INTRODUCTION

Rice is grown on 250 million Asian farms, mostly smaller than one hectare. It is the staple food for the largest number of people on Earth. It is the single largest food source for the poor, eaten by nearly half the world’s population, synonymous with food throughout Asia (Agricultural Statistics at a Glance, 2013). Likewise, farmers of a large part of the state of West Bengal are habituated in following the rice (wet season) - rice (summer) cropping sequence. This sequence also occupies the second highest area next to rice-wheat cropping sequence in our country. As rice is the staple crop of Asia and any deterioration of rice production system through climate change would seriously impair food security in this continent (Wassmann et al., 2009). Besides this, rice agriculture is not only affected by climate change, but also contributes to global warming through the release of greenhouse gases into the atmosphere (Matthews et al., 2003). Therefore, we need to be very cautious to balance food security and environmental safety by reducing greenhouse gases. So, some more investigation is yet to be done in future to standardize proper management practices which will upsurge rice production side by side reduce greenhouse gas emission.

Muramatsu and Inubushi (2009) described that methane emission from rice accounted for 56% of the total methane production. Methane oxidation in the soil, on the other hand, fell to 41% of the total production. Cheng (2008) disclosed that paddy fields emit more methane with high carbon dioxide levels. As methane gas has a heat absorption value for the greenhouse effect 23 times larger than carbon dioxide. It is feared that global warming may be accelerated due to the methane gas emission. The increased ratio of methane gas emission varies with factors including soil conditions, rice cultivar, fertilizer treatment and temperature. But within the agricultural sector the contributions from methane and nitrous oxide were relatively much greater than elsewhere as mentioned by Smith (2005). Since it is impossible to stop agricultural activities rather rice cultivation from anywhere of West Bengal, therefore it is necessary enough to the farmers to adjust this crop planning in such a way that no crop in the cropping sequence should be hampered by the ill effect of such type of climate change.

Furthermore, it is a well-known fact that the higher concentrations of greenhouse gases in the atmosphere, due to human activities, are intensifying the natural “greenhouse effect” thus increasing the Earth’s temperature. Khalil et al. (1990) advocated that agriculture was one of the responsible areas for emission of greenhouse gases which were source of global pollution. They also included that rice fields in China were major global source of methane, but forest termites in Australia were only a minor source. It was observed that the mean hourly values of CH₄ emissions flux were 17.5 mg in Beijing and 10.83 mg in Nanjing, China, as...
its emissions were affected by irrigation and the mode of fertilizing. Chen et al. (1993) stated that the irrigation might be effective in improving rice production and also in reducing \( \text{CH}_4 \) emissions. Numerous techniques can be used for minimizing the emission of methane and nitrous oxide from agricultural fields including different agronomic management practices like site specific nutrient management techniques, integrated approach in nutrient management practices using organic manures exclusively in well decomposed forms, use of nitrification inhibitors, varied tillage practices, modified water management techniques like intermittent drying and wetting (as in SRI), micro irrigation technologies, use of soil moisture sensor to predict irrigation requirement etc. So, it is necessary to think about those strategies which will reduce the emission of green-house gases from rice field and mitigate the ill impacts of changed climatic conditions. Experiment at local and regional level under rice cultivation for standardization of few strategies is very much crucial under present condition.

**MATERIALS AND METHODS**

The field experiment was carried out in strip plot design with two (2) main plot treatments (M1: system of rice intensification i.e. SRI and M2: conventional transplanted rice cultivation) and four (4) sub plot treatments (S1: 100% of Recommended dose of fertilizer (RDF) through inorganic sources, S2: 75% of RDF through inorganic sources + 25% N of RDF through organic sources, S3: 50% of RDF through inorganic sources + 50% N of RDF through organic sources, S4: 25% of RDF through inorganic sources + 75% N of RDF through organic sources) with three replication during the kharif season of 2009-10 and 2010-11 and boro season of 2010 and 2011 at the Research Farm of BCKV, Kalyani, Nadia, West Bengal. The experimental site was situated at 22°5' N latitude and 89° E longitude with an altitude of 9.75 meters above the mean sea level (MSL) and topographically the land was medium in situation having shallow tube well facility. The soil of the experimental field at 0-15 cm depth was sandy clay loam in texture with a bulk density of 1.38 g cc\(^{-1}\) and organic carbon content of 0.53 % with total N 0.049 %, phosphorous (21.9 kg ha\(^{-1}\)) and potassium (175.21 kg ha\(^{-1}\)) with a moderate soil fertility status. The test variety was satabdi (IET 4786). Recommended doses of fertilizer (120: 60: 60 and 60:30:30 kg ha\(^{-1}\): P\(_2\)O\(_5\):K\(_2\)O for boro and kharif rice respectively) were applied through urea, single super phosphate and muriate of potash. The experimental area was under the sub-tropical humid climate with an average annual rainfall of 1460 mm, generally precipitated during June to September and the mean temperature varied between 10 to 37°C. The mean maximum and minimum temperature varied 23.7 to 37.6 °C and 4.7 to 26.7 °C respectively during the investigation. Rainfall was disseminated mostly from July to September during the time of research and the maximum rainfall (407.7 mm) was recorded in the month July, 2011. Bright sunshine hours (monthly average) varied between 3.8 to 8.9 hrs during all the three years. Average relative humidity was in between 38.5 % to 96.4 % in the experimental years. The highest value of monthly mean maximum relative humidity was observed in the months of September, 2010 (96.4 %) and August, 2011 (96.4 %) (Fig.1-3).

Growth attributes were recorded from randomly selected quadrats of 1 m × 1 m size at 30, 60 and 90 days after crop planting. Yield components were assembled by taking sub-sample of 10 plants from the final harvested rice. Grain yield of rice was calculated by harvesting the 1m\(^2\) of each plot at final harvest except the border area.

Various green-house gases were collected from both boro and kharif rice field through gas chamber with the help of 50 ml disposable injection syringe with three (3) way leuer lock. At each sampling date GHG samples were collected at 0, 10, 20 and 30 minutes interval from each gas chamber. The GHGs were estimated through Gas chromatographer. All data were compiled at three main stages of rice like maximum tilling stage, panicle initiation stage and maturity stage. The fluxes of the gases were calculated with the following formula.

\[
\text{Flux of the gas} = \frac{\text{Concentration of different gases} \times \text{Temperature during collection}}{\text{Area of the chamber} \times \text{Time interval}}
\]

Impact of treatment variances in yield and emitted GHGs values were tested by analysis of variance and means were parted by least significant difference using SPSS 16 and Microsoft excel.

**RESULTS AND DISCUSSION**

This experimentation resulted that the maximum tilling stage was the highest emitter of \( \text{CH}_4 \), \( \text{CO}_2 \) and \( \text{N}_2\text{O} \) gases followed by panicle initiation and maturity stage of rice. This may be due to the fact that the metabolic activities of rice plants at the prime vegetative phase are more enough which emit more green-house gases (Fig 4-12). Besides, the plant having fewer leaves from maximum tilling stage to maturity, show descending rate of emission. Similar findings were supported by Shen et al. (2001). They stated that leaf area decreased with the increase in \( \text{CO}_2 \) at the maximum tilling stage but this was gradually reduced towards harvest. It was also found that the emission from boro rice was lower than that from kharif rice. Efficient use of fertilizers and water during boro season facilitating good growth of the crop resulting in lower emission of \( \text{CH}_4 \) and \( \text{CO}_2 \) may be the causes behind such facts. The \( \text{CH}_4 \), \( \text{CO}_2 \) and \( \text{N}_2\text{O} \) emission from rice field in both boro and kharif season irrespective of growth stages differed significantly with the different cultivation practices and nutritional management. Between two cultivation practices SRI emitted lower \( \text{CH}_4 \), \( \text{CO}_2 \) and \( \text{N}_2\text{O} \) (2.199, 1.221 and 0.57 mg m\(^{-2}\) hr\(^{-1}\) respectively) at maximum tilling stage, (1.985, 1.033 and 0.44 mg m\(^{-2}\) hr\(^{-1}\) respectively) panicle initiation stage and (1.845, 0.951 and 0.35 mg m\(^{-2}\) hr\(^{-1}\) respectively) maturity stage. This might be due to the fact that the intermittent irrigation under SRI condition restricts this green-house gas emission from rice field. Concisely to say, the best result with respect to lower emission of \( \text{CH}_4 \)(1.545, 1.248, 1.063 mg m\(^{-2}\) hr\(^{-1}\) at maximum tilling, panicle initiation and maturity stage respectively) and \( \text{CO}_2 \)(0.430, 0.211, 0.179 mg m\(^{-2}\) hr\(^{-1}\) at maximum tilling, panicle initiation and maturity stage respectively) was obtained in the all the rice crops receiving
APPROACHES TO REDUCE GREEN-HOUSE GASES FROM RICE-RICE CROPPING SEQUENCE

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N uptake Boro</th>
<th>P uptake Boro</th>
<th>K uptake Boro</th>
<th>N uptake Kharif</th>
<th>P uptake Kharif</th>
<th>K uptake Kharif</th>
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<tr>
<td>M₁</td>
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<td>121.32</td>
<td>85.13</td>
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<tr>
<td>SEm ± 1.70</td>
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Table 1: Nitrogen, phosphorus and potassium uptake (kg ha⁻¹) of rice-rice crop sequence (pooled of 2 years)

100% RDF through inorganic fertilizer (S₁). 75% N replacement through organic manures (S₂) showed the highest value of CH₄ (3.106, 3.023, 2.409 mg m⁻² hr⁻¹ at maximum tillering, panicle initiation and maturity stage respectively) and CO₂ emission (2.599, 2.412, 2.231 mg m⁻² hr⁻¹ at maximum tillering, panicle initiation and maturity respectively) during the entire crop growth period. Similar trend was observed during kharif season with higher rate of green-house gas emission. So, it can safely be stated that, the emission increases with the increase in level of substitution of N through organic manures. This might be due to the fact that organic manure enhances the CH₄ and CO₂ emission from rice field. Gon et al. (1992) advocated that incorporation of organic matter in the soil (green manure straw, animal wastes) increase methane emissions. Water regime is also an important factor which affects green-house gas emissions. The N₂O emission from rice field in both boro and kharif seasons irrespective of growth stages differed significantly with the two different cultivation practices and four nutritional management treatments. Between the cultivation practices SRI emitted lower N₂O (0.57, 0.44 and 0.35 mg m⁻² hr⁻¹) at three prime growth stages of rice. Succinctly, the best result with respect to lower emission of N₂O (0.27, 0.19 and 0.15 mg m⁻² hr⁻¹ at maximum tillering, panicle...
initiation and maturity stage respectively) was obtained in the both the seasons of rice crop receiving 75% N replacement through organic manures (S4). In both wet and summer season rice with 100% inorganic fertilization showed the highest value of N2O emission during the entire crop growth period. The fact may be that, the N2O emission increased with the increased application of inorganic fertilizers. Thus, the emission of N2O was just the reverse to that of CH4 and CO2. The application of inorganic fertilizers is the reason behind N2O emission and that of organic manures is the reason behind CH4 and CO2 emission. This finding may be supported by Muramatsu et al. (2009), Liu et al. (2009) and Zhang Guang Bin et al. (2009).

Modified water management techniques like intermittent drying and wetting (as in SRI) along with the application of 25% organic fertilization contributed lower emission of all three gases CH4, CO2 and N2O.

It can also be summarized that the growth attributes along with the yield attributes like number of effective tillers m-2, grains per panicle vis-à-vis the grain yield of both season rice crops deviated significantly with the diverse cultivation practices and the application of nutritional management practices (Fig 13 and 14). The practice of SRI showed evidence of excellent results throughout the whole period of supervision. Basically, the SRI produces a favorable environment to the crop for its better growth by mining more nutrients and water from the deeper layer of soil with its voluminous root mass under artificially created water stressed condition. In most of the circumstances, the treatment ascendancy was observed under the main plot treatment M1 (SRI) and sub plot treatment S2 (75% RDF through inorganic and 25% N through organic).
recording the boro grain yields of 5.35 and 5.70 t ha\(^{-1}\) in the respective treatments. The combined use of organic and inorganic sources of nutrients manifested excellent results throughout the entire period of surveillance. This may be due to the fact that a little bit substitution of chemical fertilizers through organic manures especially with the vermicompost has been proved to be a better choice. Because such type of combined use usually keeps the physical condition of soil better besides providing nutrients to the plant bit by bit but in a steady manner along with the added advantage of rapid, bounty and easy nutrient supplying capacity of chemical fertilizer to the crops and ultimately results in yield escalation of both season rice crops. The same trend was followed in kharif season rice. The corresponding values of grain yield of kharif rice were 3.78 and 3.90 t ha\(^{-1}\) under main and sub plot treatments respectively. Moreover, the boro season produced more yield attributes and yield than that of kharif season. This may be due to the prevalence of clear sunny weather resulting in greater utilization of solar energy by the crop for higher photo synthetic activities, more favorable distribution of temperature for greater rate of photo synthesis under optimum respiration, controlled water management, more efficient use of fertilizers and water, comparatively less incidence of pests and diseases due to more bright sun shine hours and lower humidity and less natural hazards during boro season. Thus increase mineral and water uptake vis-à-vis overall growth of rice and ultimately higher crop yield. These results are in confirmation with the opinions of Bhadoria and Prakash (2003), Chowdhury et al. (2014), Borkar et al. (2008), Sujathamma and Reddy (2004) and Singh et al. (2007).

SRI plots produced highest uptake of nitrogen by rice crop than that of conventional one in both the seasons (Table 1). This may be due to the fact that SRI having intermittent irrigation facilitating better management practices and helping the rice plant to uptake more nutrients than that the conventional cultivation practices did. (Hussain et al, 2003). The maximum nitrogen uptake (167.25, 102.81 kg ha\(^{-1}\) respectively in boro and kharif season) was recorded under the treatment S\(_2\) and this treatment was statistically similar with the treatments S\(_3\). This may be due to the fact that the vermicompost is a nutrient-
rich, microbiologically-active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of organic matter. It releases plant nutrients little by little but more steadily to the crop resulting in its superior performance vis-à-vis nitrogen uptake by the rice, whereas, the treatment $S_2$ was found to be the poorest (114.53, 77.00 kg ha$^{-1}$ respectively for boro and kharif season) in nitrogen uptake capacity. The treatment ascendancy with consideration to phosphorus and potassium uptake by rice was observed in the SRI plots. The treatment dominance with respect to phosphorus (40.92, 27.33 kg ha$^{-1}$) and potassium (151.74, 121.89 kg ha$^{-1}$) uptake by rice in boro and kharif season was identified under the treatment $S_3$ and it was followed by the treatments $S_1$. Thus, it can be said that a fractional substitution of chemical fertilizers by organic manures especially vermicompost documented the upmost uptake of total nutrients (NPK) by rice crop. This may be due to the fact that the presence of vermicompost in the treatment increased nitrogen and phosphorous availability by encouraging biological nitrogen fixation and phosphorous solubilization, stimulating root proliferation and increasing vegetative growth of the crops. Better root proliferation promotes better uptake of phosphorous and other nutrients by the crops. This result proves the findings of Selvam and Bheemaiah (2005), Aruna and Mohammad (2005), Borkar et al. (2008) and Hossain et al. (2010).

Net production value scored the premier in both the seasons of rice receiving combined use of organic and inorganic sources nutrients and grown under SRI method (Fig. 15). It was always better over the sole inorganic or combined use of organic and inorganic sources with conventional rice. Application of 75% RDF + 25% N through organic (vermicompost) under SRI practices ($M_S$) recorded the upmost value of NPV (1.583 and 0.946) by the boro and kharif season rice respectively in both the years. This is because of the low cost locally available organic waste like house-hold prepared vermicompost makes the rice cultivation highly profitable with high net production value. This view is in agreement with the findings of Selvam and Bheemaiah (2005).

REFERENCES


