Research Journal of Chemical and Environmental Sciences
Res J. Chem. Environ. Sci. Vol9 [4] August 2021: 12-17
Online ISSN 2321-1040
CODEN: RJCEA2[USA]
©Academy for Environment and Life Sciences, INDIA
Website: www.aelsindia.com/rjces.htm

RJCES

ORIGINAL ARTICLE

Potential of nitrification inhibitor on the reduction of Green House Gas (GHG) emission under intensive paddy system of Cauvery Delta Zone (CDZ)

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ABSTRACT

Nitrous oxide (N_2O) contributes almost 6 % of the overall global warming effect, on the other hand its contribution from agricultural sector is approximately 16 %. Among this almost 80 % of N_2O is emitted from the application "N" fertilizers. Hence, this study was formulated to evaluate the influence of nitrification inhibitor viz., Dicyandiamide (DCD) to minimize the N_2O emission in paddy soil of Cauvery Delta Zone which is a major paddy growing region of Tamil Nadu. The N_2O efflux was collected from the soils incorporating various approaches of "N" application along with DCD by means of "N" inhibitor. All the treatments registered the higher N_2O efflux on the second day after the application of fertilizer. The average emission recorded during initial day was 0.71 mg/m^2 /day it consequently amplified to 01.83 mg/m^2 /day on the first day, then recorded higher emission of 2.78 mg/m^2 /day on the second day and further diminished (1.40 mg/m^2 /day) on the third day. Consequently noticeable temporal variation pattern in N_2O efflux in tune with the depletion of the substrate was noticed. Among the treatments studied, Leaf Colour Chart (LCC) based "N" (@30 kg N/ha keeping the LCC value 4 as standard) + DCD @ 10 % of applied "N" followed by Site Specific Nutrient Management (SSNM) based "N" with fixed split approach {35 % N at 15 Days After Transplanting (DAT), 40 % N at 30 DAT, 25 % at 45 DAT} with use of LCC at each stage + DCD @ 10 % of applied "N" recorded lower mean emissions of 0.46 mg/m^2 /day and 0.61 mg/m^2 /day, respectively. The higher N_2O emission was recorded under early completion of "N" application (25 % basal 50 % at 20 DAT and 25 % at 40 DAT) which recoded as 5.14 mg/m^2 /day. Amongst the stages of crop growth, flowering stage recorded the higher emission of 2.12 mg/m^2 /day of N_2O and total seasonal emission was calculated as 0.16 kg/ha.

Key words: *Nitrous oxide, "N" inhibitor, Nitrogen fertilizer, paddy soils, dicyandiamide*

Received 11.06.2021 Revised 19.07.2021 Accepted 22.08.2021

INTRODUCTION

Nitrous oxide (N_2O) is one among the trace gases responsible for global warming and depletion of ozone in the stratosphere. It accounts for 5% of the total greenhouse effect and 250 times more effective than CO_2 on molecule to molecule basis in absorbing infrared radiation with 150 years of atmospheric lifetime [1]. It directs that it never reacts with the atmospheric substances nor precipitated by the moisture in atmosphere and then moves uninterrupted directly to the stratosphere to damage ozone layer and further move through NO formation as indirect measure [2]. Atmospheric concentration of nitrous oxide has raised from 285 ppbv [3] during the pre industrial era to 310 ppbv in 1996 [4]. During nitrogen cycling, this nitrogen nitrous oxide is produced through biological action in the ecosystem. Soil is one of the reckoned source of atmospheric N_2O [5]. Application of "N" fertilizers proliferates the N_2O emissions [6]. Emissions of N_2O from "N" fertilized croplands vary considerably, ranging between 0.001% and 6.8% of applied "N" [5,6]. From the agricultural soils, denitrification and nitrification are the two processes responsible for formation of N_2O. In both these processes, nitrite (NO_2^-) is formed as an intermediate compound. During the process of nitrification, NH_4^+ , in aerobic condition, gets oxidized to NO_3^- via hydroxylamine and nitrite, releasing N_2O as a byproduct, while in denitrification, the NO_3^- gets completely reduced to N_2 evolving N_2O as an intermediate product. Therefore, the end product of nitrification works as substrate for denitrification. Hence, controlling the first process will certainly help in regulation of second process to some extent. Nitrification inhibitors are composites that decrease the proportion at which ammonium is transformed into nitrates both through killing and interupting the metabolism of nitrifying microorganisms.

The Dicyandiamide (DCD) is one amoung the most widely utilised bacteriostatic nitrification inhibitors used for the agriculture [7] and decomposes in soil to non-toxic products. Effect of DCD on N2O emissions has been reported by Klein and co workers [8] in grass land, Mosier and co workers[9] in wheat and maize and McTaggart and co workers[10] in ryegrass, grassland and spring barley. The present study was undertaken to observe the influence of DCD on N_2O emission from the irrigated paddy soils of Cauvery Delta Zone to evaluate its suitability for reducing N_2O emission to the atmosphere

MATERIALS AND METHODS

This study was conducted to assess the potential of dicyandiamide (DCD) along with various "N" management approaches on the emission of N_2O from agricultural soils. The field trial was carried out at TRRI (Tamil Nadu Rice Research Institute) Aduthurai, Tamil Nadu(110 N latitude, 790 31' E longitude, 19.4 MSL). During normal years, the annual rainfall is 1200 mm of which around 70 % is received during September to October (North East Monsoon). The climate condition of the experimental site (Cauvery Delta) is sub tropical monsoon type. The experiment with fixed plots has been laid out in a RBD design (Randomized Block Design) with three replications. The details of the treatments are listed below.

Table. 1. Treatment details

T_1	:	Absolute control
T_2	:	Blanket recommendation of Nitrogen {150kg N/ha in 4 splits 25 % each at basal, 15,30, and 45 Days After Transplanting (DAT)}
T_3	:	Leaf Colour Chart (LCC) based N (30 kg N/ha keeping the LCC value 4 as standard)
T_4	:	SSNM (Site Specific Nutrient Management) based N with fixed split approach (35 % N at 15 DAT, 40 % N at 30 DAT, 25 % at 45 DAT with use of LCC at each stage)
T_5	:	Early completion of "N" application (25 % basal 50 % at 20 DAT and 25 % at 40 DAT)
T_{16}	:	T2 + Dicyandiamide (DCD) @ 10 % of applied "N"
T_7	:	T3 + DCD @ 10 % of applied "N"
T_8	:	T4 + DCD @ 10 % of applied "N"
T_9	:	T5+ DCD @ 10 % of applied "N"

* Common application (T_2 to T_9): Each 50 kg ha^{-1} of Phosphorus & potassium, micronutrient mixture @ 25 kg ha^{-1} and Gypsum @ 500 kg ha^{-1}

A uniform plot size of 25 m^2 was adopted for all the experiments as detailed above. Nitrogen was applied as per treatment schedule through urea while phosphorus and micronutrient mixture were applied entirely as basal and potassium in two equal splits (basal and at panicle initiation stage). The DCD was applied at the rate of 10% of applied N. Need based plant protection measures were taken up against pest and diseases.

From the first to three days after fertilizer application the N_2O efflux from all the plots was measured using static chambers and also measured during critical phases of crop production. To collect the gas generated in the experiment, acrylic assembly (height of 60 cm with 80 lit capacity) were positioned on the iron basement (Diameter 47 cm with 1562 cm^2 total of area) which was introduced 10 cm inside the soil one day prior to the collection of gas samples. The channel situated on the upper side of the base was filled with water to make the system air tight. One 3-way stopcock (Eastern Medikit Ltd. India) is tailored at the top of chamber to collect gas samples. Further chamber was scrupulously flushed numerous times with the help of 50 ml syringe to uniformly mix the inside air. A battery operated fan was run continuously during the sampling to circulate the air with in the chamber to facilitate the proper mixing of the gas inside.

Nitrous oxide gas samples were collected with the help of 50 ml syringes along with hypodermic needle of 24 gauge at the interval of 0, 10, 20 and 30 min. Syringes were fitted airtight with a three way stop cock to arrest the gas diffusion. The soil temperature, chamber temperature and water level inside the iron base was recorded during gas collection which was used to calculate N_2O flux. Air samples were brought immediately to the laboratory for N_2O analysis. The N_2O concentration was determined with gas chromatograph (Varian, 450 GC, German), armed with Electron Capture Detector (ECD). Under the appropriate operating conditions (column temperature 35°C, injection temperature 120°C and detection temperature 300°C) a N2O peak was noticed in a specific retention time. Before the sample analysis, gas chromatograph was standardized by using different concentrations of N_2O gas procured from Multitech Private Limited, New Delhi, India.

RESULTS AND DISCUSSION

The experimental soil is fine, montmorillonitic, isohyperthermic, Udorthentic Chromusterts under the soil textural class 'clay' coming under Kalathur soil series. It was neutral in pH with a soluble salt concentration of < 0.5 dSm^{-1}. The organic carbon status was medium falling in the range of 0.5 to 1 % (Table.1). Owing to its heavy clay content it possessed a high Cation Exchange Capacity (CEC). With regard to the available nutrient status, it recorded medium range of nitrogen (280 - 450 kg/ha) and potassium (118 to 280 kg/ha), while the available phosphorus was found to be very high (> 22 kg/ha).

Table.1.Initial characteristics of the experimental soil

Sl.No	Particulars	Values
1	pH (1:2.5)	7.77
2	Electrical conductivity (dSm^{-1}) (1:2.5)	0.32
3	Organic carbon (%)	0.66
4	Cation Exchange Capacity (C mol (p+) kg^{-1})	42.3
5	Available N (kg ha^{-1})	291
6	Available P (kg ha^{-1})	46.0
7	Available K (kg ha^{-1})	234

The measurement of nitrous oxide efflux was carried out from the soils amended with different nitrogen management practices along with 10 % of DCD. All the treatments were registered higher N_2O efflux on the second day after fertilizer application. Irrespective of all the treatments, the mean emission recorded on the initial day was - 0.71 mg/m^2/day and then increased to 1.83 mg/m^2 /day on the first day and then reached the peak maximum emission on second day (2.78 mg/m^2 /day), finally decreased to 1.40 mg/m^2 /day on the third day after fertilizer application due to the depletion of substrate. Hence, it showed a marked temporal variation pattern in N_2O efflux (Fig. 1).

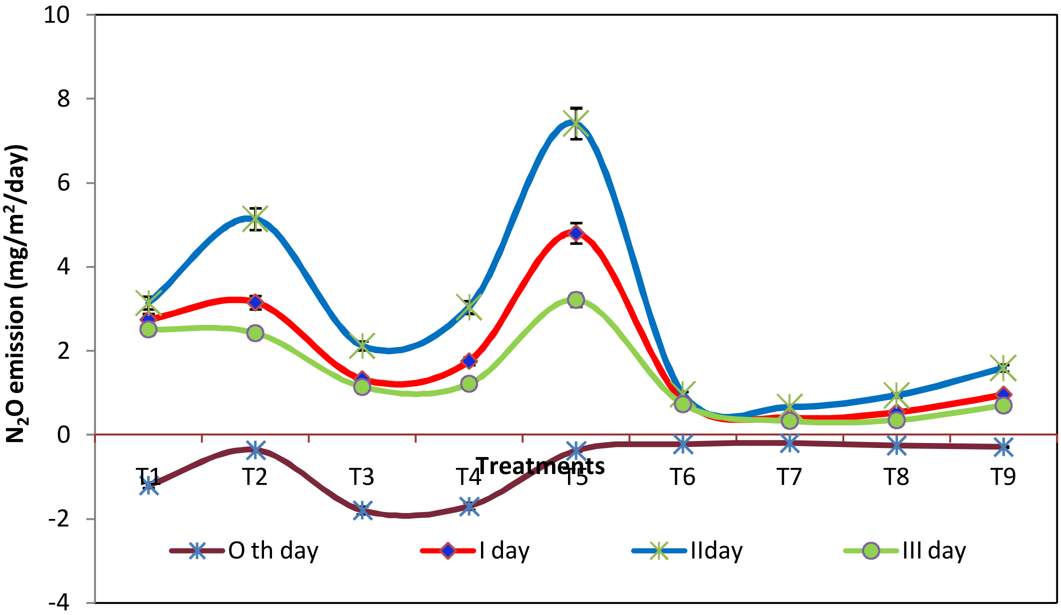

Fig.1. Influence of different nitrogen management practices on N_2O emission after the application of fertilizers

The peak N_2O efflux observed during this study was associated with application of NH_4 based fertilizer, *i.e.* urea. Ammonium based fertilizer application directly stimulates nitrification process, as it serves the substrate for nitrifying bacteria in the oxic conditions. Initial lower efflux at the start of the experiment was due to the time required for hydrolysis of urea in soil to NH_4. During the crop production, increase in N_2O emission was noticed immediately after the application of fertilisers. Further the emission rates are tends to fluctuate about a low base line level, without depending about the amount of fertilizer applied [11]. A decreasing trend of N_2O emission was ascribed to substrate exhaustion for nitrifying bacteria.

Among the treatments Leaf Colour Chart (LCC) based N (30 kg N/ha keeping the LCC value 4 as standard + DCD @ 10 % of applied N) (T_7) followed by SSNM (Site Specific Nutrient Management) based N with fixed split approach (35 % N at 15 DAT, 40 % N at 30 DAT, 25 % at 45 DAT with use of LCC at each stage+

DCD @ 10 % of applied N) (T8) recorded lowest average emission of 0.46 mg/m2 /day and 0.61 mg/m^2 /day, respectively. This might be due to need based addition of urea under LCC guided N management along with DCD have probably reduced the net NO_3-N available for denitrification in the soil as a result of increased competition by plant roots. Irrespective of the days of fertilizer application, the maximum mean emission was recorded as 5.14 mg/m^2 /day under early completion of "N" application (25 % basal 50 % at 20 DAT and 25 % at 40 DAT- T5) followed by 3.57 mg/m2 /day in blanket recommendation of Nitrogen (T2) (150kg N/ha in 4 splits 25 % each at basal, 15, 30 and 45 DAT) due to higher available NO_3-N. Therefore, in comparison to other treatments, there was an obvious reduction in the total seasonal N_2O efflux from all the DCD treatments. Irrespective of all treatments, among the critical phased of crop growth, the flowering stage documented maximum emission of 2.12 mg/m2 /day followed by tillering stage (1.63 mg/m^2/day) (Fig.2.). This is due to the coincidence of top dressing of nitrogenous fertilizers. Among the treatments, the treatment comprising of early completion of N (4.36, 5.71 and 2.68 mg/m^2 /day of N_2O during tillering, flowering and maturity, respectively) and blanket recommendation (3.57, 4.52 and 2.41 mg/m^2 /day of N_2O during tillering, flowering and maturity, respectively) recorded higher N_2O emission in all the critical stages of crop growth.

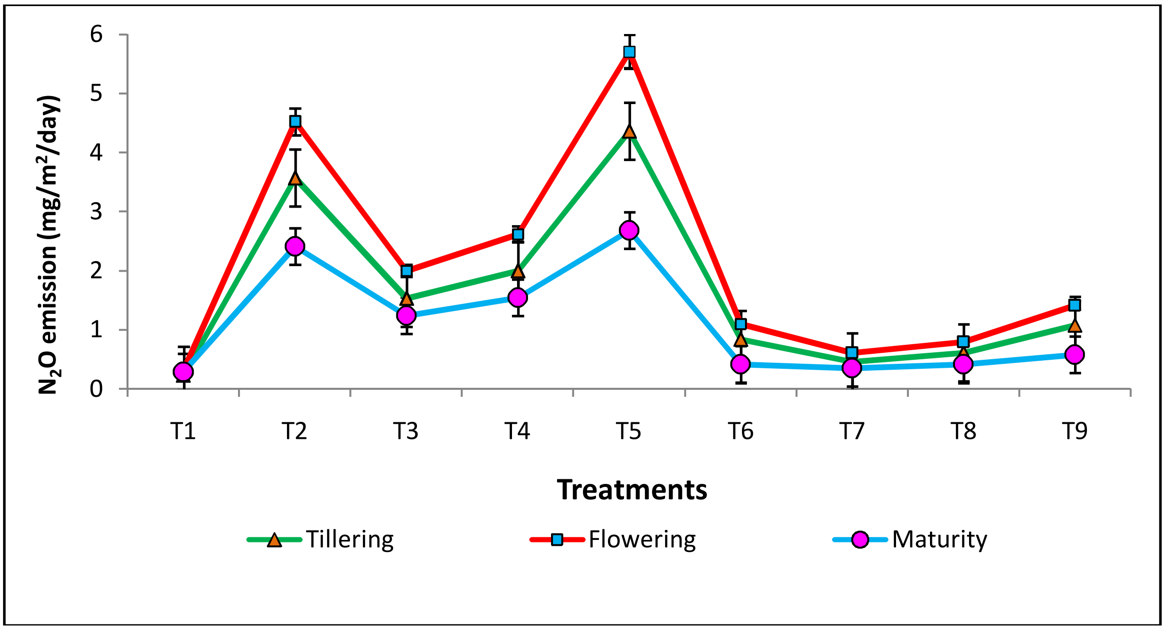

Fig.2.Influence of different nitrogen management practices on N_2Oemission on critical stages of crop growth

The cumulative N_2O emission for Kuruvai season, revealed that the highest emission of 0.31 kg/ha of N_2O recorded under early completion of "N" application followed by blanket recommendation. This might be due to the higher availability of substrate for N_2O emission. The need based application of fertilizers in the treatments LCC based N +DCD and SSNM based N+ DCD recorded lowest seasonal emissions of 0.08kg/ha and 0.04 kg/ha, respectively. The treatment LCC based N and LCC based N +DCD received same dose of N fertilizes however the later was additionally supplied with 10% DCD which contributes 62.5 % reduction of N_2O emission compared to the treatment without DCD application

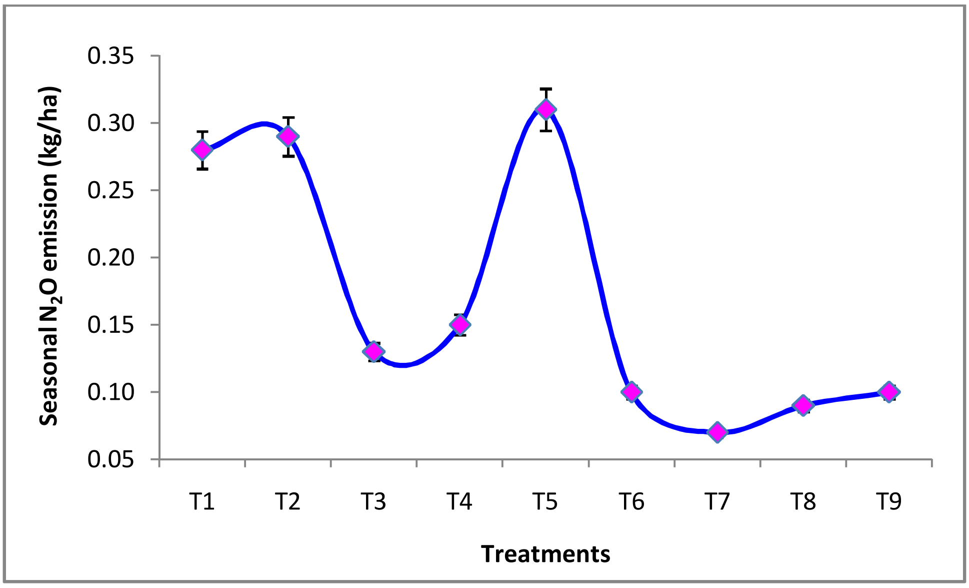

Figure 3. Influence of different nitrogen management practices on seasonal N_2O emission along with DCD treatments

DCD is not a biocide and has no effect on soil microbial biomass (Di and Cameron, 2004). This DCD act particularly on an ammonia monooxygenase confined in nitrosomonas through obstructive the site where ammonia is transformed to nitrite. It is also water soluble and biodegradable into carbon dioxide, water and ammonia. Its degradation rate and its efficiency decreases with time after application to soils. Increasing the soil temperature, pH, organic matter and moisture reduces its effectiveness [12,13]. DCD is a commonly used nitrification inhibitor; several investigations had also proved that DCD worked as a potential nitrification inhibitor for Indian conditions [14]. It is naturally broken down in the soil into non-toxic product with no traces of residue left beyond the cropping year. A reduction in the N_2O to the tune of 40% in a dry sandy loam soils has been reported [15], 58–78% when mixed with urea in grassland and barley fields [10], 63% in lab condition [16] and 52.6% in winter wheat when fertilized with urea [17]. In some treatments, N_2O emissions were generally low and the soil even functioned as a sink for N_2O as evidenced by the negative N_2O efflux. Kitzler and co workers [18] detected negative N_2O fluxes from pine forests with moderate N-deposition, whereas a pine forest with high “N” loads exclusively functioned as a source of N_2O during winter. N_2O sink is an unusual trend, it needs to be established the mechanisms behind this sink phenomenon which is still unknown.

CONCLUSION

It could be inferred that both LCC based N management as well as the SSNM with fixed split N approach along with 10% of DCD registered lower N2O emission. It is also reasonable to suggest that DCD have potential to decrease nitrous oxide emission and other wise increase the efficiency of N cycle. They are potentially additional tool to assist agriculture to achieve its economic and environmental goals considerably. Hence, as a simple tool, LCC based “N” management along with 10% of DCD is found to be the optimal N fertilization strategy for rice, since it gives lower N_2O emission besides savings of N as compared to blanket “N” recommendation. More research is required therefore to move this emerging technology from the current “proof of concept” situation to a practical, cost effective technology on the farm.

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E. Parameswari, V.Davamani, T.Ilakiya and S.Paul Sebastian. Potential of nitrification inhibitor on the reduction of Green House Gas (GHG) emission under intensive paddy system of Cauvery Delta Zone (CDZ). Res. J. Chem. Env. Sci. Vol 9[4] August 2021. 12-17