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Greenhouse gases emission from soils under major crops in Northwest India

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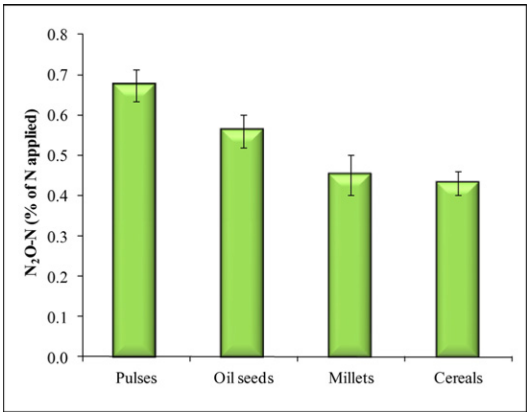
HIGHLIGHTS

- Nitrous oxide, methane and carbon dioxide emission were quantified from soils under cereals, millets, oilseeds, and pulses in northwest India.
- The emission of nitrous oxide ranged from 0.57–1.3 kg ha^{-1}, methane from 27.78–29.50 kg ha^{-1} and carbon dioxide from 2377–3910 kg ha^{-1}.
- Emission of nitrous oxide as percent of applied N was highest in pulses (0.67%) followed by oilseeds (0.55%).
- Global warming potential (GWP) of soils under different crops ranged from 3053 to 3968 kg CO_2 ha^{-1}.

GRAPHICAL ABSTRACT



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ABSTRACT

Quantification of greenhouse gases (GHGs) emissions from agriculture is necessary to prepare the national inventories and to develop the mitigation strategies. Field experiments were conducted during 2008–2010 at the experimental farm of the Indian Agricultural Research Institute, New Delhi, India to quantify nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) emissions from soils under cereals, pulses, millets, and oilseed crops. Total cumulative N_2O emissions were significantly different ($P > 0.05$) among the crop types. Emission of N_2O as percentage of applied N was the highest in pulses (0.67%) followed by oilseeds (0.55%), millets (0.43%) and cereals (0.40%). The emission increased with increasing rate of N application ($r^2 = 0.74$, $P < 0.05$). The cumulative flux of CH_4 from the rice crop was 28.64 ± 4.40 kg ha^{-1}, while the mean seasonal integrated flux of CO_2 from soils ranged from 3058 ± 236 to 3616 ± 157 kg CO_2 ha^{-1} under different crops. The global warming potential (GWP) of crops varied between 3053 kg CO_2 eq. ha^{-1} (pigeon pea) and 3968 kg CO_2 eq. ha^{-1} (wheat). The carbon equivalent emission (CEE) was least in pigeon pea (833 kg C ha^{-1}) and largest in wheat (1042 kg C ha^{-1}). The GWP per unit of economic yield was the highest in pulses and the lowest in cereal crops. The uncertainties in emission values varied from 4.6 to 22.0%. These emission values will be useful in updating the GHGs emission inventory of Indian agriculture.

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1. Introduction

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are three most important greenhouse gases (GHGs) contributing 87% of the total radiative forcing (Myhre et al.; IPCC, 2013). Atmospheric concentrations of these gases have exceeded the pre-industrial levels by 40%, 150%, and 20%, respectively (Ciais et al; IPCC, 2013). Agricultural activities have a significant contribution to the anthropogenic emissions of these GHGs, and hence to the global climate change. Globally, agriculture, forestry and other land use (AFOLU) sector accounts for 24% of total anthropogenic emissions of GHGs mainly CH_4 and N_2O (IPCC, 2014). Of the global anthropogenic emissions in 2010, agriculture accounted for approximately 43 and 47% increase in N_2O and CH_4 emissions, respectively, as compared to 1970 (IPCC, 2014). The Indian agriculture contributed to 18% of total GHGs emissions from India (Pathak et al., 2014), which is mainly through livestocks, irrigated rice fields and application of nitrogenous fertilizer.

The main source of CO_2 from agricultural soils is through biological decomposition of soil organic matter under aerobic conditions, disturbances of soil and vegetation carbon pools by ploughing/tillage (Schutz et al., 1989). Submerged rice fields are the potential source of CH_4 produced by the microbial decomposition of organic matter under anaerobic conditions (Bhatia et al., 2005). The amount of CH_4 emitted from rice fields depends on crop duration, water regimes and cultivars grown (Jain et al., 2004). Major sources of N_2O are inorganic and organic nitrogenous compounds in soil, fertilizers and manure. Emissions of N_2O from soils are highly variable depending upon soil type, N and organic C availability, temperature, pH, soil moisture, season, crop type, fertilization, and agricultural soil management practices such as irrigation and tillage (Snyder et al., 2009; Pathak et al., 2010).

The signatory countries to United Nations Framework Convention on Climate Change (UNFCCC) need to regularly update their inventory of GHGs. A major difficulty in estimating the magnitude of emissions from soils is the relative lack of measured data and the non-availability of reliable country-specific emission coefficients. Different crops have different management practices that may lead to the difference in the emission of GHGs. It is, therefore, necessary to generate emission coefficients of GHGs from soils under different crops and management practices to reduce the uncertainties in the inventory and suggest suitable mitigation strategies. Field experiments were conducted to quantify the emissions of N_2O, CH_4 and CO_2 from soils under major cereals, pulses, millets and oilseeds grown in northwest India.

2. Materials and methods

Field experiments were conducted during *kharif* (July to October) and *rabi* (November to March) seasons from 2008 to 2010 growing cereal crops (maize, rice, and wheat), pulses (green gram, pigeon pea, and chickpea), millets (sorghum and pearl millet) and oilseed crops (groundnut, soybean and mustard) in a Typic Haplustepts at the experimental farm of the Indian Agricultural Research Institute, New Delhi. The experimental sites are located in the Indo-Gangetic alluvial plains (latitude 28°14′N and longitude 77°12′E) at an altitude of 228 m above the mean sea level. The climate is subtropical and semi-arid with mean maximum and minimum temperatures ranging from 43.9 °C to 45.0 °C and 6 °C to 8 °C, respectively, with occasional occurrence of frost in the month of January (Fig. 1). The rainfall and minimum and maximum temperatures during crop growing seasons were recorded at the meteorological observatory located at the farm. The groundwater table is at 6.6 and 10 m depth during the rainy and summer seasons, respectively. The physicochemical properties of the soils of two experimental sites and the crop management practices are given in Tables 1 and 2, respectively.

2.1. Crop management

All the crops were grown under conventional farmers' practice, each with three replications. The size of each experimental plot was 5.5 m × 6.0 m. The bare fallow plots without fertilizer were taken as a control. Nitrogen (N) was applied as urea in three splits (50% basal + 25% each as two top dressings) in all the crops except chickpea, in which the entire N was applied as basal (Table 1). Phosphorus (26.2 kg P ha^{-1}) and potassium (40 kg K ha^{-1}) were incorporated into the soil at the time of sowing through single superphosphate (SSP) and muriate of potash (KCl), respectively. Irrigation water (5 ± 2 cm) was applied through check-basin method, and a total of five irrigations were given to the crops except rice, where irrigation was given at every 2–3 days interval. Standard recommended practices were followed to control the weeds, insects and diseases.

2.2. Gas sample collection and analysis

Gas samples were collected using the closed-chamber technique (Pathak et al., 2002). Chambers of 50 cm × 50 cm × 100 cm (length × width × height) made of 6 mm acrylic sheets were used with aluminium channels placed in the soil (Bhatia et al., 2010). The channels were inserted 10 cm into the soil and filled with water to make the system air-tight. A battery operated fan, fixed inside the chamber, was used to mix the air inside. The chambers were placed in between the plants in all the upland crops. In rice crop the chamber was placed on the plants enclosing four plants. Gas samples were collected at 0, 20 and 40 min after the chamber was placed in the plot with the help of a hypodermic needle (24-gauge). After drawing the sample, syringes were made air tight with a three-way stopcock and brought to the laboratory for analysis. Headspace volume and air temperature inside the chamber was recorded, which were used to calculate flux of the gases. The samples were collected once in a week throughout the cropping season between 10 and 11 h from each replicate. The gas samples were collected on 0, 3, 5, 7, 13, 17, 20, 23, 26, 34, 37, 41, 48, 55, 63, 69, 76, 79, 86, 93, 100, 110, 117, and 120 days after sowing (DAS) for sorghum, pearl millet, soybean, ground nut, pigeon pea, green gram and maize crops; on 0, 6, 13, 21, 27, 34, 41, 48, 51, 52, 53, 60, 66, 72, 73, 79, 81, 85, 90 and 95 days after transplanting (DAT) for rice crop and on 0, 1, 5, 7, 13, 14, 16, 17, 23, 27, 31, 34, 37, 44, 47, 52, 55, 59, 62, 66, 69, 72, 76, 80, 83, 87, 88, 94, 98, 104, 107, 111, 116, 121, 123, 125, 128 and 138 DAS for chickpea, mustard and wheat crops.

Concentration of CH_4 in the gas samples was estimated by Gas Chromatograph (GC 8A Series, Shimadzu) fitted with a flame ionization detector (FID) while N_2O samples were analysed using Gas Chromatograph (HP 5890) fitted with electron capture detector (ECD). A GC-computer interface was used to measure the peak area. The NIST traceable N_2O (500 and 1000 ppbv), CH_4 (1 and 2 ppmv) and CO_2 (350 and 500 ppmv) standards obtained from Spectra Gases, USA, were used for the calibration.

Carbon dioxide was sampled and analysed using infrared-based continuous soil CO_2 flux analyser (LI-8100) in all the upland crops. The LI-8100 system was used with short-term survey chambers (diameter of 20 cm) and soil temperature probe to obtain soil CO_2 flux and soil temperature. The closed-chambers were placed on the soil between the plants and the rate of increase in the chamber CO_2 concentration was used to determine the soil fluxes as described by Daripa et al. (2014).

Estimation of total CO_2, CH_4, and N_2O emissions during the crop season was done by successive linear interpolation of average emission on the sampling days assuming that emission followed a linear trend during the periods when no sample was taken (Bhatia et al., 2010). Emission factors (EFs) were calculated by subtracting the fluxes from the fallow plots and are expressed as the percentage of total-N applied in the case of N_2O and kg CO_2 ha^{-1} in the case of CO_2. The EF for N_2O–N (kg kg^{-1} of N applied) was arrived at by normalising the emission with reference to the gross cropped area under each crop.