Chamber Experiment on Effects of CO_2 Concentration and Temperature on Maize Growth

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

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

[3]*Faculty of Agriculture, Mustafa Kemal University, TR-31040, Antakya, TURKEY*

[4]*Marine and Highland Bioenvironment Center, Saga University, JAPAN*

e-mail: [1]thara@bpes.kyushu-u.ac.jp, [2]ynakano@agr.kyushu-u.ac.jp, [3]yano@mku.edu.tr,

[4] *kooriyama_m@hotmail.com*

1. Introduction

Phenological responses of crop on micrometeorological variation should be quantitatively expressed to predict the effect of climate change on crop production. The objective of the present study was to evaluate the combined effects of elevated air temperature and carbon dioxide (CO_2) on the growth and water use of maize. The effect of water stress was additionally examined because the drying period would increase due to the global climate change.

2. Materials and methods

The experiment was conducted in three closed growth chambers at Biotron Institute of Kyushu University (E130° 14', N33° 38'), Japan. Air temperature and CO_2 concentration in chambers were controlled as shown in Table 1. 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 growth rate. Four more pots were placed in the chamber 3 to examine the effect of water stress (treatment termed STRESS). 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, 2004, 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. Irrigation water was applied through a PVC tube of inner diameter 30 mm. Mean soil moisture in a pot came to high content (pF 1.5) immediately after an irrigation. Soil moisture of STRESS treatment was gradually decreased by watering less than THCH treatment since 58 DAS. The change from the vegetative to reproductive period occurred at about 30 DAS. The silking and maturity stages were judged on 58 and 96 DAS, respectively.

Crop height and the number of leaves were measured every 1-3 days, and a pot was weighed before watering. On 28, 45, 58 and 96 DAS, four plants were sampled from each treatment for measurements of biomass 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.) in each chamber, and shortwave radiation was measured every 3 minutes with a pyranometer (LI-200SB, LI-COR, inc.) in the chamber 3.

3. Results and discussion

3.1 Crop development

Figure 1 shows the changes of the area of active leaf, that is not dead leaf, for TLCL, TLCH and THCH. There was no significant difference among treatments at 27 and 45 DAS. At 58 and 96 DAS, there were clear differences due to the effects of the growth environment. For THCH the increase in leaf area was inhibited in the period of 45-58 DAS, i.e. the late reproductive period, due to the increased air temperature. The decrease between 58 and 96 DAS for THCH was smaller than other treatments. This reveals that the life span of leaf in THCH was longer than other treatments. Difference in specific leaf area (SLA) among treatments was very small all through the growing stages (Fig.2). SLA decreased with the progress of the growing stage.

Table 1 Meteorological condition in chambers

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

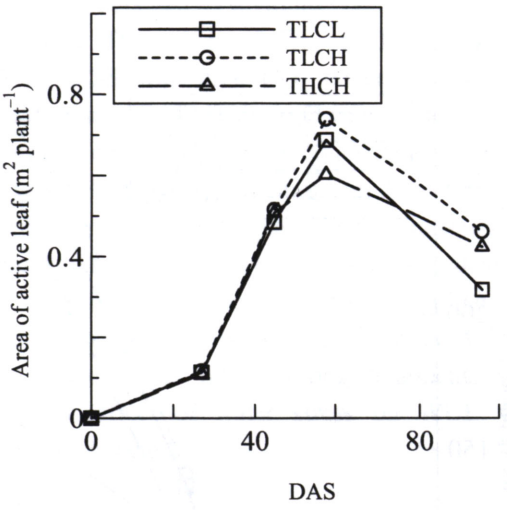


Fig. 1 Changes in active leaf area.

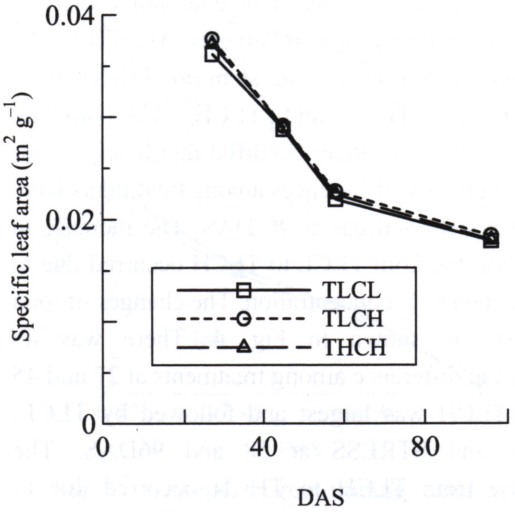
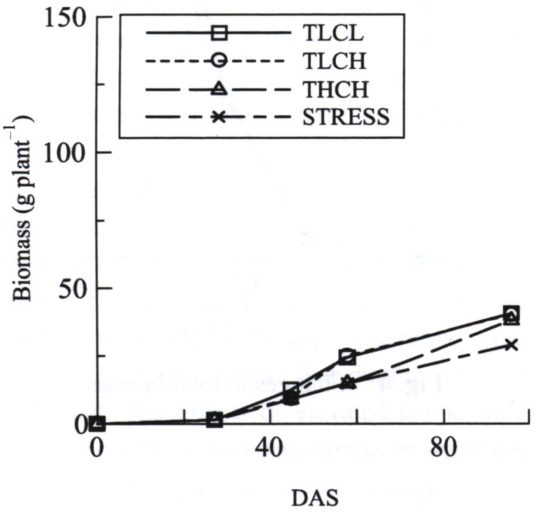
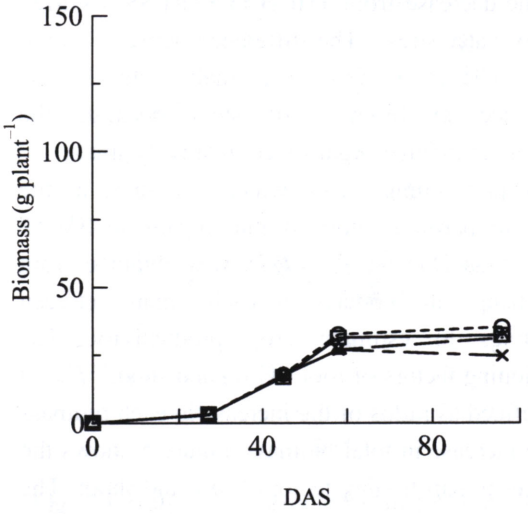


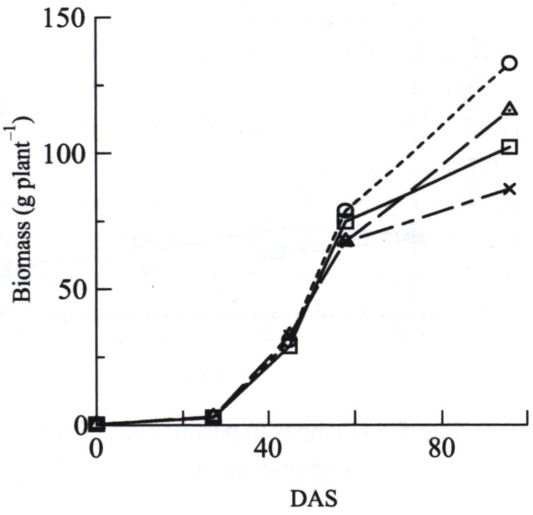
Fig. 2 Changes in specific leaf area.



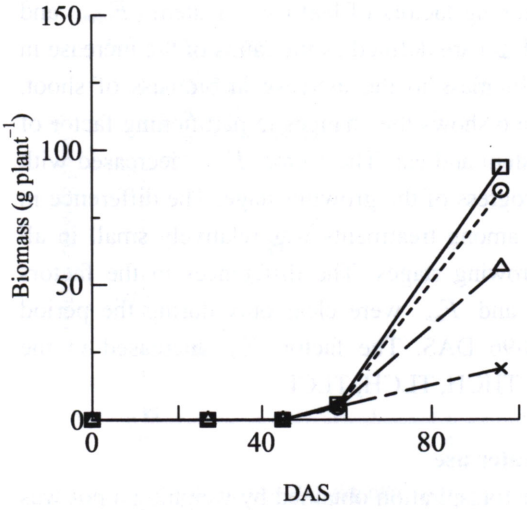
a) root



b) leaf



c) stem



d) ear

Fig. 3 Changes in biomass of organs.

Figures 3 a) – d) show the change in biomass of root, leaf, stem and ear in four treatments. At 58 DAS the biomass of root, leaf and stem in THCH were smaller than TLCL and TLCH. The biomass decreases of each organ occurred due to higher air temperature. The differences among treatments were clear for stem and ear at 96 DAS. The increase in stem biomass from TLCL to TLCH occurred due to the elevated CO_2 concentration. The changes of total biomass are shown in Fig. 4. There was no significant difference among treatments at 27 and 45 DAS. TLCH was largest and followed by TLCL, THCH and STRESS at 58 and 96DAS. The decrease from TLCH to THCH occurred due to elevated temperature, the increase from TLCL to TLCH occurred due to elevated CO_2 concentration and the decrease from THCH to STRESS occurred due to water stress. The difference between TLCL and TLCH at 96 DAS was mainly due to the difference in biomass of stem because the differences in other organs were relatively small.

The partitioning factor, which is defined as the factor to partition biomass into organs in SWAP model (van Dam et al., 1997), was obtained from the change in biomass of each organ between samplings to estimate crop productivity. The partitioning factors of root (F_{root}) and shoot (F_{shoot}) are defined as ratios of the increase in each biomass to the increase in total biomass. Figure 5 shows the changes in partitioning factor of root and shoot. The factor F_{root} was about 0.2 at the first growing stage and decreased gradually for all treatments. The partitioning factors of leaf (F_{leaf}), stem (F_{stem}) and ear (F_{ear}) are defined as the ratios of the increase in each biomass to the increase in biomass of shoot. Figure 6 shows the changes in partitioning factor of leaf, stem and ear. The factor F_{leaf} decreased with the progress of the growing stage. The difference in F_{leaf} among treatments was relatively small in all the growing stages. The differences in the factors F_{stem} and F_{ear} were clear only during the period of 58-96 DAS. The factor F_{ear} increased in the order, THCH, TLCH, TLCL.

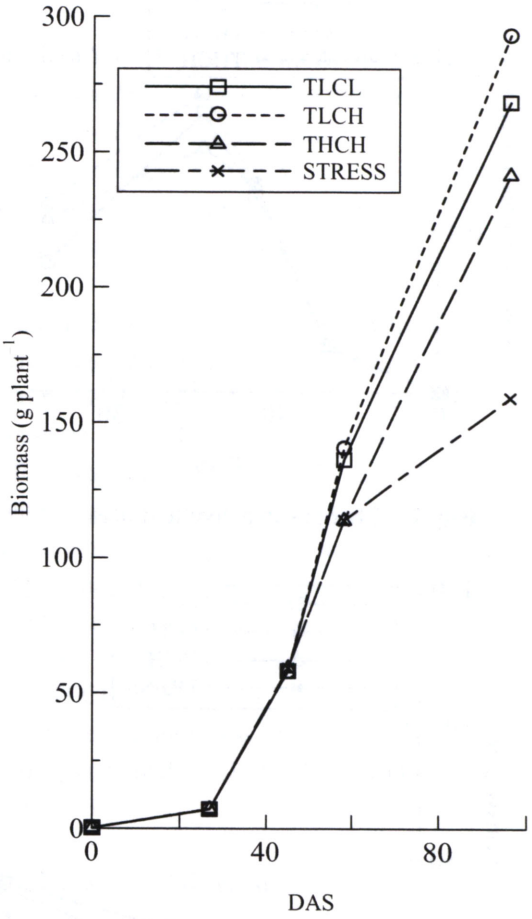


Fig. 4 Changes in total biomass.

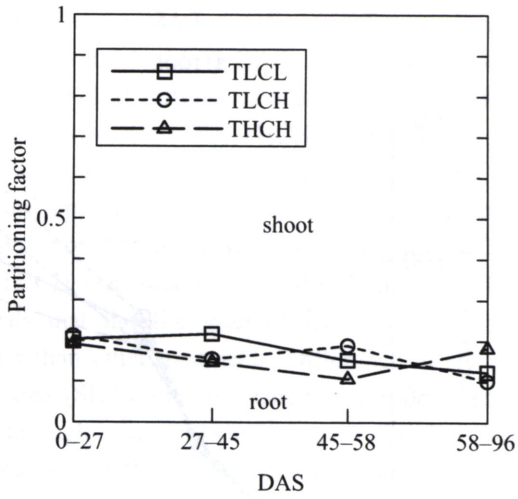


Fig. 5 Changes in partitioning factor of root and shoot.

3.2 Water use

The transpiration obtained by weighing a pot was divided with vapor deficit for correction because relative humidity in chamber 2 (TLCH) was 8% higher than the set value. The time courses of corrected transpiration (Tr_c) were affected by the growth progress. The variation of shortwave radiation and the difference of the growth environment also affected the change in Tr_c . The corrected transpiration from a unit area of active leaf

(Tr_{Lc}) was obtained by dividing Tr_c with leaf area of a plant. The values of Tr_{Lc} in TLCH, THCH and STRESS with high CO_2 concentration were smaller than TLCL with low CO_2 concentration because of decreased stomatal conductance (Fig. 7).

Figure 8 shows the relationship between total biomass of sampled plant and transpiration cumulated from emergence to the sampling date for four sampling. The slope of the regression line of a relationship is equal to water use efficiency (WUE). The difference in WUE among treatments was slight.The effect of water stress on WUE was obviously detected.

4. Conclusions

In this study, the effects of elevated air temperature and carbon dioxide (CO_2) and water stress on the growth and water use of maize were examined through a chamber experiment. Higher air temperature caused the decrease in total biomass during the late reproductive period and grain filling period and elevated CO_2 concentration caused the increased in total biomass (especially in stem). The difference in the partitioning factors among treatments was small during vegetative and reproductive period and was clear during the grain filling period. The effects of elevated temperature and CO_2 concentration and water stress on water use efficiency were small.

Reference

Van Dam, J.C., J. Huygen, J.G. Wesseling, R.A. Feddes, P. Kabat, P.E.V. van Walsum, P. Groenendijk and C.A. van Diepen, 1997. Theory of SWAP version 2.0. Simulation of water flow, solute transport and plant growth in the Soil-Water-Atmosphere-Plant environment. Wageningen Agricultural University and DLO Winand Staring Centre. Technical Document 45.

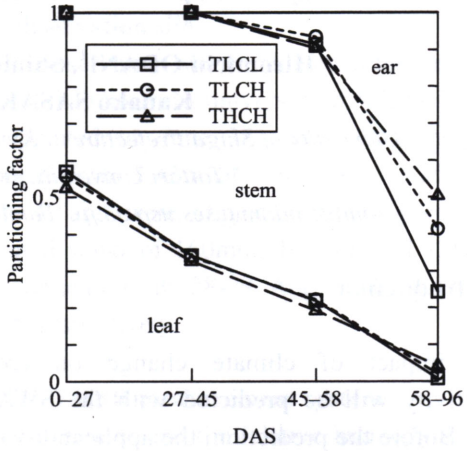


Fig. 6 Changes in partitioning factor of leaf, stem and ear.

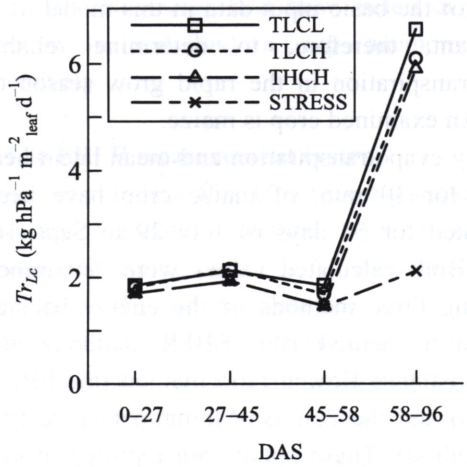


Fig. 7 Changes in corrected transpiration from a unit area of active leaf.

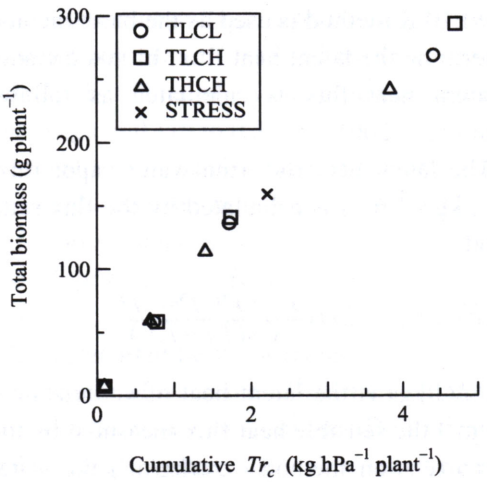


Fig. 8 Relationship between biomass production and transpiration.