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Impact of Nitrogen Fertilizers on Methane Emissions from Flooded Rice

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ABSTRACT

Methane is second most potent greenhouse gas emitted under anaerobic condition in rice soils. Effects of different nitrogen fertilizer application on methane emissions in flooded paddy field were studied. The experiment was laid out in a randomized complete block design with three treatments and three replications. The treatments were control (0 kg N ha^{-1}), urea (120 kg N ha^{-1}) and ammonium sulfate (120 kg N ha^{-1}). In all treatments P (60 kg P_2O_5 ha^{-1}) along with K (40 kg K_2O ha^{-1}) were also applied as basal dose. The cumulative seasonal methane flux was highest in urea 36.3 (kg ha^{-1}) followed by control 35.2 (kg ha^{-1}) and ammonium sulfate 28.5 (kg ha^{-1}). Ammonium sulfate application reduced total seasonal emission by 19.5% as compared to control while it reduced CH_4 emissions by 21.6% as compared to urea application. On the basis of this study we can conclude that application of ammonium sulfate is an effective tool for mitigating methane emissions from rice soils.

Keywords: Rice, Methane, Urea, Ammonium sulfate.

INTRODUCTION

Methane (CH_4) atmospheric concentration has significantly rises due anthropogenic activity. Graedel and McRae[1] presented first evidence that atmospheric concentration of CH_4 is increasing. In agriculture submerged rice (*Oryza sativa L.*) soils are the major source of CH_4 emission to atmosphere. Rice is second most consumed cereal in world after corn and out of total rice 90% is cultivated in Asia under irrigated conditions. Under continues standing water soil redox potential (Eh) drops sharply within few days and leads to process methanogenesis in soil[2]. In methanogensis, soil archaea methanogens degraded organic matter and produce CH_4[3]. CH_4 emission from rice soil is a net balance of production by methanogens in reducing environment after oxidation by methanotrophs in oxidizing environment and it is influenced by several factors such as water conditions, Eh, soil temperature, pH, fertilizer managements, and organic matter[4-5]. Water management's practices such as alternate drying and wetting, mid-season drainage, system of rice intensification etc were effective tools to reduce CH_4 emission from rice cultivation. Water management practices have limitation in lowland area where water management is difficult task so there is need for other effective interventions for CH_4 reduction from lowland or continues flooded rice soils. CH_4 is second most potent greenhouse gas after carbon dioxide and it is 25 times greenhouse with more potent gas as compared to carbon dioxide[6-7]. According to IPCC[8] CH_4 contributes 16% of total emissions at global level and out of total rice field alone contribute 10% of total CH_4 emission at global level[9]. Kumar *et al*[10] reported that by the end of twenty first century global mean temperature may rise up to 1.5°C due to increased in global greenhouses gases atmospheric concentrations. Global warming is major concerned of 21[st] century for scientific and policy maker. As the world population was increasing so under such scenario CH_4 mitigation from rice field needed without having any negative impact on rice production. Rice production depends on type and amount of nitrogen (N) based fertilizers applied for cultivation. N based fertilizer amendments may be used for CH_4 emissions mitigation from the rice soil. Impact of different N based fertilizer on CH_4 emission is less evaluated so it is needed. The objective of this field experiment is to evaluate the impact of nitrogen fertilizer on CH_4 emissions from rice soil under continuous flooded condition.

Fig.1: Experimental site of Indian Agricultural Research Institute, New Delhi, India

MATERIAL AND METHODS

Site Descriptions

Field experiment was carried out at the

Table 1: Pri-transplanting physicochemical properties of the experimental site

Soil parameter	Value
Sand (%)	46
Slit (%)	32
Clay (%)	22
pH (1:2.5 :: soil: water)	8.4
Organic C (%)	0.58
CEC* (c mol kg^{-1})	7.3
Hydraulic conductivity (cm d^{-1})	4.7
Olsen P (kg ha^{-1})	31.9
$KMnO_4$ extractable N (kg ha^{-1})	250
NH_4^+-N (kg ha^{-1})	24.8
NO_3^--N (kg ha^{-1})	34.1
Moisture content at field capacity (%)	21.2

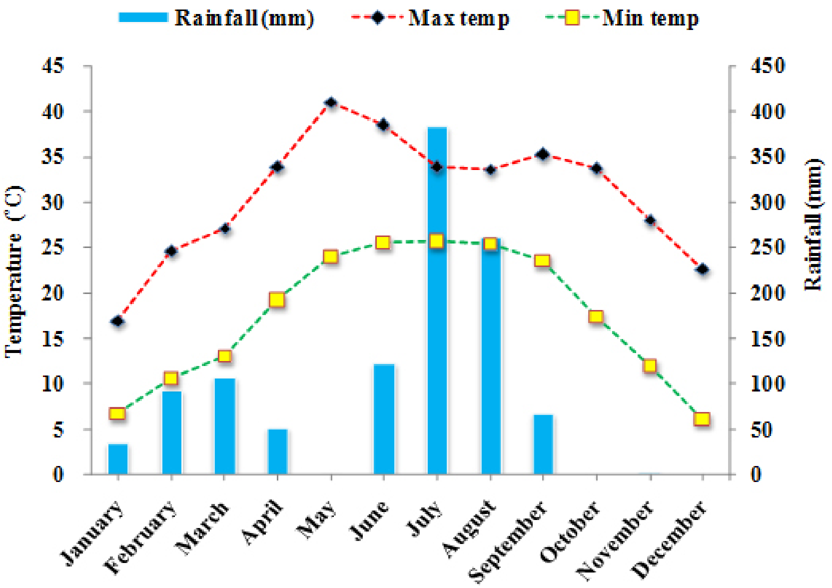

Fig. 2: Metrological data of experimental site

research farm of Indian Agricultural Research Institute, New Delhi, India, during kharif season of year 2015 (Fig. 1). The climatic condition of the region was sub-tropical, semi arid that was characterized by dry winter and maximum rainfall occurs during from June to September of year (Fig. 2). The soil of study site was sandy loam in texture and pri-transplanting physicochemical properties of experimental site soil are mentioned in Table (1).

Experimental design and treatments details

The experiments consist of three treatments with three replicate each which are arranged in RBD. Composition and dose of various treatments were mentioned in Table (2). Pusa Basmati 1509 variety of rice (*Oryza sativa* L.) was adopted for conducting the experiment. Two to three rice seedlings (23 days age) were transplanted at 15 x 20 cm spacing. Continuous flooding condition at 8 ± 4 cm water level was maintained by groundwater irrigation for entire cropping period. The field was naturally allowed to dry three weeks before harvesting of crop. No chemical interventions (pesticide and herbicide) were applied to avoid their additional effects. Weeding was done manual when required.

Table 2: Different treatments used during rice cultivation

Treatment	Dose	Method of application
Control	N (0 kg N ha^{-1}), P (0 kg P_2O_5 ha^{-1}), K (0 kg K_2O ha^{-1})	Not applicable
Urea	N (120 kg N ha^{-1}), P (60 kg P_2O_5 ha^{-1}), K (40 kg K_2O ha^{-1})	P and K were applied basally, while N (Urea) applied in three splits in 50% (basal) and, 25% (tillering) and 25% (panicle initiation) of total dose.
Ammonium sulfate (AS)	AS (120 kg N ha^{-1}), P (60 kg P_2O_5 ha^{-1}), K (40 kg K_2O ha^{-1}),	P and K were applied basally, while N (Ammonium sulfate) applied in three splits in 50% (basal) and, 25% (tillering) and 25% (panicle initiation) of total dose.

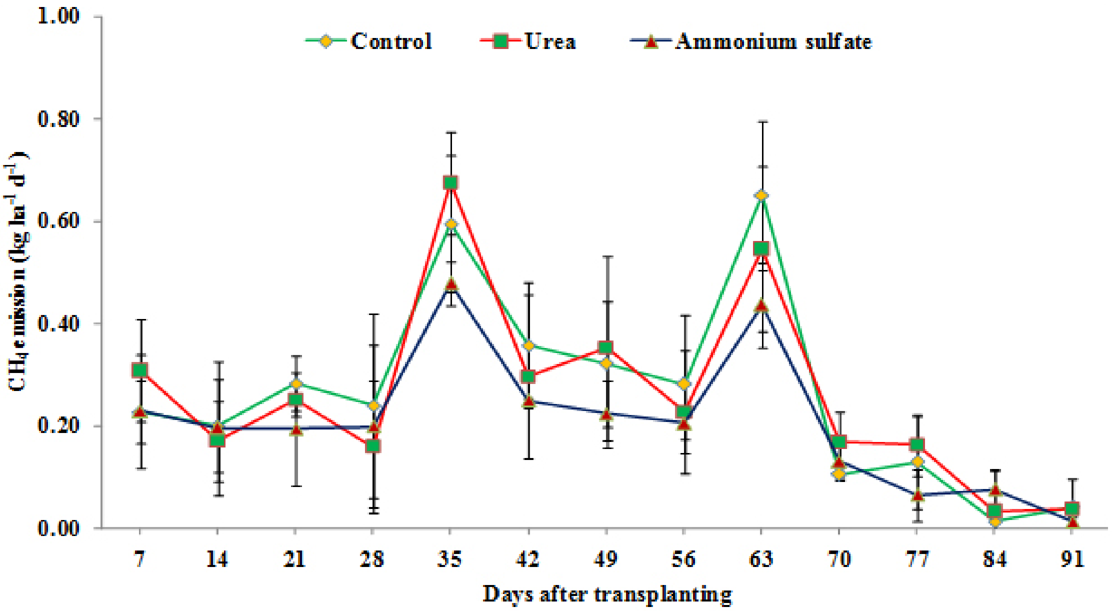

Fig.3: Methane emissions from rice soil under different nitrogen based fertilizer amendments

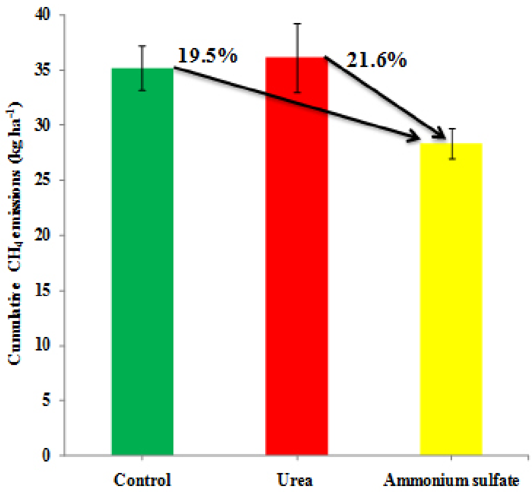

Fig. 4: Cumulative seasonal methane emissions from rice soil along with methane reduction in percentage

Methane sampling collection and analysis

Gas samples were collected at 7 days regular interval throughout the rice cultivation by manual closed chamber technique[11]. Gas samples were collected between 9 am to 11 am and samples were withdrawn from top of the chamber using 20 ml air-tight syringes at 0, 1/2 and 1 hrs. Concentration of CH_4 gas in the collected gas samples were measured by using gas chromatography equipped with column and a flame ionization detector.

RESULT AND DISCUSSION

Methane emission among all treatments was low during first three weeks and significantly increased with plant growth and lower soil Eh. The highest flux peak was observed at 35 days after transplanting (DAT) and second peak occur at 63 DAT (Fig 3).

Two higher CH_4 peaks may be due to degradation of soil organic matter by methanogens bacteria under anaerobic conditions and similar flux were also reported by[12] in rice soil. The cumulative seasonal CH_4 flux was 35.2 kg ha^{-1} under the control treatment The highest cumulative CH_4 flux was recorded in urea (36.3 kg ha^{-1}) treatment followed by control (35.2kg ha^{-1}) and ammonium sulfate (28.3 kg ha^{-1}). As compare to control, urea fertilizer application enhances CH_4 emissions by 2.72% and ammonium sulfate amendments reduce CH_4 emissions by 19.5% as compared to control (Fig. 4). Ammonium sulfate application reduced the total seasonal CH_4 emissions by 21.6% over urea (Fig. 4).

The higher CH_4 emission under nitrogen applied plots over no nitrogen amendments has been reported[13]. Urea application enhances the ammonium ions concentration in soil and due to structural symmetry between CH_4 and ammonium ion[3] methanotrophs bind with ammonium ions instead of CH_4 therefore results in less CH_4 oxidation by methanotrophs in soil which finally result in higher CH_4 emission from soil[14].

Minami[15] observed about more than 15% reduction in average CH_4 flux from rice soil by incorporated with ammonium sulfate at 200 kg N ha^{-1} rate as compared to 200 kg N ha^{-1} urea incorporation. Similar finding were also observed by Ali *et al*[16] and they reported 16% and 21% reduction in total seasonal CH_4 flux by ammonium sulfate over urea in upland and lowland rice soil in Bangladesh respectively. On addition of ammonium sulfate in soil concentration of active sulfate ions was increased[16] which result in higher population of sulfate reducing bacteria in soil. Sulfate reducing bacteria compete with methanogens bacteria for organic matter as they both feed on similar substrate[5] therefore on application of ammonium sulfate suppressed methanogens activity in soil which result in CH_4 flux reduction form rice soil.

CONCLUSIONS

In this field study we evaluate the impact different nitrogen based fertilizer on methane emission from rice soil. A total cumulative methane emissions was highest in urea applied plots and lowest in ammonium sulfate plots. Ammonium sulfate application reduces 19.5% and 21.6% as compare to urea and control respectively. Therefore, based on this study it could be suggested that application of ammonium sulfate significantly reduce methane emission from rice soils.

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