Growth and water use efficiency of rice grown under elevated atmospheric CO2 concentrations and temperature

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Objectives

The objectives were to determine the effects of elevated CO2 concentrations ([CO2]) and air temperatureon growth, evapotranspiration, and water use efficiency (WUE) of rice (*Oryza sativa* L., cv. Dongjinbyeo).

Materials and methods

? *Controlled-environment chamber and experimental design*: Rice crops were grown season-long in six temperature gradient chambers (TGCs). These TGCs were located three adjacent irrigation paddies of Chonnam Nat'l Univ., Gwangju (126°92' E, 35°31' N), Korea, and consisted of three elevated [CO2]-TGCs and their companion ambient [CO2]-TGCs. Over season, [CO2] in elevated [CO2]-TGCs was controlled to 550ppmV, and resulted eventually in 56721ppmV. For ambient [CO2]-TGCs, it was maintained at natural ambient [CO2] (av.378ppmV). There were four temperature plots in the range from local ambient temperature to ambient +3oC in each TGC. The experiment was a split-plot design with the whole plots arranged in randomized complete blocks (3 replications). The levels of [CO2](ambient and elevated [CO2]) were whole-plot treatment and the levels of temperature (4 regimes) were the split-plot treatment.

? *Plant culture:* Seedlings were transplanted into paddies inside TGCs, with a hill (3 seedlings/hill) spacing of 15cm and a row spacing of 30cm, 5 June 2004. Fertilizers were applied at the rate of 11, 4.5 and 5.7g m-2 for N, P2O5 and K2O, respectively. Paddies were flooded throughout the season except when drainage needed to do other works. Other crop managements were similar to those used by local farmers.

? *Measurements and plant sampling*: Leaf number (age) on the main stem was counted with 2-3 days intervals until when a flag leaf appeared. Evapotranspiration (ET) was measured everyday, using lysimeter technique with a mariot tube (see Fig.1). The lysimeters were placed in two different locations of each TGC. Three hills from each of 4 temperature subplots in each TGC were destructively sampled including root at 23 (mid-tillering), 46 (PI), 73 (anthesis), 92 (mid-ripening) and 111 (maturity) days after transplanting (DAT), and green leaf area index (GLAI), tiller and panicle number (when present) measured. The biomass of the plant parts was determined separately after oven-drying at 80oC over 1 week. Water use efficiency (WUE), in terms of biomass accumulation, was calculated from the ET and crop biomass.

Results and discussion

Elevated [CO2] reduced the final leaf number (flag leaf age) on main stem of rice crops, with an average reduction of 5% across all temperature regimes in this experiment (Fig.2). The response of leaf number to elevated [CO2] and temperature partially mirrored that of crop phenology (i.e. days to anthesis; data not shown). Up to PI, the GLAI was greater in rice crops grown with either elevated [CO2]or higher temperatures than in crops with ambient [CO2] and temperature, though [CO2] x temperature interaction was not detected (Fig. 3a). Averaged across all temperature regimes, the increase in GLAI due to elevated [CO2] was by 13%. At anthesis however, the GLAI did not respond to [CO2] and air temperatures, and at maturity negatively did to [CO2] and positively did to air temperatures (Fig. 3bc). Over season, crop total biomass was increased with either rising [CO2] or air temperatures, though no synergistic effect of [CO2] and temperature was observed (Fig 3abc). Averaged across all temperatures, the [CO2]-induced increase in total biomass was by 27%, 22% and 6% at PI, anthesis and grain maturity, respectively. In both local ambient and ambient +2oC conditions, elevated [CO2] significantly decreased daily ET throughout the season (Fig 4). The decrease in ET due to elevated [CO2]was by 15% in ambient temperature and by 10% in ambient +2oC when the ET was cumulated over season. Elevated [CO2] significantly enhanced WUE of rice crops, with an average increase of 23% in ambient temperature and of 27% in ambient +2oC (Fig.5). This was largely a result of greater biomass and less ET with elevated [CO2]. Our results suggest that the reduced leaf number (age) of rice crops grown under elevated [CO2] is probably result of earlier crop phenology. This, in turn, together with faster leaf senescenceis thought to have led to small GLAI in late in the season, possibly resulting in potentialdecrease of canopy photosynthetic performance, as evidenced by the lack of biomass response to elevated [CO2] at grain maturity.

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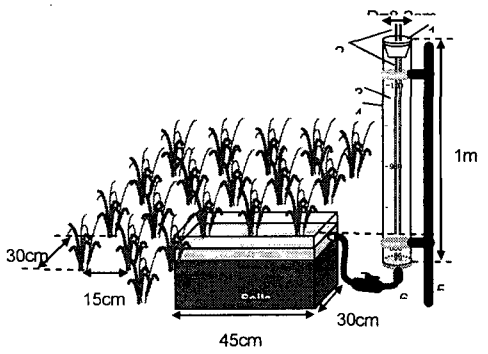

Fig. 1. A simple schematic drawing of the lysimeter installed in the TGCs. 1-Rubber cork; 2- Ventilation pipe; 3- Water; 4- A cycle tube for containing water; 5- Tube-fixing shelf; 6- Water duct; 7- Valve; 8- Stainless steel box bottom closed (fixed in the 25cm depth of soils).

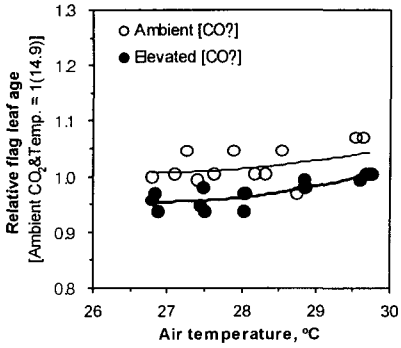

Fig. 2. Relative age of flag leaf on the main stem of rice crops grown under two levels of [CO2] and various air temperatures in the TGCs.

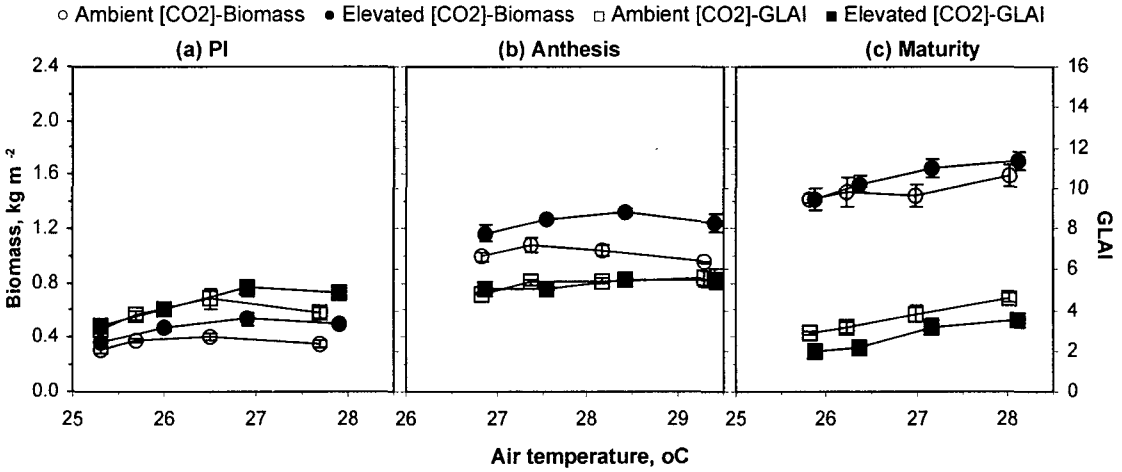

Fig. 3. Crop biomass and GLAI of rice grown under two levels of [CO2] and four temperature regimes at PI, anthesis and grain maturity. Data are the means of three replications. Bars are the standard error of the means. +, *, ** and ns indicate $p<0.1$, $p<0.05$, $p<0.01$ and no significance, respectively.

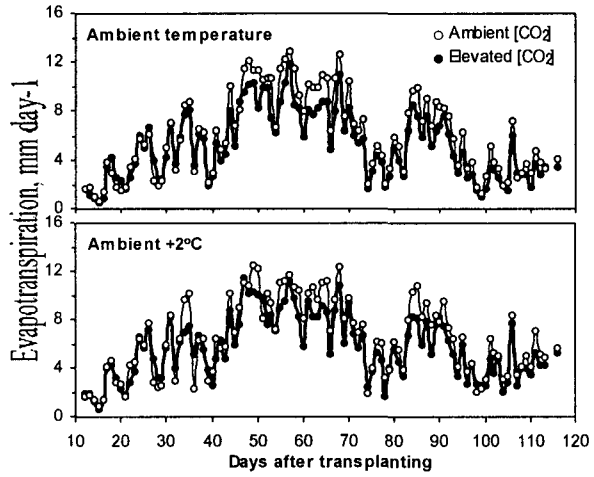

Fig. 4. Daily ET from the lysimeters withrice crops under two levels of [CO2] and air temperature conditions. Data points are the means of three replications.

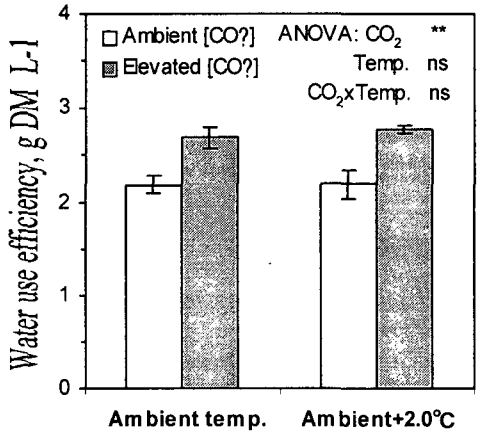

Fig. 5. WUE of rice crops grown under two levels of [CO2] and air temperatures. Data columns are the means of three replications. Bars are the standard error of the means. ** and ns indicate $p<0.01$ and no significance, respectively.