Estimation Model of Rice Panicle Temperature with Respect to an Increase in Atmospheric CO\textsubscript{2} Concentration and Canopy Microclimate Factor

Abstract

By analyzing the microclimate observational result in a free air CO\textsubscript{2} enrichment (FACE) experiment, we developed an estimation model of rice panicle temperature based on heat balance. This model is helpful to predict high temperature-induced spikelet sterility during the flowering stage and rice-grain ripening which are particular concerns brought on by global warming and elevated carbon dioxide (CO\textsubscript{2}) concentration in the atmosphere.

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Background and Purpose

Elevated CO\textsubscript{2} concentration in the atmosphere could promote rice growth and yield. But on the other hand, the high CO\textsubscript{2} concentration leads to stomatal aperture decrease, reduction of transpiration, and canopy temperature rise. As a result, sterility in the flowering stage, which has become a problem for warming temperatures or hot regions could be exacerbated. In order to predict the occurrence of sterility under high temperature and elevated CO\textsubscript{2}, it is necessary to correctly predict the rice panicle temperature. Because the rice panicle temperature greatly depends on the microclimatic condition of paddy fields, it is impossible to simply use air temperature to estimate the panicle temperature. Through observations of microclimate in free-air CO\textsubscript{2} enrichment (FACE) experimental paddy fields, we developed an estimation model of rice panicle temperature with respect to the process that affects panicle temperature by microclimate around panicle (Figure 1) and clarified the increase of panicle temperature upon elevated CO\textsubscript{2} in the atmosphere.

Achievements and Features

1. Microclimate at heading and flowering stages was observed at two kinds of FACE paddy field plots (cultivar Wuxiangjing 14) in, Wuxi, Jiangsu province, China: current CO\textsubscript{2} concentration plot and elevated CO\textsubscript{2} concentration plot (current CO\textsubscript{2} concentration + 200ppm). With high CO\textsubscript{2} concentration, stomatal aperture decrease reduces leaf transpiration and the cooling effect, which deprives leaves heat (latent
The leaf temperature is 1~2°C higher in elevated CO₂ plot than in current CO₂ plot (Figure 2). In addition, the temperature of the canopy is 0.5~1°C higher in the elevated CO₂ plot, but the relative humidity is 5~8% lower.

2. Because there is no stomatal aperture in the panicle surface, and transpiration occurs though the epidermis, there is no direct effect on panicle transpiration in the elevated CO₂ concentration plot. In both CO₂ concentration plots, the panicle transpiration rate is high just after flowering, but with a tendency for reduction after several days.

3. With measured data on microclimate change in the FACE experimental paddy field and panicle transpiration rate, the heat balance model to estimate panicle temperature has been developed. It is understood that a 0.5 to 1°C rise of panicle temperature (Figure 3a) and microclimate change by elevated CO₂ concentration could promote high temperature-induced spikelet sterility. In addition, while the panicle temperature rises, the humidity in rice canopy is reduced (Figure 2) and the panicle transpiration (dehydration) is enhanced (Figure 3b) at same time.

4. Because the panicle temperature increase by elevated CO₂ concentration exists not only in the flowering stage but also in the ripening stage, the elevated CO₂ concentration increases high temperature-induced spikelet sterility in flowering stage and immature kernels. Finally, it may reduce rice quantity.

**Application and Notes**

1. This result can be used to predict high temperature-induced spikelet sterility in rice and elucidate phenomenon of high temperature rice grain ripening which is happening frequently during recent years caused by global warming and elevated CO₂ concentration. It also can be used to explore high temperature tolerance cultivars.

2. To estimate panicle temperature, data on meteorological elements including the amounts of global solar radiation and downward long-wave radiation, air temperature, humidity, and wind velocity and transpiration characteristics of each cultivar are needed.
Figure 1. The process of panicle temperature variation due to microclimate change in paddy canopy by elevated CO$_2$ concentration in the atmosphere

Figure 2. Microclimate change in paddy canopy by elevated CO$_2$ concentration (FACE) (Note the difference of the two types of plot: [elevated CO$_2$] – [current CO$_2$])
Figure 3. Variation of panicle temperature (a) and panicle transpiration (b) by elevated CO$_2$ calculated based on the estimation model of panicle temperature. (Note the difference of the two types of plot: [elevated CO$_2$] – [current CO$_2$])