Improving rice models for more reliable prediction of responses of rice yield to CO_2 and temperature elevation

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Introduction

Increased CO_2 concentration and air temperature are two very important variables associated with global warming and climate change. Assessing the putative impacts of these factors on rice production is crucial for global food security due to rice being the staple food for more than half of the world population. Rice crop models are useful for predicting rice productivity under climate change. However, model predictions have uncertainties arisen due to the inaccurate inputs and the varying capabilities of models to capture yield performance. A series of modeling activities were implemented by the AgMIP Rice Team (consisting of 16 rice models currently) to improve the model capability for reducing the uncertainties of model prediction.

Materials and Methods

The simulation exercise and model improvement were implemented in phase-wise. In the first modelling activities, the model sensitivities were evaluated to given CO_2 concentrations varying from 360 to 720 μmol mol^{-1} at an interval of 90 μmol mol^{-1} and air temperature increments of 0, 3, 6 and 9 ^{o}C (Li et al., 2015). In the second phase, in order to improve model response to CO_2 elevation, rice models were tested against

Free-Air CO_2 Enrichment (FACE) measurements and individual model groups conducted essential modifications on the quantification of model response. The models were firstly calibrated with the data under ambient CO_2 concentration and were then tested against the evaluated CO_2 FACE data. Further simulation exercises and model modifications were undertaken to improve response to CO_2 and temperature elevation using data from chamber experiments.

Results and Discussion

The quantified enhancement of rice grain yield varied from 2 % to 38 % when the CO_2 increased from 360 to 540 μmol mol^{-1}, and 4 to 68 % if it was doubled from 360 to 720 μmol mol^{-1}. Model predictions of grain yield changes significantly varied from +68 % to -75 % with 3 ^oC temperature increase, and from +30 % to -98 % with 6 ^oC increase, although the averages of all model predictions showed a 20 % and 40 % decreases with 3 and 6 ^oC increase which is close to literature reports. The large variations among models are due to fundamental differences in model algorithms that describe CO_2 fertilization and temperature effects on plant development, biomass accumulation and yield formation (Confalonieri et al., 2016, under review).

Models differed in simulated yield enhancement ranging from 1 % to 19 % with ~200 μmol mol^{-1} CO_2 elevation after models were calibrated to ambient CO_2 condition in FACE experiments. Calibration reduced model-to-model variation, and the average grain yield enhancement over all model estimations agreed with field measurements from FACE experiments conducted at two field sites.

The results of simulation exercises with chamber experiments show the models captured the CO_2 fertilization and temperature effects on above-ground biomass with low variation among models, but less agreement among models on predicted CO_2 effects on grain yield. Many models overestimated the grain yield gains per unit CO_2 elevation on higher CO_2 conditions. Most models also underestimated the grain yield decline due to increased air temperature, which indicates a need to improve model functions related to grain-set and grain growth at elevated temperatures.

References

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