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# Effect of methane emission, mechanisms and management options in rice field

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## Abstract
Rice is grown in approximately one third of the world's irrigated cropland. Rice represents one half of the irrigated cropland in Asia. Rice is often grown in monsoonal climates due to its tolerance to flooding. The global average surface temperature has increased with 0.6 ± 0.2°C over the last century. It is caused by the increased concentration of greenhouse gases (GHGs) in the atmosphere and leads to a phenomenon widely known as 'greenhouse effect'. Global average surface temperature has increased with 0.6 $^0$C over the last century and it predicted to increase 1.4-5.8 $^0$C by the year 2100 Methane is one of the strong greenhouse gas having warming potential of 21 times greater than $CO_2$ and it contributes 20 per cent towards global warming. Now it's concentration in the atmosphere is 1858 ppb (up to April 2018) compare to 722 ppb during pre-industrial period. Improper management of organic residues, fertilizers, irrigation water, method of rice cultivation *etc*., are the main reasons for more methane emission from the rice field. So, proper management of these is very important to reduce the methane emission and to ensure higher productivity in rice. Methane contributes 20 per cent towards global warming followed by CFC's (12%), ozone (7%) and nitrous oxide (4%) but the highest contribution is from the carbon dioxide (62%).

**Keywords:** Methane, paddy, nitrogen, perspex box, straw

## Introduction
The global average surface temperature has increased with 0.6 ± 0.2°C over the last century. According to the Intergovernmental Panel on Climate Change's (IPCC) SRES scenarios the global average surface temperature is predicted to increase 1.4 to 5.8°C over the period 1990 to 2100 (Anon., 2011) [1]. Methane has, among other greenhouse gases like carbon dioxide, nitrous oxide and chlorofluorocarbons, a strong infrared absorption band, which traps the outgoing long wave radiation from earth's surface. The warming potential of methane and nitrous oxide is 21 times and 280 times greater respectively than that of carbon dioxide in 100 years' time scale. (Goudie 2002) [7] remarks that land changes are the largest human induced emission of methane. In the year 2017 the methane concentration in the atmosphere was 1880 ppb compared to the preindustrial level of 722 ppb. (Schimel 2000) [14] concludes that the methane concentration was continuing to increase at an annual rate of 1 per cent. It is clear that the emissions of methane have increased during this period. The emissions from rice is high but has not increased as much as livestock during the last decades. According to (Goudie 2002) [7] it is difficult to estimate the long term level of methane in the atmosphere due to the fact that methane reacts quickly with other substances, which decreases the amount of methane.

Methane contributes 20 per cent towards global warming followed by CFC's (12%), ozone (7%) and nitrous oxide (4%) but the highest contribution is from the carbon dioxide (62%).

## Sources of methane emission
According to IPCC methane is emitted through both biological and industrial processes and the atmospheric concentration of methane has increased approximately 246 per cent of its preindustrial concentration (Table. 1). Methane is produced in an anaerobic environment such as rice paddies, swamps, sludge digesters, rumens and sediments. According to (Sommer *et al.* 2004) [16] the anthropogenic methane sources are of special interest, because they offer an opportunity to manipulate and reduce the emissions. Approximately 410-660 million tons methane are emitted globally per year and between 25.4 and 54 million tons of this is due to irrigated rice fields.

**Table 1:** Sources of methane

| Sources | | % contribution | |
|---|---|---|---|
| Natural sources (36%) | Wetlands | 78 | 100 |
| | Termites | 12 | |
| | Oceans | 10 | |
| Anthropogenic sources (64%) | Fossil fuel | 33 | 100 |
| | Livestock | 27 | |
| | Landfills and waste | 16 | |
| | Biomass burning | 11 | |
| | Rice agriculture | 09 | |
| | Bio fuels | 04 | |

### Rice agriculture (9%)
Rice is grown in approximately one third of the world's irrigated cropland. Rice represents one half of the irrigated cropland in Asia. Rice is often grown in monsoonal climates due to its tolerance to flooding. Intensification of cultivation of irrigated rice has been registered, above all in Asia, especially that of wet rice, which is an exceptionally large source of methane. During the dry stages of the rice large amounts of nitrous oxide is emitted from the paddy field. These areas also have problems with waterlogging and increased salinity in the soil. The intensification of wet and irrigated rice production is believed to increase application of fertilizer, herbicides, pesticides and the use of genetically engineered crops.

### Measurement and analysis of methane
The methane emission rate was measured by the static box technique. At the measurement sites aluminium channels were fixed permanently well in advance of sampling. The bases were mounted with a U-shaped channel to hold water. The perspex box (30 cm × 50 cm × 70 cm) was then placed over the aluminium channel bases. The open end of the perspex box rests on the channel. The water seal surrounding the perspex box makes the system airtight. Battery-operated fans inside the perspex box mix the air in the chamber. The box was fitted with tygon tubing terminating in a gastight stopcock and air samples were collected in glass bottles by the water displacement method. Glass air-sampling bottles were fitted with a three-way stopcock and a neck with a self-sealing silicon rubber septum. Samples were collected at fixed intervals of 0, 15, 30 and 45 minutes. The averages of all fluxes were considered as the flux value for the day. Methane fluxes were determined once a week in the morning and afternoon, starting 15 days after transplanting and continuing over the entire crop-growing season. After collection, samples were brought to the laboratory and concentration was determined by a gas chromatograph (Varian 3800), fitted with a flame ionization detector (FID) and Porapak N column, 180 cm long and 1/8 inch outside diameter. Column, detector and injector temperatures were maintained at 90 ◦C, 130 ◦C and 130 ◦C, respectively. Nitrogen was used as the carrier gas, hydrogen as the fuel gas and zero air as the supporting gas with flow rates of 20, 30 and 250 ml $min^{-1}$, respectively. Ambient and box air temperatures, barometric pressure and water level inside the chamber were measured during each sample collection to calculate the chamber air volume at standard temperature and pressure.

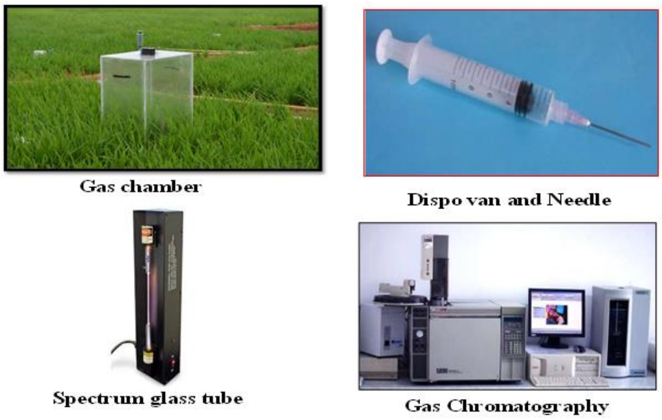


**Fig 1:** Instruments needed for collection of methane gas

### Estimation of methane emission
Rolston (1986)

$F = D \times E / B$

F: Methane emission rate (mg $m^{-3}$)

D: Actual area of methane obtained after 0.5 ml gas sample feed to gas chromatography

E: Cross section of chamber or volume of chamber ($m^3$)

B: 0.5 ml concentration of gas feed to gas chromatography using syringes.

### Management of methane emission
#### Selection of variety
Parashar *et al*., reported that, among different cultivars IET 7633 recorded less methane emission (1.3 mg $m^{-2}$ $hr^{-1}$) followed by Rassi and TELLA HAMSA but the highest was recorded in IET 7641. Higher grain yield was recorded in ANNADA (4996 kg $ha^{-1}$) followed by IET 7633 (4777 kg $ha^{-1}$).

Gogoi *et al*., reported that, ten rice cultivars were screened for methane emission popularly grown during the monsoon season of Assam. The results showed that the methane emission of rice cultivars ranged from 8.83 g $m^{-2}$ (IR 36) to 18.63 g $m^{-2}$ (Monohar Sali) over three and a half months. Variety IR 36 was found to emit the least methane (3.98, 6.17, 5.67 and 3.64 mg $m^{-2}$ $hr^{-1}$ during early tillering, late tillering, panicle initiation and ripening stage, respectively) amongst all the cultivars. Five cultivars were identified as high methane-emitting cultivars (>15 g $m^{-2}$).

### Method of cultivation
Jagadish *et al*., reported that, among the different establishment techniques Dry-DSR was achieved lowest methane emission during all the crop growth stages as compared to the other treatments it was mainly due to higher aerobic condition leads to the inactivity of methanogenes population due to higher redox potential.

Jayadeva *et al*., reported that, SRI establishment technique recorded significantly higher methane emission (2.31 and 2.71mg $plant^{-1}$ $day^{-1}$, respectively) during early stages of crop growth (40 and 50 DAS, respectively). The methane emission under aerobic establishment technique was lower than normal transplanting (1.54 and 1.66 mg $plant^{-1}$ $day^{-1}$, respectively) during early stages (40 and 50 DAS, respectively). During early stage of crop growth (30 DAS), application of FYM with recommended NPK recorded significantly higher methane emission (0.130 mg plant$^{-1}$ day$^{-1}$, respectively). At later stages, incorporation of paddy straw with recommended NPK recorded higher methane emission (25.99 mg plant$^{-1}$day$^{-1}$, respectively).

**Manures, fertilizers and amendments**

Anitha and Bindu, reported that, $CH_4$ emission was decreased at vegetative stage, gradually increased at reproductive stage and decreased at grain filling to maturity. Methane emission was higher from Heading to flowering, accounting for 35.21 per cent to 41.53 per cent of total cumulative emission. CRNF significantly affect the methane emission. The methane emission was less in N supplied through CRNF in all the growth stages compare to urea and the highest emission was observed in N supplied through organic (FYM) in both Uma and Jyothi rice.

Hoang *et al.,* reported that among different sources of N fertilization, ammonium chloride recorded less methane emission in all the growth stages compare to urea. This might be due to the quick decomposition property of ammonium chloride in flooded condition. In case of urea which is rapidly hydrolysed in to ammonium carbonate then it serves as substrate for methanogenic bacteria as carbon source.

**Water management**

Shantappa *et al*., reported that methane emission was higher in flooding irrigation method from vegetative stage to maturity stage (39.4 mg m$^{-2}$ day$^{-1}$ to 36.1 mg m$^{-2}$ day$^{-1}$) but inverse relationship in nitrous oxide (69.3 µg m$^{-2}$ day$^{-1}$ to 7.9 µg m$^{-2}$ day$^{-1}$) followed by saturation method of irrigation (33.1 mg m$^{-2}$ day$^{-1}$ to 32.3 mg m$^{-2}$ day$^{-1}$ and 78.0 µg m$^{-2}$ day$^{-1}$ to 11.7 µg m$^{-2}$ day$^{-1}$, respectively).

Kumar *et al.,* revealed that, Irrespective of treatment methane emission was more at vegetative and reproductive stage due to very well developed aerenchyma tissue and intense reduced condition. Total methane emission was more in continuously flooded condition (34.6 kg ha$^{-1}$) and the least was in irrigation at soil water potential of -60 kPa (13.7 kg ha$^{-1}$). But the grain yield was more in continuously flooded condition (4.80 t ha$^{-1}$) followed by irrigation at soil water potential of -20 kPa (4.72 t ha$^{-1}$) and -30 kPa (4.69 t ha$^{-1}$).

**Straw and organic residue management**

Cai *et al*., reported that, Irrespective of N rate, application of wheat straw at 8 t ha$^{-1}$ recorded higher methane emission (7.35, 6.37 and 27.37 mg m$^{-2}$ ha$^{-1}$ in 2003, 2004 and 2005, respectively in application of N at 270 kg ha$^{-1}$) compare to no straw application. This was mainly due to higher CN ratio of wheat straw it serves as substrate for methanogenic bacteria to produce more methane.

Gaihre *et al.,* reported that, application of rice straw at 6 t ha$^{-1}$ recorded higher methane emission compare to no straw application and it peaks at 28 and 85 DAT then emission of methane was decreased. This might be due to higher CN ratio of rice straw and also development of intense reduced condition in the soil resulted in higher activity of methanogens and suppression of methanotrops.

Ma *et al.,* opined that, among the different straw treatments, burying of wheat straw at 3.75 t ha$^{-1}$ recorded higher methane emission (21.8, 82.8 and 28.1 g m$^{-2}$ in 2004, 2005 and 2006, respectively) compare to evenly incorporated and no straw in all the 3 years. And there was no significant difference in grain yield among the treatments in all the 3 years.

**Farming system**

Datta *et al.,* reported that, fish rearing increased $CH_4$ emission from field plots planted with rice cultivars namely, Varshadhan (96.33 kg ha$^{-1}$) and Durga (89.15 kg ha$^{-1}$) compare to rice cultivars alone (45.38 and 51.33 kg ha$^{-1}$, respectively). This was mainly due to drop in flood water oxygen level due to presence of fish and mechanical action of fish leading to release of soil entrapped methane. But the rice yield was more in case of rice+fish culture due to additional nutrients from decomposing dead fish and litter, nutrient recycling and release of fixed nutrients due to fish activity.

Tang *et al.,* reported that, among three different cropping systems, application of winter cover crop residues *i.e.* rapeseed and potato residues increased the methane emission (61.53 and 79.03 g m$^{-2}$, respectively in 2012 and 66.20 and 84.64 g m$^{-2}$, respectively in 2013) and GWP (15405 and 19786 kg $CO_2$ ha$^{-1}$, respectively in 2012) compare to winter fallow. This was attributed to supply of carbon source to methanogenic bacteria. Particularly in rice-rice-potato system emission was more due to high amount of potato residue. There was no significant difference in rice yield among cropping systems.

**Conclusion**

Cultivation of low methane emitting rice cultivars (IR 36, Shyamla, IET 7633 *etc*.,) coupled with SRI/aerobic method of rice cultivation can minimize the methane emission with more water saving and less/no yield reduction. Use of right fertilizer (ammonium sulphate in place of urea) and irrigating the rice fields at 0.10 bar soil matric potential could minimize methane emission from rice fields without any loss in rice grain yield. Incorporation of humified organic matter such as rice straw compost and vermicompost could minimize methane emission from rice fields with co-benefits of increased soil fertility and crop productivity.

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