Effects of elevated CO_2 levels and N fertilization on biomass and C and N contents of rice: Insights from Tsukuba FACE

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Rice is a staple crop in monsoon Asia, and its world production is the second largest next to that of maize. Rice paddies under submergence are an anthropogenic source of methane as a potent greenhouse gas. According to the fifth IPCC assessment report, rice paddies account for approximately 11% of the anthropogenic methane emissions. It is of great concerns how the increasing atmospheric CO_2 levels (eCO_2) affect rice production and rice paddy methane emissions in the near future. In many cases, nitrogen (N) fertilizers are applied to rice paddies, and the N cycle in rice paddy ecosystems is closely interacted with the carbon (C) cycle. To enhance the predictability of rice production and C and N cycles in rice paddy ecosystems in the future, effects of eCO_2 and different N availability on C and N cycles in rice paddy ecosystems and these mechanisms should be unraveled.
A free-air CO_2 enrichment (FACE) experiment in an open field enables to elucidate responses of actual ecosystems to eCO_2. The National Institute for Agro-Environmental Sciences, Japan, had operated a FACE facility (Tsukuba FACE) in Tsukubamirai City, Ibaraki Prefecture since 2010. Single cropping of paddy rice is conducted with the following agricultural practices; submersion in late April; fertilization and puddling in middle May; transplanting of rice seedlings in late May; continuous submergence until the drainage in middle to late August; harvesting in middle to late September; a fallow season with bare soil and rice residues until the next spring; and several tillage events with a mixing depth of approximately 15 cm during the fallow season. Four rectangular bays are used for experiments. A FACE plot is set in each bay, accompanied by an ambient plot. Each FACE plot is equipped with an octagonal ring with a diameter of 17 m for pure CO_2 release. The FACE equipment automatically regulates CO_2 release to achieve the average target CO_2 levels, 200 ppm above the ambient level. Treatments other than CO_2 are N fertilization (0N, no application; SN, 8 g N m^{-2}; HN, 12 g N m^{-2}), temperature (ambient, +2°C for floodwater), and rice cultivars.
Five-year data (2010–2014) of Koshihikari, a staple cultivar in this region, showed that the aboveground biomass of rice was increased by eCO_2 for all the N treatments (0N, +8%; SN, +10%, HN, +11%). The brown rice yield at SN and HN were also increased by eCO_2 (SN, +12%; HN, +11%), whereas that at 0N did not respond to eCO_2. Thus, the harvest index (the ratio of yield to aboveground biomass) of SN and HN were unchanged by eCO_2, but that of 0N was decreased by 5% under eCO_2. This result implies that the CO_2 fertilization effect does not reach to grains under low N availability. The seasonal methane emissions were increased by 5% (SN) under eCO_2. In the presentation, study results on the carbon and nitrogen contents and the allocation of biomass between shoot and root under eCO_2 and different N availability will be shown. It is expected that such the knowledge gives good insights to research on responses of C and N cycles in terrestrial ecosystems to eCO_2.
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