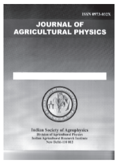
Vol. 22, No. 1, pp. 1-6 (2022)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in



Research Article

Relation between Water Filled Pore Space, NO$_3^-$-N and N$_2$O Emission from Wheat Cropped soil

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ABSTRACT

Greenhouse gas (GHG) emissions contribute enormously to climate change. N$_2$O is a crucial greenhouse gas emitted from crop fields and is affected by management and soil properties of the crop field. Agronomical management practices such as irrigation profoundly affects nitrous oxide (N$_2$O) emissions from soil. Proper irrigation management considering soil type helps in mitigating N$_2$O emissions from crop field soils. Also, N-fertilizer's use has direct influence on N$_2$O emission from managed soils. Therefore, in the present study, N$_2$O emissions from wheat crop (HD2967) were examined in relation to the irrigation provided and nitrogenous fertilizer applied to wheat crop grown in two *rabi* seasons (2015-2017). Positive correlation was observed between water filled pore spaces and N$_2$O emission from wheat crop field for both the growing seasons (2015-17). Positive correlation was also observed between NO$^-_3$- N and N$_2$O emission indicating nitrogenous fertilizer application increases N$_2$O emission in wheat crop.

Key words: Nitrous oxide, Climate Change, Water filled pore spaces, Wheat

Introduction

Agriculture contributes to climate change by emitting greenhouse gases. However, because they are interconnected, it is also influenced by climate change, both directly and indirectly. Significant volumes of greenhouse gases (GHGs) are discharged into the atmosphere, with soil management and livestock accounting for 14 percent of the total. Nitrous oxide (N$_2$O) plays role in climate-alteration gases contributing 5%, to escalate global warming (Watson *et al*., 1996). Nitrous oxide (N$_2$O) is produced in agricultural soil because of microbial nitrification and denitrification (Bhatia et al., 2012a). The rate of N$_2$O emission from crop field is greatly influenced by many factors which includes soil temperature, soil moisture, soil air and carbon availability, type of crop, residue management and application of nitrogenous fertilizers.

Nitrous oxide emissions from wheat crop fields in Trans Indo-Gangetic Plains ranged between 0.31 and 0.98 kg N$_2$O–N/ha/year, depending on fertilizer and irrigation treatments (Gupta *et al*., 2016). The rice–wheat system of the Indo-Gangetic plains resulted in N$_2$O–N emissions of 1.57 kg/ha, or 0.38 percent of applied N when N applied by urea was 240 kg N/ha/year (Pathak *et al*., 2002). It has been estimated that N$_2$O emission from wheat fields in India is 0.17 Tg/year which is a significant cause of climate change (Bhatia *et al*., 2012b). N$_2$O emissions are so much influenced by availability of N in soil which in turn is affected by chemical fertilizers present in the agricultural soils (Cowan *et al*., 2021;

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Fig. 1. Pictorial representation of experimental plot with placement of closed chambers for gas sampling at MB-14 B experimental farm of the Centre for Environment Science and Climate Resilient Agriculture (CESCRA) division in IARI

Fagodiya *et al*., 2019). Another factor influencing N_2O emission is soil moisture due to its ability to regulate availability of oxygen to soil micro-organisms (Davidson *et al*., 2000). Crop management and soil conditions have an impact on greenhouse gas (GHG) emissions from crop fields. Irrigation is one such activity that has a significant impact on soil nitrous oxide (N_2O) emissions (Bhatia *et al*., 2010). As a result, efficient irrigation management combined with crop field soil attributes might reduce N_2O emissions from agricultural soils.

Materials and Method

A field experiment was carried out during (2015-16 and 2016-17) growing wheat (*Triticum aestivum* L.) in the *rabi* season, at the MB-14 B experimental farm of the Centre for Environment Science and Climate Resilient Agriculture (CESCRA) division in IARI, New Delhi, India (28°35′ N and 77°12′ E), in the trans Indo-Gangetic alluvial tract which is located at an elevation of 228 meters above mean sea level (AMSL) (Fig.1). New Delhi is situated in northern part of India, and it has subtropical and semi-arid type climate. The mean annual maximum air temperature is 35°C and the mean annual minimum air temperature is 18°C. The mean monthly minimum and maximum temperature ranges from ~4 to 6°C in January and~ 40°C to 45°C in the month of June, respectively. The area receives ~650 to 750 mm annual rainfall, up to 80-85 % occurring from June to September. Soil type is Ustochrept with pH 8.6 and texture is sandy loam (21% clay, 33% silt and 46% sand). Wheat crop (HD 2967) was directly sown during *Rabi* season on 30th November, 2015. The plant to plant spacing was 5cm and row to row spacing was 20 cm with plant density of 25 plants m^{-2}. The crop was irrigated with proper time interval keeping in mind all the critical stages. Nitrogen application rate was 120 kg ha^{-1} in 3 splits doses, first 50% as basal and next 50% in two equal halves (25% each) at 21 DAS and 52 DAS and 87 DAS as top dressing. At the time of sowing, a base dosage of P and K was administered at a rate of 60 kg ha^{-1}. All the inter-cultural practices in both the crops such as sowing, weeding, and thinning management as well as crop pest control activities were taken care of as per standard procedures. Weeding was done manually, and no chemicals (herbicide and pesticide) were used to avoid their added effects. Treatment details of the crop are mentioned in Table 1.

The collection and sampling of GHGs from the experimental site was performed by adopting closed chamber technique (Malyan *et al*., 2019; Bhatia *et al*., 2005). The chambers used were made of acrylic sheet of 6 mm thickness with a standard box dimension of 50 cm × 30 cm × 100 cm (length × breadth × height). Chamber (box) was fitted with battery operated fan to homogenize its inner air and temperature monitored by a thermometer was kept inside the chamber. To collect gas samples from the chamber, a three-way stopcock fitted at the top was attached with rubber septum (Eastern Medikit Ltd. India). Aluminum channels were utilized as a base for placing the acrylic chamber points and were randomly placed in the field at the sampling points. After installing the chamber above it, the aluminum channels were pushed into the soil to a depth of 10 cm and then filled with water to create an airtight system. The gas samples were taken from the chambers using hypodermic needle of 24 gauge fitted with a 50 mL syringe. The chambers were flushed numerous times with the syringe before taking the sample. The gas sampling was carried out in the morning time and three samples were drawn from each chamber at 0, 1/2 and 1 hrs. between 9:00 and 11.00 A.M. After collecting each sample, syringes were air tightened with a three-way stopcock and returned to the laboratory within 24 hours for further examination of GHG concentrations. The head space

Table 1. Wheat crop field treatment specifics

Treatment	Wheat crop	
	2015 -2016	2016-2017
Variety	HD 2967	HD 2967
Date of Sowing	30.11.2015	02.12.2016
Irrigation schedule	• Average Irrigation amount: - 50-60 mm	
(Days after sowing- DAS)	• No. of irrigation: - 5	
	• 20 DAS	
	• 40 DAS	
	• 60 DAS	
	• 75 DAS	
	• 95 DAS	
Fertilizer scheduling	NCU	DAS
• NCU (split doses) @120 kg/ha	1. 50% -	21
• P&K @ 60 Kg/ha	2. 25% -	52
	3. 25% -	87
	P&K	
	100% basal dose	

volume inside the chamber was also measured to quantify the site's GHG flow. Similarly, samples were drawn once in a week (7 days regular interval) throughout the cropping season (Bhatia *et al*., 2012b). The concentrations of N_2O in the collected gas samples were measured in the research laboratory using Gas Chromatographs (GC) (Hewlett Packard 5890 Series II) equipped with different detectors such as electron capture detector (ECD) and flame ionisation detector (FID), and a stainless-steel column (6 1/8- Porapak N). The carrier gas in GC was N_2, which flowed at a rate of 14 ml min^{-1}. The standards of GHGs, used for calibration, were obtained from Spectra Gases (NIST standards), USA.

The concentration of N_2O in the gas samples was determined using a GC coupled with an ECD (GC-ECD). The temperatures of the injector, column, and detector were kept constant at 120°C, 50°C, and 350°C, respectively. For gaseous calibration, the standards (NIST standards) used were 500 ppbv and 1 ppm for N_2O. The peak area was plotted and measured using a GC-computer interface and a Hewlett Packard integrator. The N_2O concentration in a gas sample was calculated using the method described by Pathak *et al*. (2003). The estimation of total N_2O emission during both the crop seasons was carried out by successive linear interpolation of mean emissions of a particular GHG during the sampling days of the cropping season assuming that emissions followed a linear trend during the non-sampling periods (Malyan *et al*., 2021a; 2021b).

Nitrate in Soil

For estimating nitrate nitrogen (NO_3^--N) in the soil, we followed standard procedure of the Keeney and Nelson (1982).

Water Filled Pore Space (WFPS)

It is the ratio of volumetric soil moisture content to total soil porosity. Since particle and water densities are consistent at 2.6 and 1 kg/l, the WFPS of soil was calculated simply by combining its bulk density and soil moisture content. It was calculated using the formula as given below:

WFPS = [Gravimetric moisture content x Soil bulk density] / Total soil porosity

Where,

Soil porosity = 1- [soil bulk density/ soil particle density]

Soil particle density was estimated by pycnometer method and the bulk density was estimated using cylinder method (Blake and Hartge, 1986).

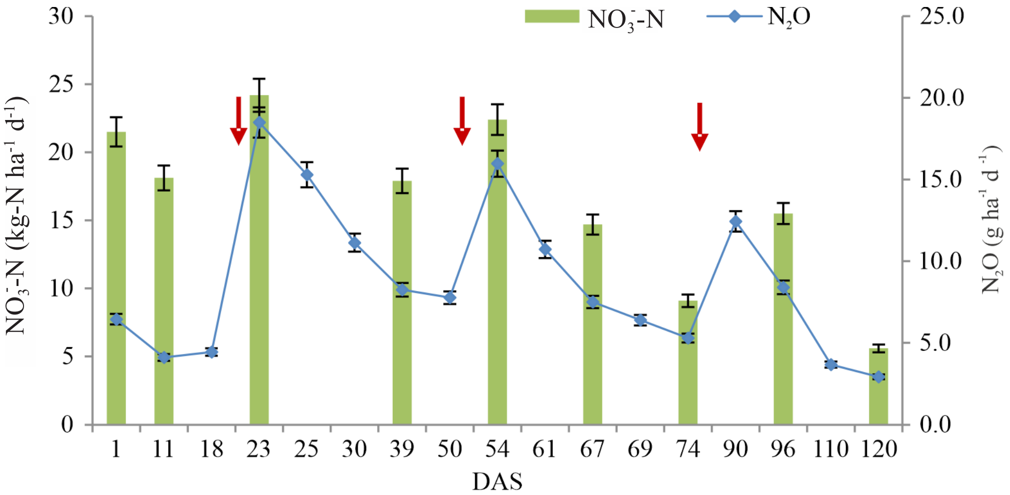

Fig. 2. Relation between N_2O emission and NO_3^--N in wheat field for both rabi seasons (2015-17)

Results and Discussion

In our study, the highest NO_3^--N was observed during the peak flux of N_2O emission (23 DAS). This coincided with the maximum value of NO_3^--N in soil (Fig. 2) which was due to fertilizer application on 20 DAS. This shows that application of nitrogenous fertilizer resulted in the increase in soil ammonium content due to hydrolysis of urea in the presence of high WFPS and with time the partially oxidized condition led to nitrification of the soil ammonium to nitrate rapidly (Banerjee *et al*., 2002). Thus, higher nitrate content in the soil lead to a comparatively high value of N_2O emission indicating use of N-fertilizers has a direct influence on N_2O emission (Zanatta *et al*., 2010). Moreover, with a decrease in NO_3-N availability in soil, the N_2O emission also correspondingly declined in a similar trend due to reduced denitrification (Cavuela *et al*., 2013). The maximum N_2O emission coincided with the maximum WFPS value and NO_3-N in soil. Three peaks of N_2O emission were observed during the crop season, which were 18.5, 16.0 and 12.5 N_2O (g ha-1d-1) at 23, 54 and 90 DAS (cumulative data), respectively. The corresponding WFPS values on these days were 75.8%, 68% and 61%, respectively. Higher value of soil water content leads to increase in rate of N_2O emission mainly due to limited oxygen diffusion in soil through soil pores (Bhattacharya *et al*., 2018). Baggs and Bateman (2005) reported through their experiment that nitrification rate increases with increase in WFPS but after 60% WFPS denitri-fication dominates which is mainly due to reduced availability of substrate (O_2 and CO_2) for nitrifiers caused by restricted rates of diffusion resulting in anaerobic condition. Thus, beyond 60% of WFPS value denitrification process is usually associated with soil moisture content. Positive correlation (R^2 = 0.55) was found between WFPS and N_2O (Fig. 4) indicating increase in WFPS will lead to anaerobic condition suitable for denitrification which can be supported by similar research report of Garcia-Marco *et al*. (2014) which states that the percentage of WFPS was the primary factor associated in N_2O emission and must be kept below 80% to reduce emissions. Similarly, positive correlation (R^2 = 0.63) was observed between NO_3^--N and N_2O (Fig. 3) which indicates direct effect of nitrogenous fertilizer application on N_2O emission.

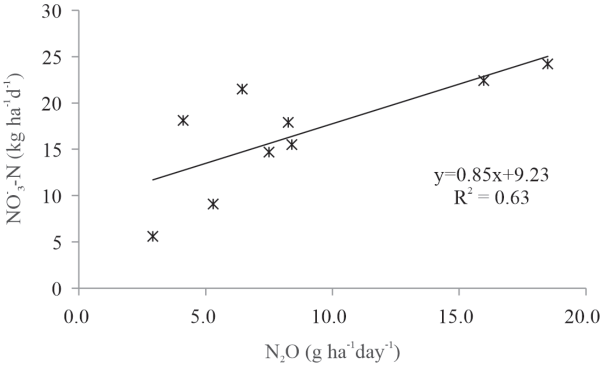

Fig. 3. Relation between N_2O emission and NO_3-N in wheat field for both *rabi* seasons (2015-17)

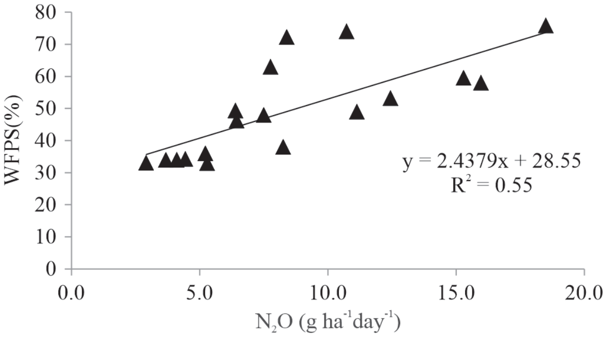

Fig. 4. Relationship between WFPS and N_2O emission from wheat crop for both *rabi* seasons (2015-17)

Conclusion

Through our study, it was observed that both nitrogenous fertilizer application and irrigation scheduling facilitates N_2O production and emission from wheat crop. The nitrogen fertilizer should be applied as per crop requirement, to enable better N uptake by plant and reduce the NO_3 availability for loss as N_2O through denitrification. The irrigation scheduling should not coincide with a fertilizer N application event as anaerobic conditions will increase the WPFS and NO_3 will undergo denitrification Therefore, judicious scheduling of nitrogenous fertilizer application along with time of irrigation management will avoid the favorable condition for N_2O emission from soil and could be one of the mitigating measures for N_2O emission from fertilized crop soils.

Acknowledgement

The authors express gratitude to the PG School and Director, ICAR-Indian Agricultural Research Institute, New Delhi, for providing the necessary facilities and financial support, for conducting this research work. Financial assistance provided by the NICRA project is also acknowledged.

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Received: January 14, 2022; Accepted: March 30, 2022