Producing More Rice with Less Greenhouse Gas Emissions from Paddy Fields

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Nitrous oxide (N_2O) is a potent greenhouse gas that significantly contributes to global warming (Smith et al., 2007). Also, it enhances atmospheric PM2.5 accumulation, and aggravates stratospheric O_3 depletion (Ravishankara et al., 2009, Huang et al., 2014). Agro-ecosystems contribute the most important part to total anthropogenic N_2O emissions (ca. 60%) as well as to the global food security (IPCC, 2013). Increasing photosynthate allocation to grain has been widely regarded as an effective strategy of genetic and agronomic innovation for a further increase in crop yield (Yang and Zhang, 2010; de Ribou et al., 2013). However, to our knowledge, no experiments have so far assessed its effects on cropland N_2O emissions.

We conducted three independent and complementary experiments to assess the effects of photosynthate allocation on N_2O emission. In experiment 1, a rice variety field experiment was performed to determine the relationships between field N_2O emissions and the ratio of grain yield to total aboveground biomass, known as the harvest index (HI) in agronomy. In experiment 2, a wild type rice and its mutant with similar biomass but significant differences in grain yield were tested to examine the effect of photosynthate allocation on N_2O emissions. In experiment 3, we altered rice plant photosynthate allocation by removing the plant spikelets to explore the underlying mechanisms.

The rice variety experiment showed that N_2O fluxes were significantly and negatively correlated with HI. N_2O fluxes were significantly lower under the wild type variety with a high HI than the low-HI mutant. Spikelet removal drastically decreased grain yield and HI, but significantly increased N_2O emission. Biomass accumulation and N uptake after anthesis were significantly and positively correlated with HI. Biomass accumulation and N uptake of the WT were significantly greater than those of the Mutant. Spikelet removal decreased plant biomass and N uptake. Reducing photosynthate allocation to grain by spikelet removal significantly increased new root growth, soil dissolved organic C, and soil denitrification potential. Our findings demonstrate that N_2O emissions from cropland can be reduced by optimizing photosynthate allocation, indicating an opportunity for genetic and agronomic efforts to increase crop yield with less N_2O emissions.

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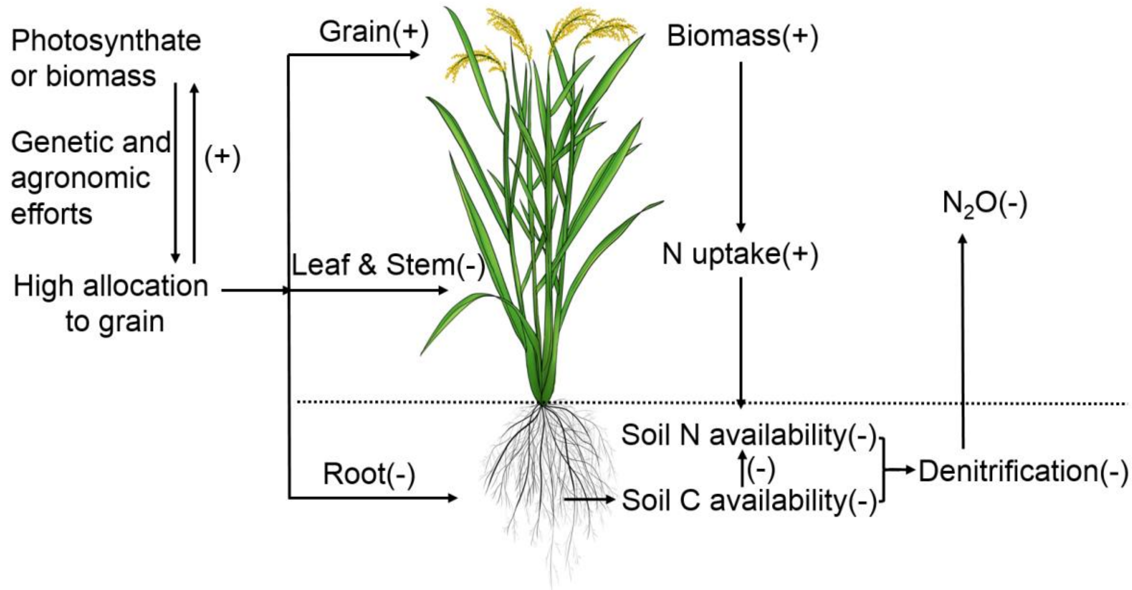

Figure 1. A conceptual framework of the effects of high photosynthate allocation to grain on N_2O emissions from a paddy field.

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