No effect of elevated CO_2 on fertilizer-derived nitrogen use efficiency of paddy rice: possible degradation of soil fertility on a long-term basis

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Atmospheric concentrations of carbon dioxide (CO_2) have been steadily increasing. Elevated CO_2 levels (E-[CO_2]) have an effect of increasing plant photosynthesis known as the CO_2 fertilization effect that potentially increases crop production. On the other hand, the CO_2 fertilization effect also increases the demand of other nutrients, typically nitrogen (N). It is expected that N availability affects crop responses to E-[CO_2] and then N use efficiency of the crop. The purpose of this study was to elucidate the E-[CO_2] responses of two varieties of single-cropping paddy rice in the Kanto Region, Japan, with respect to use efficiencies of fertilizer-derived N by rice plants.

This study was conducted in 2015 at the free-air CO_2 enrichment facility for paddy rice cropping in Tsukubamirai City, Ibaraki Prefecture, Japan (Tsukuba FACE). The Tsukuba FACE was consisted of four rectangular bays of fields. A CO_2-enrichment plot was set in each bay, accompanying a plot without a CO_2 treatment. The target E-[CO_2] at the center of the FACE plots was 200 ppm above the ambient concentrations. Two rice cultivars were used in this study, i.e., Koshihikari (a standard japonica cultivar) and Takanari (a high-yielding indica cultivar). Polymer-coated ^{15}N-labeled urea (3.2 % ^{15}N) that releases almost the N over the course of 70 days (LP-70) was used as a controlled-release fertilizer with an application rate of 80 kg N ha^{-1} at the basal fertilization. No supplemental fertilization was conducted. Rice plants were sampled at the panicle initiation, heading, and maturing stages to determine the biomass, total N concentration, and ^{15}N abundance of each part (roots, straw, leaves, dead leaves, and panicles) of the rice plants. The total N content and fertilizer-derived N content of each part of the rice plants were then calculated. The paddy soils from 0 to 15 cm at 5-cm intervals were sampled at the maturing stage to quantify the total N and fertilizer-derived N content in each layer. The recovery efficiency (RE, ratio of the fertilizer-derived N absorbed by the rice plants) and the agronomic efficiency (AE, ratio of the fertilizer-derived N accumulated in the panicles of rice plants) were calculated to evaluate the use efficiency of applied fertilizer by rice plants. It is noted that AE is usually expressed as the ratio of the fertilizer-derived N accumulated in brown rice that was substituted by the accumulation in panicles in this study. Please see Hayashi et al. (2021) for details of the methods.

While E-[CO_2] significantly increased the whole plant biomass and the total N content in panicles, it did not increase the total N and the fertilizer-derived N content in the whole plant. The RE ranged between 65 % and 69 %, and the AE ranged between 38 % and 44 %. The effect of CO_2 on RE and AE was not significant. The REs, 69 % at the maximum in this study, implies an upper limit of use efficiency of N fertilizer, even for polymer-coated (controlled-release) fertilizer. The REs, higher in Koshihikari, and the AEs, higher in Takanari indicated that Takanari preferentially allocated fertilizer-derived N to panicles. E-[CO_2] significantly increased the rice N uptake from sources other than fertilizer, of which mineralization was the most-likely source. Monitoring of soil fertility and appropriate fertilization management are, therefore, necessary for sustainable rice production avoiding long-term decline in soil N fertility.

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