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Nitrogen uptake and grain yield of rice grown under elevated atmospheric CO_2 and temperature

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Objectives

The objectives were to determine how nitrogen (N) uptake and grain yield of rice (*Oryza sativa* L., cv. Dongjinbyeo) may be affected by elevated atmospheric carbon dioxide concentrations ([CO_2]) and air temperature (Ta).

Materials and methods

- Controlled-environment chamber and experimental design: In 2004, of six temperature gradient chambers (TGCs) located in the irrigation paddies of Chonnam Nat'l Univ., Gwangju (126°92' E, 35°31' N), three TGCs were enriched with [CO_2] of 567±21ppmV over season. The three remaining TGCs were maintained at natural ambient [CO_2] (av.378ppmV). There were four temperature plots in the range from local ambient Ta to ambient +3°C in each TGC. The experiment was a split-plot design. Two levels of [CO_2] (ambient and elevated) were the whole-plot treatment and four levels of Ta (ambient, +0.5°C, +1.5°C, +2.5°C) were the split-plot treatment.
- Plant culture: Seedlings were transplanted into the paddies inside TGCs and into the open field (for determining chamber effects) at 30x15cm^2 hill spacing (3 seedlings /hill) on 5 June 2004. Fertilizers were applied at the rate of 11, 4.5 and 5.7g m^{-2} for N, P_2O_5 and K_2O, respectively. Other crop managements were similar to those used by local farmers.
- Measurements and plant sampling: Three hills from each of the temperature subplot inside TGCs and from the open field were destructively sampled including root at the key development stages of rice crop. The biomass of plant parts was determined separately after oven-drying at 80°C over 1 week. Grain yield (defined as dry mass of filled grains) and it components were measured. All parts of the plant were also used to determine N content by the Kjeldahl method.

Results and discussion

- N uptake: Up to panicle initiation (PI), plant N uptake was increased significantly with elevated [CO_2] (13% across Ta regimes) and Ta (24-46% across [CO_2] levels) (Fig. 1). The increased N uptake due to elevated [CO_2] was greater with increasing Ta. This led to the increase in total grain number per unit land area (Fig 2a). After PI, however, N uptake decreased significantly with elevated [CO_2]. This may have resulted in the fast senescence and the decrease in growth duration of rice under elevated [CO_2]. At maturity total plant N uptake was decreased significantly (4% across all Ta regimes) with elevated [CO_2], whereas it was increased with rising Ta. No interactive effect between elevated [CO_2] and Ta on N uptake was found over season.
- Yield and its components: With elevated [CO_2], grain number per panicle, % of filled grains and individual grain weight were decreased slightly. As a result, rice grain yield in this experiment was not altered by elevated [CO_2] (Fig. 3), in spite of the increased panicle number. With rising Ta, % of filled grain also was decreased remarkably, resulting in severe decreases in grain yield, regardless of the [CO_2] (Fig. 2b). No interactive effect between elevated [CO_2] and Ta on grain yield and its components was found.
- N use efficiency: N use efficiency for biomass (NUEb) increased significantly (18% across all Ta) with elevated [CO_2] (Fig 4a). This was due to that total biomass was greater than that of total N uptake under elevated [CO_2]. Positive interaction between elevated [CO_2] and Ta on NUEb was detected. N use efficiency for grain yield (NUEy) decreased significantly with rising Ta, regardless of [CO_2] (Fig. 4b). This was due largely to the reduced % of filled grains (i.e. increased spikelet sterility) with rising Ta.

It was likely that chamber *per se* had little effect on rice growth when compared with the open field.

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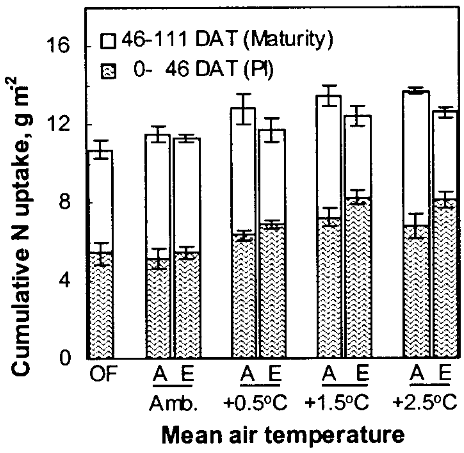

Fig. 1 Plant N uptake of rice grown under different [CO_2] (A: ambient, E: elevated) and Ta (Amb.=25.8°C) at PI and maturity (OF: open field).

Anova results:	0-46DAT	46-111DAT	0-111DAT
CO_2:	*	**	*
Temp:	**	ns	**
CO_2 x Temp:	ns	ns	ns

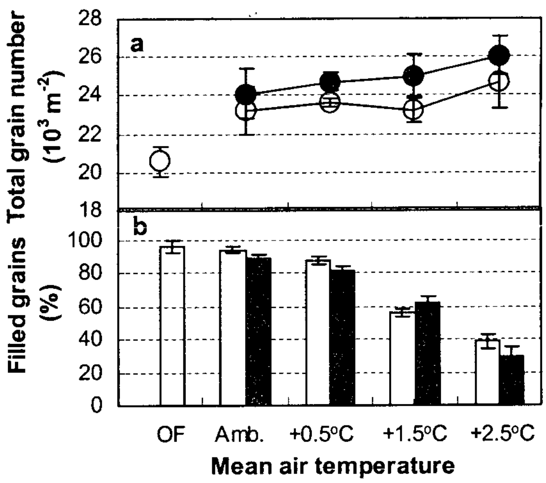

Fig. 2 Total grain number per unit land area (a) and percentage of filled grains (b) of rice grown under different [CO_2] and Ta at maturity (○□: amient [CO_2], ●■: elevated [CO_2]).

Anova results:	Total grain number	Filled grains %
CO_2:	ns	ns
Temp:	ns	**
CO_2 x Temp:	ns	ns

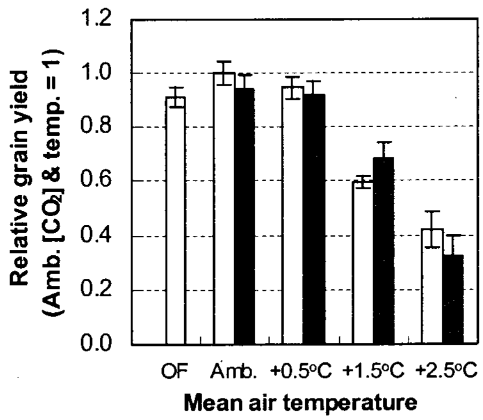

Fig. 3 Relative grain yield (1=541g m⁻²) of rice grown under different [CO_2] and Ta at maturity (□: ambient [CO_2], ■: elevated [CO_2]).

Anova results:	Grain yield
CO_2:	ns
Temp :	***
CO_2 x Temp :	ns

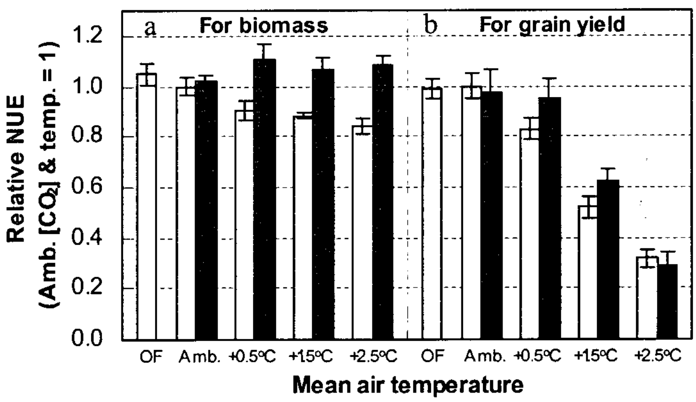

Fig. 4 Relative NUE for biomass (1=121g per g N) and for grain yield (1 = 46 g per g N) of rice grown under different [CO_2] and Ta at maturity (□: ambient [CO_2], ■: elevated [CO_2]).

Anova results:	NUEb	NUEy
CO_2:	*	ns
Temp :	ns	**
CO_2 x Temp :	*	ns