# TECHNICAL BULLETIN

No. 64, 2023

## Mitigation of Greenhouse Gas Emissions From Rice-based Cropping Systems

The present concentrations of greenhouse gases (GHG) like $CO_2$, $CH_4$ and $N_2O$ in the atmosphere are 403 ppm, 1834 ppb and 327 ppb, respectively, which have increased by 100 ppm, 955 ppb and 48 ppb in the last 100 years. Scientists fear that if GHG concentrations in the air continue to increase at these rates, the global temperature will have risen by three degrees by the year 2100 very adversely impacting the climate. In Bangladesh, 85% of agricultural land is cropped to wetland rice which emits carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$), the two major greenhouse gases (GHG) known to contribute to global warming. It is estimated that rice farming alone contributes 7.2% of the total GHG emissions in Bangladesh. This estimate was made using default emission factors due to a lack of measured data. Fertilizer deep placement (FDP) is recognized as one of the best fertilizer management practices that saves N by 30% and increases rice yield by 15-20%. The alternate wet and dry (AWD) technology for irrigation is being promoted because it saves water by up to 38% and reduces costs. Fortunately, FDP and AWD have also the potential to curb GHG emissions. Research on GHG mitigation options, while increasing rice productivity, is crucial in the context of climate change (CC). This KGF sponsored project assessed GHG emissions from rice-rice and rice non-rice cropping systems and studied the effectiveness of FDP and AWD technologies in reducing GHG emission from crop fields.

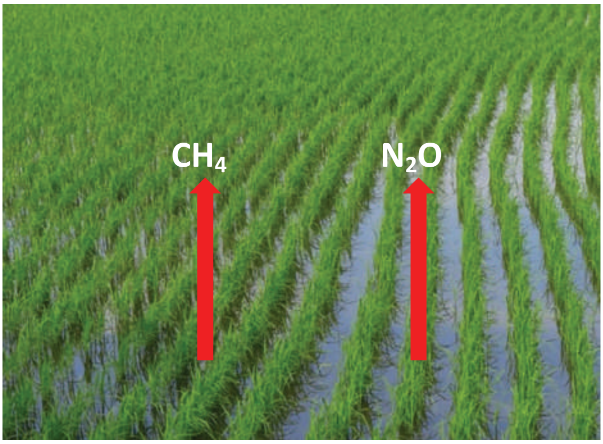


**Fig. 1. GHG emission from a wetland rice field**

### Methodology

Experiments were conducted at BAU and BRRI to study the effects of N source and application methods on rice yield, nitrogen use efficiency (NUE) and to quantify ammonia ($NH_3$) volatilization, ammonium-N ($NH_4$+-N) in floodwater, and emission of $CH_4$ gas under continuous standing water (CSW) and AWD irrigation regimes. Field experiments were conducted on rice under AWD and CSW conditions. Eight fertilization treatments with different N sources including integrated plant nutrient system (IPNS) based organic amendments were tested. Ordinary prilled urea (PU) and urea briquettes (UB) were the N fertilizers. PU was broadcast while UB was placed 7-10 cm below the soil surface (urea deep placement-UDP). Organic fertilizers, i.e., poultry litter (PL), vermicompost (VC) calculated on the basis of integrated plant nutrient system (IPNS) were used as the other treatments. Floodwater samples were collected and $NH_4$+-N content in them and ammonia ($NH_3$) volatilization from the rice field was measured. Measurements of the GHG emission from the rice field were made using standard methods.

## Results and Outputs

Broadcast PU and manure in rice fields produced higher $NH_4$-N in floodwater compared with that in UDP plots, which consequently caused a higher N loss because ammonium present in floodwater is prone to losses through $NH_3$ volatilization and surface runoff (Fig. 2). Ammonia volatilization varied among the N treatments (broadcast PU, UDP and PU+CD) under two cropping patterns (Boro-T. Aus-T. Aman and mustard-Boro-T. Aman). The magnitude of $NH_3$ volatilization from the PU treatments (16.3% of applied N) increased with increasing N rate and volatilization from the UDP treatment was negligible (0.45 % of applied N) irrespective of the N rate.

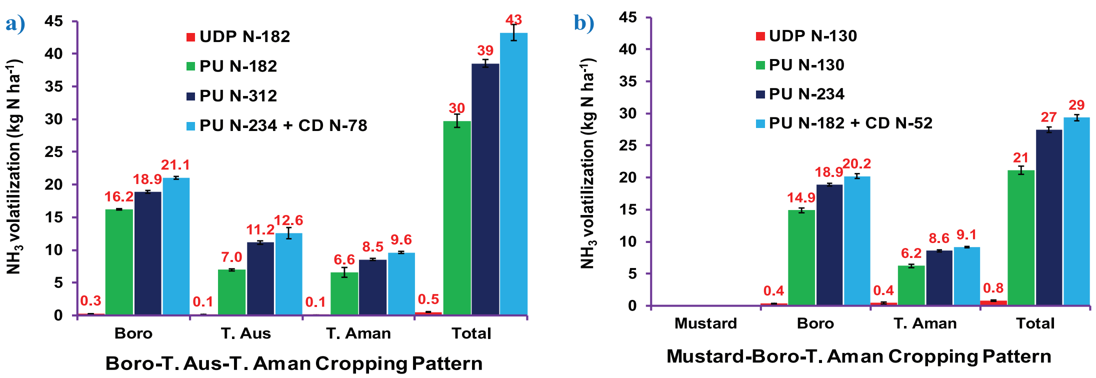


**Fig. 2. Ammonia volatilization from crop fields in two cropping patterns: a) Boro-T. Aus-T. Aman, b) mustard-Boro-T. Aman under different N treatments**

Distinct emission peaks were observed after the first, second and third topdressing of PU under AWD condition. Peaks of $N_2O$ flux were observed for broadcast PU treatments after 2–7 days of topdressing. Some $N_2O$ emission was also observed from the UB treatment. The $N_2O$ fluxes among the treatments showed similar patterns during the fallow period for all the treatments indicating that there might be a little residual N left in the fallow period. UDP significantly reduced $N_2O$ emission compared total total $N_2O$ emission with broadcast PU. The total N loss as $N_2O$ emission was about three times higher (833 g/ha/yr) in the broadcast PU treatment than UB treatment (254 g/ha/ya). The emission from the UDP plot was negligible and similar as that from the control plot. These results suggest lower GHG emissions (carbon dioxide equivalent, $CO_2$ eq.) with UDP than with PU. The $N_2O$ emission factors calculated for UB were 0.12, 0.14 and 0.17 in Boro, T. Aus and T. Aman rice, respectively and for PU these were 0.40, 0.46 and 0.55, respectively.

The total $CH_4$ emissions in the Boro-T. Aus-T. Aman cropping pattern were estimated as 292, 385, 551 and 652 kg/ha/yr from control, UDP, PU and PU+CD plots, respectively, and in the mustard-Boro-T. Aman cropping pattern these figures were 194, 266, 372 and 442 kg/ha/yr, respectively (Fig. 3).

AWD irrigation regime for rice reduced $CH_4$ emission by around 10 % compared to the conventional continuous standing water (CSW) regime. UDP reduced GHG emissions

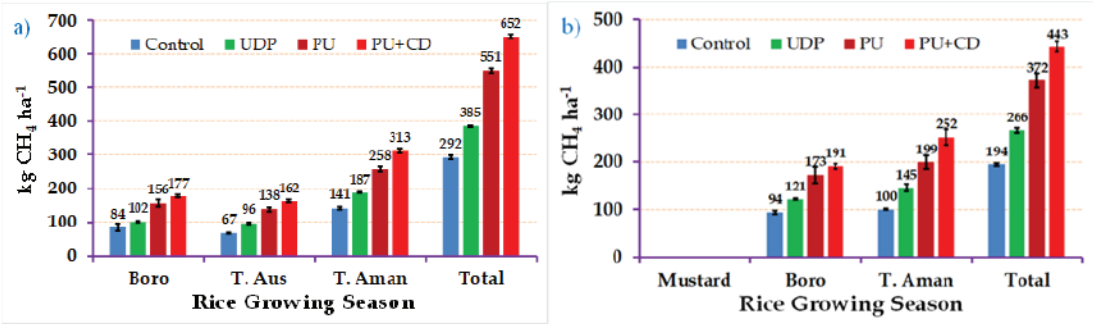


**Fig. 3. $CH_4$ emissions from control, UDP, broadcast PU and broadcast PU+CD plots under two cropping patterns: a) Boro-T .Aus –T. Aman pattern and b) mustard-Boro-T.Aman**

compared to broadcast prilled urea (BPU). The emission factors for UDP in Boro, T. Aus and T. Aman rice was calculated to be 0.12, 0.14 and 0.17 and that for BPU to be 0.40, 0.46, and 0.55, respectively. Urea briquette (UB) deep placement reduced the use of prilled urea (PU) by 25%. UDP significantly reduced the amount of N in floodwater compared to BPU. Ammonia volatilization was negligible with UDP while volatilization from BPU treatments increased with increasing N fertilizer rate. Fertilizer response was similar between CSW and AWD water regimes. However, UDP either as PU or as UB increased rice yield by 3.99 - 31.20% over that obtained with PU. The reduction in GHG emissions ($N_2O$, $CH_4$) due to UDP and AWD practices would provide a good data set for carbon credits on the global carbon market. Therefore, UDP adoption should be promoted to achieve multiple benefits: Save N fertilizer, increase NUE and grain yields, and reduce losses of reactive N species to the environment. On an average, AWD irrigation reduced GWP by about 8% in T. Aus, 11% in T. Aman and 26% in Boro season compared with CSW under same the same fertilizer management regime.

**Table 1. Average seasonal total GHG emissions in Boro and carbon credit estimation from different fertilizer treatments under different N fertilization and water management regimes in Bangladesh**

| Fert. treat. | CSW | | | AWD | | | Carbon credit and claim due to AWD adoption | | |
|---|---|---|---|---|---|---|---|---|---|
| | $CH_4$ (kg/ha) | $N_2O$ (g/ha) | Total GHG (GWP) $CO_2$eq (kg/ha) | $CH_4$ (kg/ha) | $N_2O$ (g/ha) | Total GHG (GWP) $CO_2$eq (kg/ha) | Carbon credit (t $CO_2$ eq reduction/ha) | Carbon credit (Tk/ha) | Total claimable amount (million Tk) |
| Control (N-0) | 84 | 9 | 2103 | 77 | 46 | 1949 | | | |
| UDP (N-78) | 102 | 40 | 2559 | 98 | 92 | 2498 | 0.28 | 854 | 3,821 |
| PU (N-78) | 156 | 143 | 3953 | 164 | 311 | 4235 | | | |

In calculations of soil carbon dioxide equivalent ($CO_2$ eq) emission and carbon credit, it was estimated that, in the Boro season, the total $CO_2$ eq emission of $CH_4$ and $N_2O$ gases under CSW at the BAU farm rice field were 2103, 2559 and 3953 kg/ha for $T_1$ (control), $T_2$ (UDP) and $T_3$ (BPU) treatments, respectively, while under AWD, the figures were 1949, 2498 and 4235 kg/ha, respectively. The use of AWD water management reduced seasonal $CO_2$ eq emission by 0.28 t/ha and carbon credit by Tk 854/ha compared to CSW (Table 1). The estimates for T. Aus were 1679, 2439 and 3546 kg/ha and for T. Aman 3540, 4697 and 6516 kg/ha, respectively. The US government has endorsed a ‘central’ estimate cost of $36 per ton of reduction of $CO_2$ eq from rice fields. Using this toll on carbon, the social cost of carbon

(SCC) can be estimated by multiplying the reduction of $CO_2$ eq from 1 ha of land by area of the cultivated rice in a country (44,75,827 ha in Bangladesh) and may be claimed from the global carbon market. The estimated claims to the global carbon market due to adoption of AWD irrigation in Boro compared to CSW irrigation was Tk 3,821 million (Table 1). Similarly, adoption of UDP produced carbon credit of Tk 3,152 million in T. Aus and Tk 30,721 million in T. Aman compared to BPU.

## Expected Impact

- Up to 25% N can be saved using UDP technology without any yield penalty, and that will also help save money
- The GHG emission data can be used as a guide in preparing a national inventory for GHG emissions, particularly from rice-based farming systems and could be used for mitigation strategies and related policies
- The policy makers would be able to claim carbon credit because of mitigating GHG emission through improved water and fertilizer management
- This project provides a complete picture of GHG emission from rice fields and available mitigation options so that policy makers can take decisions for the dissemination of UDP, AWD and other technologies to make rice farming environmentally sustainable and resilient to climate change
- Capacity building of scientists for conducting GHG research in the future.

## Recommendations

- This study should be continued in different AEZ of Bangladesh to develop a nation-wide GHG inventory
- Slow-release N fertilizers like neem coated urea need to be developed and used for increasing N use efficiency and mitigation of GHG emissions from rice fields
- Methane emission under varied soil conditions both in the Boro and T. Aman seasons need to be quantified
- Research on the use of household biomass ash and biochar to mitigate methane emission from rice fields needs to be expedited
- Further research is needed throughout the country under diverse soil and environmental conditions for the calculation of default factors and claiming carbon credits from the global carbon market.

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This Technical Bulletin has been prepared on the basis of technical information available from a completed BKGET-KGF Funded Project, the details of which are given below:

**Project Code and Title:** CEP-III. Mitigating Greenhouse Gas Emissions from Rice-based Cropping Systems through Efficient Fertilizer and Water Management

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