Combined Effects of Elevated Temperature and Carbon Dioxide Concentration on Growth and Water Use of Maize

Tomokazu HARAGUCHI[1], Yoshisuke NAKANO[2], Tomohisa YANO[3] and Masumi KORIYAMA[4]

[1,4]*Faculty of Agriculture, Saga University, 1 Honjo-Machi, Saga 840-8502, JAPAN*

[2]*Faculty of Agriculture, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, JAPAN*

[3]*Faculty of Engineering, Kyushu Kyouritsu University, 1-8 Jiyugaoka,Yahata-nishi-ku, Kitakyushu 807-8585, JAPAN*

1. Introduction

Phenological responses of crop on micrometeorological variation should be quantitatively expressed to predict the effect of climate change on crop production. Evaluating influence of the global climate change on water use of crop is important for the irrigation planning. The objective of the present study was to evaluate the combined effects of elevated air temperature and carbon dioxide (CO_2) concentration on the growth and water use of maize.

2. Materials and methods

The experiment was conducted using three closed growth chambers at Biotron Institute of Kyushu University (E130° 14', N33° 38'), Japan in summer of 2004 and 2005. Air temperature and CO_2 concentration for a treatment were controlled as shown in Table 1. Chamber used for a treatment was different in 2004 and 2005. A set value of relative humidity was 70 % in all chambers. Sixteen Wagner pots with an area of 0.05 m^2 were placed in each chamber for measurements of growth rate and transpiration rate. Mixture of Andosols and Masa (sandy soil) (1:1 volume) was put into each pot with 10 g of chemical fertilizer (N-P-K; 16%-16%-16%) as basal dressing. Three seeds of maize (*Pioneer G-98*) were sown in each pot on June 11 in 2004 and June 13 in 2005, and seedlings were thinned to one plant five days after budding. For preventing soil surface evaporation, soil surface was covered with white plastic beads 10 days after sowing (DAS). Irrigation water was applied through a PVC tube of inner diameter 30 mm.

Crop height and the number of leaves were measured, and a pot was weighed few times a week. On 28, 45, 58 and 96 DAS in 2004, and 28, 42, 55 and 96 DAS in 2005, four plants were sampled from each treatment for measurements of dry matter weight and leaf area. Air temperature and humidity were measured every 10 minutes using a humidity and temperature logger (Sensor HA9630, Logger HA3631, NIHON SHINTECH Co., Ltd.), and solar radiation, R_s, was measured every 3 minutes with a pyranometer (LI-200SB, LI-COR, inc.) in each chamber.

Table 1 Meteorological condition for treatment.

Treatment	Air temperature (℃) day/night	CO_2 (ppm)
TLCL	28/22	350
TLCH	28/22	700
THCH	32/26	700

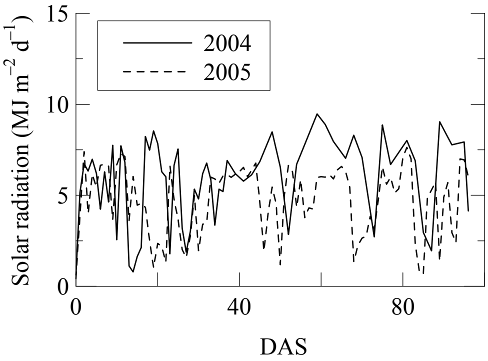


Fig. 1 Time courses of solar radiation.

3. Results and discussion

3.1 Crop growth

Figure 1 shows the time courses of solar radiation from the day of sowing in 2004 and 2005. Daily solar radiation in 2004 was larger than 2005, and total solar radiations during the experiment period (96 days) in 2004 and 2005 were 562 and 459 MJ m^{-2} ,respectively.

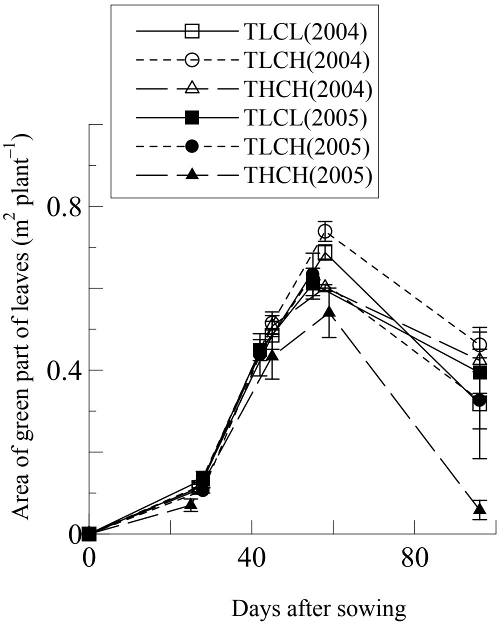


Fig. 2 Time courses of area of green leaves.

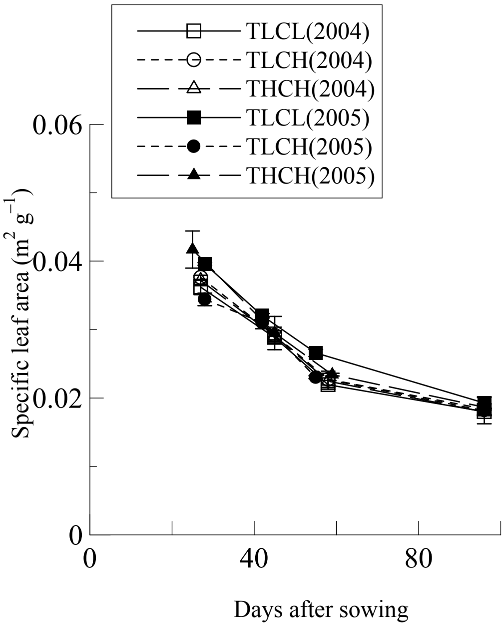


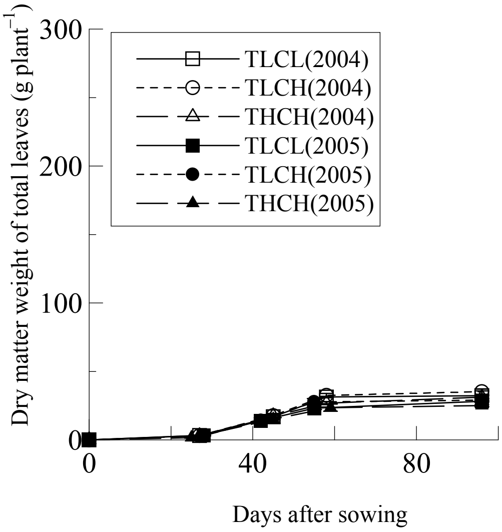
Fig. 3 Changes in specific leaf area.

Emergence of seedling and silking occurred on three and fifty-eight days after sowing for all treatments in both year.

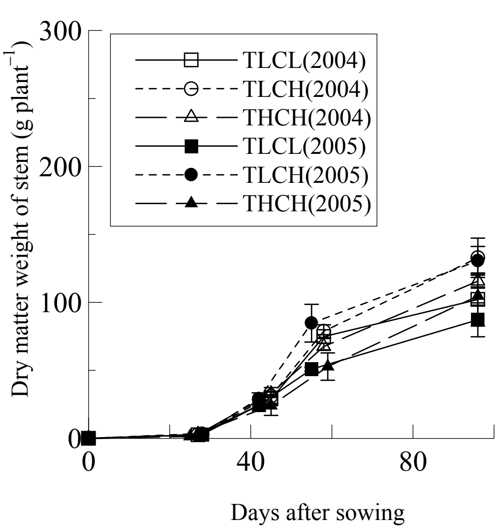
Figure 2 shows the changes of the area of green leaves per a plant. There was no significant difference among treatments and years at the first and second samplings. The change in green leaf area changed depending on days after sowing rather than thermal time or solar radiation during this period although thermal time was different among treatments and solar radiation condition were different among years. At the third and last samplings, there were significant differences due to the effects of the growth environment.

The change of the specific leaf area was well expressed with time from the sowing except for TLCL in 2005 (Fig. 3).

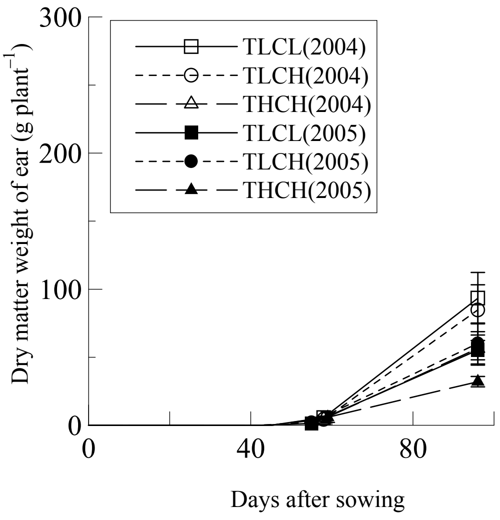
Dry matter weight (DMW) of total leaves, including green, yellow and dead leaves, was highest in TLCH and lowest in THCH at the maturity stage (Fig. 4a). The difference in DMW of total leaves due to treatment was smaller than other organs. The change in dry matter weight of stem was highest in TLCH and lowest in TLCL at the maturity stage (Fig. 4b). DMW of stem was well expressed with a function of solar radiation cumulated from sowing except for TLCH at the third sampling. The change in dry matter weight of ear was lowest in THCH, and that in TLCH was almost equal with that in TLCL (Fig. 4c). DMW of ear was well expressed with a function of the cumulated solar radiation.



a) leaf



b) stem



c) ear

Fig. 4 Changes in biomass of organs.

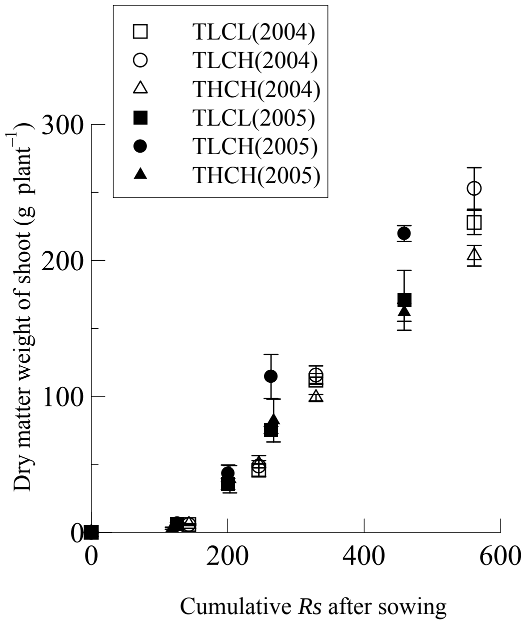


Fig. 5 Relationship between dry matter weight of shoot and cumulative shortwave radiation.

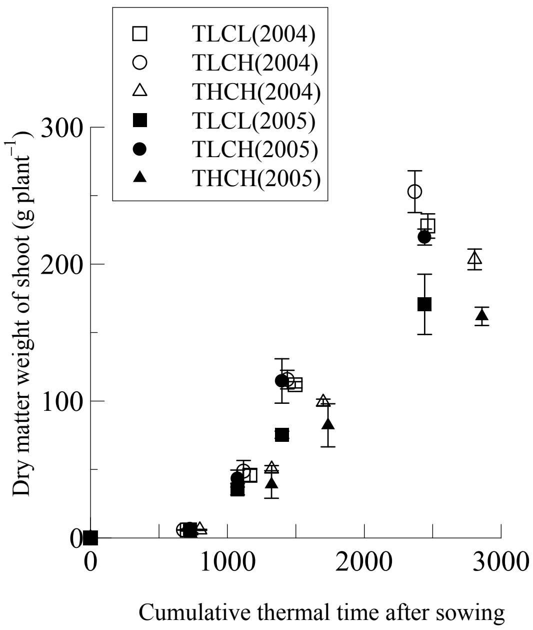


Fig. 6 Relationship between dry matter weight of shoot and cumulative thermal time.

Figure 5 shows the relationships between dry matter weight of shoot (leaves + stem + ear) and cumulative solar radiation from sowing (MJ m^{-2}). The difference in DMW among treatments was clearly illustrated at the last sampling. DMW of shoot at the maturity stage was highest in TLCL and lowest in THCH. DMW in 2004 was larger than that in 2005 for all treatments. This difference

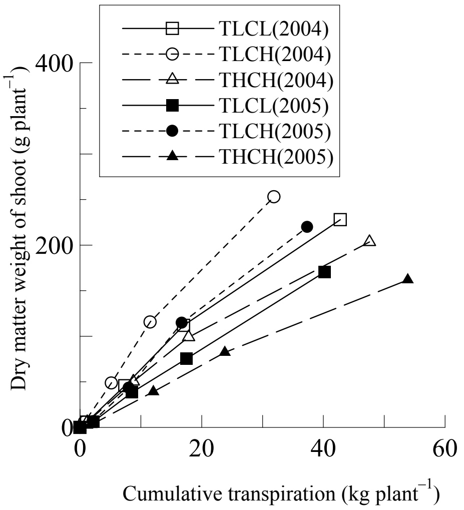


Fig. 7 Relationship between dry matter weight of shoot and transpiration.

was probably occurred because of the difference in total solar radiation during the growth period. The relationship for each treatment was expressed well than the relationship using the thermal time (℃ d) (Fig. 6).

3.2 Water use

Figure 7 shows the relationship between shoot biomass of sampled plant and transpiration cumulated from emergence to the sampling date for four sampling. The ratio of dry matter weight to cumulative transpiration at the last sampling corresponds to the water use efficiency during total growing period (WUE_t). The ratios of WUE_t in TLCH and THCH to TLCL were 1.5 and 0.8 for 2004, and were 1.4 and 0.7 for 2005.

The slopes of the line between two continuous data are equal to water use efficiency during the period (WUE_p). WUE_p was decreasing with the progress of growing stage. There was a tendency that WUE_p was highest in TLCH and lowest THCH during certain period.

The time courses of transpiration were affected by the growth progress. The variation of solar radiation and the difference of the growth environment also affected the change. The transpiration from a unit area of active leaf was obtained by dividing transpiration per a plant with green leaf area of a plant. The transpiration per unit leaf area in TLCH and THCH with high CO_2 concentration were smaller than TLCL with low CO_2 concentration because of decreased stomatal conductance.

Conclusions

The experiments for the combined effects of elevated air temperature and carbon dioxide (CO_2) on the growth and water use of maize in 2004 and 2005 reveal that:

- The rise in CO_2 concentration caused the increase in biomass of shoot especially in that of stem from the comparison treatments TLCL and TLCH.
- The increase in air temperature caused the reduction in biomass of shoot (leaf and ear).
- Water use efficiency increased due to the rise in CO_2 concentration, and decreased due to the increase in air temperature.

Acknowledgement

This is a partial contribution from the ICCAP Project (Impact of Climate Changes on Agricultural Production System in the Arid Areas), being promoted by the Research Institute for Humanity and Nature (RIHN) and the Scientific and Technical Research Council of Turkey (TÜBİTAK).