" [1]. "In the agriculture sector, rice is a predominant crop that meets 70 per cent of the world's population feed mostly grown in tropical climates, and higher temperatures increase the amount of methane emitted" [2]. "Rice is the prime source of food for more than 65% of the world's population and it is one of the most important major food crops. It continues to hold the promise to sustain food production contributing 20-25 per cent of the agricultural GDP and assuring food security for more than half of the total population. As world food demand continues to grow, rice yields will need to increase by around 28% by 2050 to match demand, further increasing emissions" [3]. "Among the GHGs, CO_2 is regarded as another important causative constituent of global warming potential. In addition, the concentration of atmospheric CO_2 has been gradually increasing from about 280 ppm at the beginning of the industrial revolution to 450 ppm at present (IPCC 2023) and it will be reaching its peak of 600 ppm during, 2050 (IPCC). Agricultural management practices *viz.,* tillage, method of irrigation, fertilizer management and intercultural operations strongly have the prospective to influence methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions. According to IPCC 2023, anthropogenic activities' contribution to greenhouse gases (GHGs) like methane, carbon dioxide and nitrous oxide emissions from agriculture hiked about 10–12% (56±6.6 $GtCO_2$-eq) in 2019 than in 2010 (6.5$GtCO_2$-eq). Especially, the wet paddy field is considered to be an important anthropogenic CH_4 emission source" [4]. "The majority of the area under rice cultivation in India is a submerged system of cultivation. Wetlands show an important role in climate change, because of their capacity to modify atmospheric concentrations of greenhouse gases such as methane, carbon dioxide and nitrous oxide, which are dominant greenhouse gases contributing to about 60%, 20% and 6% of the global warming potential, respectively" [5]. "The submerged condition of wetlands causes inefficient decomposition due to the absence of oxygen that exceeds the rate of production. This anoxic state conceives a huge amount of carbon accumulation in wetlands, which makes them a sink of carbon [6]. A higher rate of decomposition than production (photosynthesis) in a wetland as a result of climate change might result in a shift from a sink to a source of carbon; i.e., carbon dioxide and methane emissions to the atmosphere" [7]. The quantity and degree of methane fluxes wide ranged depending upon various decisive factors *viz.,* climate, soil properties, paddy cultivars, agricultural management practices, and water regimes.

"Tillage operation induces the carbon fluxes as CO_2 by breaching up soil aggregates and exposing the protected organic matter to microbial action" [8]. "Besides that, minimizing soil disturbance decreases SOC decomposition rate, and this way of change in the management practice would pave decreased transfer of C from soil to the atmosphere and can be a way of climate change mitigation" [9].

Though agriculture is the largest contributor to GHGs, an urgent call to mitigate/reduce the CH_4 and CO_2 emissions pave the way to increase the accumulation of organic carbon in the soil biota. Reduction of CH_4 and CO_2 could be achieved through several practices such as tillage, précised nutrient management, IPNS, and irrigation management. "Relating to nutrient management, soils are considered a dynamic bio medium where it acts as natural reserves of plant nutrients, but these reserves are mostly in unavailable forms for plants, and only a small portion is liberated every year through either biological activity or chemical processes. This release is too slow to replenish for the removal of nutrients by intensive agricultural production and to meet the crop requirements. The addition of nutrients through inorganic fertilizers is quite inevitable for any crop grown in the conventional method of cropping. Simultaneously, the use of organic manures alone may not meet the crop requirement due to the presence of relatively low levels of nutrients. Therefore, to make the soil well supplied with all the plant nutrients readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields" [10].

To identify the consequences of these factors on nutrient management field trials were conducted to study the cartel use of organic manures and inorganic fertilizers on methane and carbon dioxide fluxes and yield magnitude of the rice crop. With regards to the CH_4 and CO_2 emission pattern, the combined application of organic manures and inorganic fertilizers recorded a lesser value INM-applied treatments.

2. MATERIALS AND METHODS

Field trials were conducted at Ayan Aathur Village with a coordinate of 11°23'N latitude, 79°29'E longitude, and an altitude of +26 m MSL. The experimental site soil had a pH of 7.8, EC- 0.46 dSm^{-1}, organic carbon - 0.49%, total carbon-0.77%, $KMnO_4$-N - 135 kg ha^{-1}, Olsen- P- 13.8 kg ha^{-1}, NH_4OAc- K- 163 kg ha^{-1} and classified under sandy clay loam.

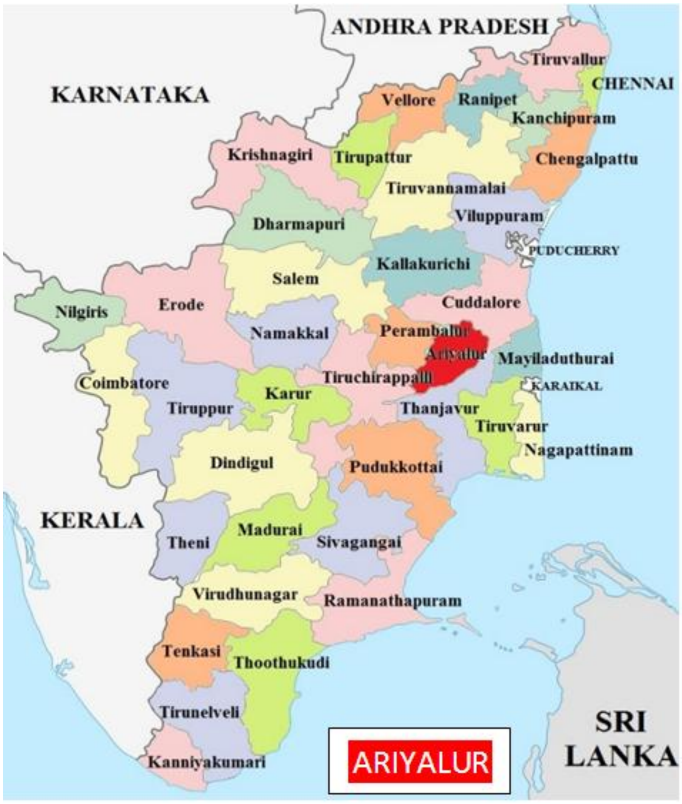

Fig. 1. Site MAP

The experiments consist of 7 treatments viz., T_1- Control, T_2- RDF alone, T_3 – T_7 supplemented with different organic sources viz., Farmyard manure @ 12.5 t ha^{-1}, vermicompost, pressmud, poultry manure and composted coir pith are @ 5t ha^{-1} along with 100% RDF respectively for rice crop. Experiments that were randomized, replicated, and steered in the field with well-described procedures were involved in this study. As per the treatment appropriate quantity of organic manures were incorporated along with associative symbiosis and phosphorus solubilizing microbial biofertilizers @ 2 kg ha^{-1} as a soil application at the time of last ploughing. As per the treatments, a blanket recommendation of nutrient schedule ~~of~~ i.e., 150:50:50 kg N, P, and K ha^{-1} was followed throughout the period of study~~.~~ and the same were supplemented through urea (46% N), DAP (18% N and 46% P_2O_5), and muriate of potash (60% K_2O) respectively. Half of recommended N and potash K and the full dose of P_2O_5 were applied basally as per the treatment. Five hills of rice crop were chosen at random within each net plot and tagged for recording bio-metric and need-based other observations both in soil and plant were taken at various stages of crop.

2.1 Organic Carbon and Organic Matter

The organic carbon content was determined by the method suggested by [11]. The organic matter was calculated from the organic carbon content by using the applying factor 1.72 and expressed in percentage.

Organic matter (%) = total organic carbon (%) x 1.72

2.2 LICOR CH_4 Analyzer

"CH_4 fluxes were measured in rice crops during the vegetative, flowering, and maturity stages. Li-7700 is a high-speed, high-precision methane Analyzer designed to use in eddy covariance flux and atmospheric monitoring applications. It uses wavelength modulation Spectroscopy (WMS) to make high-speed precise measurements of methane concentrations at ambient pressure and temperature. It is designed to withstand environmental extremes expected during outdoor deployment, with data output up to 20 Hz bandwidth. The CH_4 analyzer has a low power requirement of 8 W during normal operation, and withstands outdoor environmental extremes, with a temperature range from -25°C to 50°C without damage or calibration shifts. Analogue input channels to integrate sonic anemometer, wind speed (U, V, and W), and sonic temperature (T_s) data with CH_4 and CO_2 data removable USB flashcard and enabling versatile data output options. Ethernet communication data transfer RS-232 serial communications" [12].

2.3 Calibration OF LI-COR 7700

Li – 7700 calibrations offset and sensitivity was checked before and offsetting zero span gases in a balance of air with CH_4 accuracy greater than the gases that are free of volatile organic compounds other than methane. Removed the radiation shield and installed the calibration to ensure that it seals around the top and bottom openings to connect the 'zero gas" (0 ppm CH_4 in the air). Allow for 10 to 30 minutes for calibration depending on the flow rate.

2.4 LICOR CO_2 Analyzer

"The LI-7500A is a high-performance, non-dispersive, open-path infrared CO_2 and H_2O Analyzer designed for use in eddy covariance flux measurement systems. Three components of wind velocity (U, V, and W) and temperature were measured with a sonic anemometer (Hs, Gill) while the densities of CO_2 and water vapour were measured with an open-path CO_2/H_2O Analyzer (LI-7500A). The sensor heads of the sonic anemometer and the IRGA were mounted all most at a height of 3.0 m above the ground, where the direction of the sonic anemometer was 180 ± 1°. The horizontal distance between the two sensor heads was 0.16 m, and the data from the sonic anemometer and the IRGA were sampled at 10 Hz and stored in CR 100 data logger (CR 100, Campbell, S/N1396) which was retrieved using a compact flash card" [12].

2.5 Calibration OF LI-7500A IRGA

IRGA was new, before installing it was calibrated two times during calibration offset, and sensitivity was checked before and after setting Zero and the span of the IRGA following the instruction manual (LI-COR, 2001). CO_2 span gas (344.1 ppm and 488.7 ppm) was supplied from cylinders. The calibration was done in a laboratory maintaining a room temperature of 27°C during calibration.

Fig. 2. LICOR CH_4 and CO_2 Analyzer

2.6 Statistical Analysis

The experimental data on observations from various characters were statistically analyzed and whenever the results were found significant, the critical differences arrived at 5 per cent level to draw statistical conclusions [13].

3. RESULTS AND DISCUSSION

The INM imposed treatments mainly with Farmyard manure @ 12.5 t ha^{-1} with RDF show positive influenc on all yield components of rice over other organic amended treatments which are presented in Table 1. FYM added the soil organic carbon and organic matter which ensure the steady pace of supplying the nutrients and ultimately enhances the catering capacity of soil throughout its crop growth period especially the pre and post-anthesis stages and grain filling stage. A lower grain and straw yield of 6506 and 7019 kg ha^{-1} was recorded in composted coir pith-imposed plots and the same on par with RDF alone supplemented treatment during both the crop period. Comparatively lower catering capacity of soil with imposed organics and failure to supply the required nutrients at different stages of the crop in RDF alone supplemented plots might be.

About the SOM and SOC (Table 1), the same increasing trend was observed during the study. Composted coir pith imposed INM plots registered a lower value of SOM (1.04%) and pressmud INM imposed plots recorded lower SOC of (6.1 g ka^{-1}) than other INM imposed treatments of rice crop. The increased soil organic carbon is due to the addition of organic manures which improved the Physico-chemical properties of the soil, especially in sandy clay loam soil. The addition of organic manures along with inorganic fertilizer in a continuously flooded condition paves the way for the highest organic carbon accumulation which is a main factor for the improvement of soil quality index and minimized environmental hazards [14]. Furthermore, positive interaction between the organics with inorganic NPK eventually increased the overall growth components both above and below ground which attribute the entire physiological function by way of providing nutrients and its relative growth hormones which in turn leads accumulation of more photosynthates. It shows a positive sign to the increased microbial activity from diversified nourishment substrate.

3.1 Effect of INM ON CH_4 and CO_2 Fluxes in Rice–sunflower Production

“A higher level of water regime presence of vegetation can play an augmenting role in the emission of methane at different temperature conditions. It seems that plants at a low water table play a key role in the transport of methane through aerenchyma cells, evading the methanotrophic soils at the upper layer. Besides, the rate of methanogenesis and methane emission at low water levels might be lower in non-vegetated constructed wetlands than the vegetated ones” [15]. Similarly, the obtained data on methane emission (Table 2) revealed that the elevated diurnal variation coupled with the continuous flooding pattern of irrigation had a marked influence on CH_4 ecosystem exchange at all growth stages (Fig. 4) of rice crop. Experimental plots nourished by different sources of organics with INM recorded noticeable methane emission trend lines in different stages mostly high in vegetative and declining in the harvesting stage of rice crop.

Table 1. Effect of INM on grain, straw yield, SOM, and SOC of rice

Experimental year	Crop duration 2016-2018			
Treatments	**Grain Yield kg ha^{-1}**	**Straw Yield Kg ha^{-1}**	**SOM %**	**SOC g Kg^{-1}**
Control (No fertilizers)	3818	4814	0.88	5.2
100% RDF alone	6163	6759	1.01	5.9
FYM @ 12.5 t + 100 % RDF	9027	8915	2.82	8.2
VC @ 5 t + 100% RDF	8418	8411	1.32	7.7
Pressmud @ 5 t + 100% RDF	7140	7574	1.12	6.1
PM @ 5 t + 100% RDF	7818	7959	1.22	7.1
CCP @ 5 t + 100% RDF	6506	7019	1.04	6.6
S.E(m)	187.5	129.5	0.02	0.19
CD(P=0.05)	401.3	277.1	0.06	0.40

VC- Vermicompost, PM- Poultry manure waste, CCP- Composted Coir Pith, RDF- Recommended Dose of Fertilizer

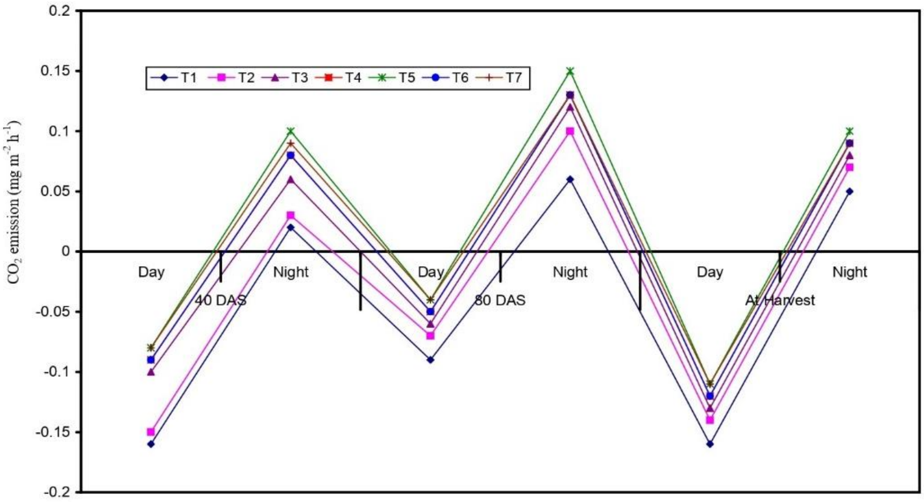

Fig. 3. Effect of INM on Carbon Dioxide Emission in Rice

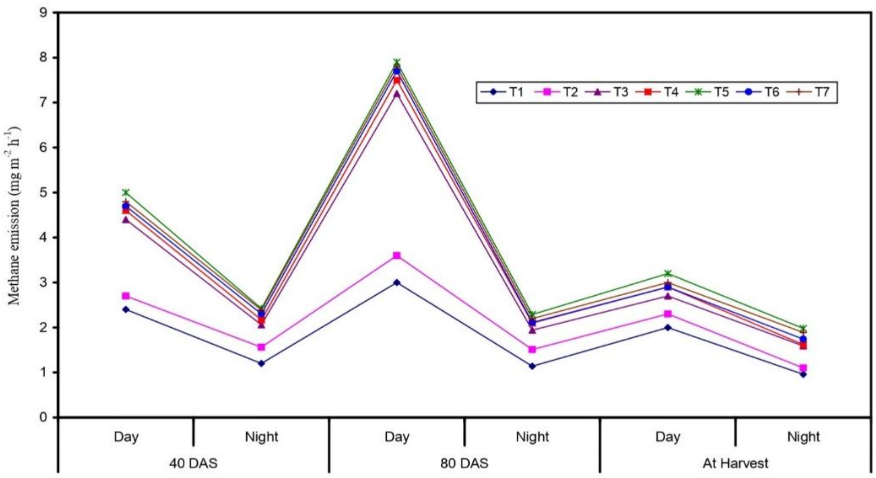

Fig. 4. Effect of INM on Methane Emission in Rice

Table 2. Effect of INM on CH_4 and CO_2 emission in Rice (Compiled mean average of 2 years data)

Treatments	CH_4 emission (mg m^{-2} h^{-1})						CO_2 emission (m mol m^{-2} s^{-1})					
	40 DAS		80 DAS		At Harvest		40 DAS		80 DAS		At Harvest	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Control (No fertilizers)	2.6	1.3	3.4	1.1	2.2	1.1	-0.13	0.04	-0.10	0.06	-0.13	0.04
100% RDF alone	2.9	1.6	3.7	1.4	2.9	1.3	-0.12	0.06	-0.08	0.11	-0.12	0.07
FYM @ 12.5 t + 100 % RDF	4.7	2.3	7.3	2.0	3.2	1.8	-0.11	0.06	-0.06	0.12	-0.12	0.07
VC @ 5 t + 100% RDF	4.9	2.4	7.4	2.1	3.4	1.9	-0.10	0.07	-0.05	0.13	-0.11	0.08
Pressmud @ 5 t + 100% RDF	5.4	2.6	7.9	2.3	3.9	2.2	-0.09	0.09	-0.04	0.15	-0.10	0.09
PM @ 5 t + 100% RDF	4.9	2.5	7.7	2.2	3.6	1.9	-0.10	0.07	-0.05	0.13	-0.12	0.08
CCP @ 5 t + 100% RDF	5.1	2.6	7.8	2.2	3.7	2.1	-0.08	0.08	-0.04	0.14	-0.11	0.09
S.E(m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

VC- Vermicompost, PM- Poultry manure waste, CCP- Composted Coir Pith, RDF- Recommended Dose of Fertilizer

The farmyard manure @ 12.5 t ha^{-1} integrated with 100% RDF supplemented plots recorded lower methane fluxes peaks of 4.7 and 2.3, 7.0 and 2.0, and 3.2 and 1.8 mg m^{-2} h^{-1}methane emission and carbon dioxide value of -0.11 and 0.06, -0.06 and 0.12 and -0.12 and 0.07 m mol m^{-2} s^{-1} during both day and night time at 40, 80 DAS and at harvest respectively. Simultaneously, the plots supplemented with press mud @ 5 t ha^{-1} + 100% RDF recorded significantly a higher peak of 5.4 and 2.6 and 7.9 and 2.3 and 3.9, and 2.2 mg $m^{-1}h^{-1}$ methane emission, and the treatment with composted coir pith @ 5 t ha^{-1} + 100% RDF recorded the higher carbon dioxide emission of -0.08 and 0.08, -0.04 and 0.14 and -0.11 and 0.09 m mol m^{-2} s^{-1} in both the day and night time at 40, 80 DAS and at harvest respectively. Among the different organic manures tried, press mud @ 5 t ha^{-1} integrated with 100% RDF received plots exhibit a high potential in the amount of methane and Composted Coir Pith exhibits a high potential of CO_2 exchange to the ecosystem other organic manures Compared to FYM other organic manures showed an increasing trend of CH_4 emission throughout the period. This might be due to the high resistant capacity of organic manure against decomposition due to the high C:N ratio which will be escaped through ebullition. Besides, the higher amount of CH_4 emission at the reproductive stage of the crop in all treatments might be due to the production of more sloughed-off root tissues coupled with root exudates increasing the methanogenesis which paves the way for increased CH_4 emission [16], [17]. In the case of CO_2 emission, the emission pattern of CO_2 proved that the initial stage of the crop released more amount *i.e.,* on 40 DAS, and decreased amount of emission at 80 DAS i.e., at the reproductive stage and also further declining trend was observed at harvest stage in all respective treatments (Fig. 3). These results corroborate the findings of [18] narrated that the addition of organic manure could increase CO_2 emission no matter of the aerobic and anaerobic conditions in paddy soils.

4. CONCLUSIONS

1. The least CH_4 and CO_2 emission values were acquired in one of the INM practices through farmyard manure @ 12.5 t ha^{-1} along with 100% recommended dose of fertilizers in rice.
2. Higher CH_4 and CO_2 emission values were obtained in the INM practice through Pressmud 5 t ha^{-1} along with 100% recommended dose of fertilizers in rice.
3. Though the lesser CH_4 and CO_2 emission values were attained in the RDF alone practice it is important to consider the long-run sustainability of soil fertility and the system production.
4. Probably it is proven by higher SOC and SOM accumulation in the INM practice through farmyard manure @ 12.5 t ha^{-1} along with 100% recommended dose of fertilizers which paves attain a higher grain and straw yield in rice.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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