Article title	Impacts of urea deep placement with intermittent irrigation on nitrous oxide and nitric oxide emissions and nitrogen use efficiency from lowland rice cultivation
Keywords	Deep placement, Nitric oxide
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Abstract	Urea deep placement (UDP) and alternate wetting and drying (AWD) irrigation method are two promising rice production technologies. However, studies on the impacts of UDP under AWD irrigation on nitrous oxide (N2O) nitric oxide (NO) emissions are still limited. We investigated the effects of UDP on N2O and NO emissions, nitrogen use efficiency (NUE) and rice yields compared with conventional broadcast application of prilled urea (PU) under AWD irrigation. Emissions were measured from three fertilizer treatments — no N, UDP and PU using an automated gas sampling and analysis system continuously for two consecutive Boro (dry) rice seasons in Bangladesh. For UDP, urea briquettes were placed in 7-10 cm below soil surface between four hills of rice at each alternate row after ten days of transplanting, while PU was applied as broadcast in three equal splits. Treatments were arranged in a randomized complete block design with three replications and emissions were measured at every three-hour interval. N2O emissions were irregular and event specific. Fertilizer induced emission peaks were observed after broadcast application of prilled urea (PU), but they were not observed in UDP. However, emissions peaks during dry period were more prominent in UDP compared to PU. Nevertheless, seasonal cumulative N2O emissions were similar between UDP and PU treatments. Across the season, UDP and PU showed yield-scaled N2O emission 96.3 and 88.7 g t–1 grain and emission factors were 0.49 and 0.23%, respectively. In contrast to N2O emission, NO fluxes were small and not affected by either fertilizer or water management. Across the season, UDP significantly increased rice yield, agronomic use efficiency and recovery efficiency of N by 29%, 109% and 167%, respectively compared to broadcast PU. Since UDP significantly increased grain yield and NUE compared to broadcast PU, and maintained similar emissions of N2O with PU, UDP could be equally effective under AWD irrigation as with continuous flooding condition. Therefore, UDP might be considered an eco-friendly technology for improving rice yields and reducing GHG emissions, particularly N2O emissions in both water regimes.
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