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Review on Climate Control Chamber studies in studying plant environment interaction under climate change scenarios

CLIMARICE II: "Sustaining rice production in a changing climate"

V.Geethalakshmi, K.Bhuvaneshwari and A.Lakshmanan
(Agro Climate Research Centre, TNAU, Coimbatore)

This Technical brief summarizes some of the studies conducted on rice using a climate control chamber and outlines the studies that will be undertaken in the Climate Control Chamber facility that has been established at the Agro Climate Research Center at Tamil Nadu Agricultural University, Coimbatore.

In recent years a numbers of technologies have been developed to study the impact of climate change on agricultural systems. Crop response to climate change could be studied by using a climate control chamber and data base generated using these facilities will be more realistic for impact assessment analysis under changing climatic conditions. Most of the research on plant response to climate change have been studies conducted under a controlled environment. Controlled climatic condition technologies have been successfully applied to study the response of plant to increasing temperature, green house gases and light quality variation.

Climate Control Chamber at TNAU, Coimbatore, India

Effect of CO_4 and CO_2 on Crop penology

Weiguo Cheng et al conducted a pot experiment under controlled-environment chambers during the 2002 rice growth season showed that the increase in CO_4 emissions caused by elevated CO_2 was significant after the grain-filling stage of rice; the total emissions were enhanced 58% by elevated CO_2. The CO_4 emitted by ebullition-diffusion accounted for 11.3% and 11.9% of total emissions under ambient and elevated CO_2 conditions, respectively. In contrast, no CO_4 was emitted from plant-free pots, suggesting that the CO_4 emitted from rice-plant pots was most contributed by the rice plant through root exudates and root autolysis products. The CO_4 flux decreased when the flooding water was drained under both ambient- and elevated- CO_2 treatments, implying that drainage management will have an important role in mitigating future CO_4 emissions from paddy fields, when more CO_4 will likely be emitted from flooded rice paddy soils under increasing atmospheric CO_2 concentration (Cheng et al 2003).

The temperature gradient chamber (TGC) with the facility for CO_2 enrichment allows the creation of various CO_2 and temperature regimes for crops over the entire growth period with relatively inexpensive construction and running costs. TGC is a useful tool in understanding rice responses to changes in atmosphere and temperature. A CO_2 enrichment experiment on rice in the TGC showed that a doubling of the CO_2 concentration markedly enhanced crop dry matter production. Temperature had less effect on dry matter production, although panicle dry weight was greatly decreased at higher temperature as a result of high-temperature-induced sterility of rice spikelets (Horie, 2006).

The increasing atmospheric CO_2 concentration probably will have significant direct effects on vegetation whether predicted changes in climate occur or not. Greenhouse and growth chamber studies, plant growth and yield have typically increased more than 30% with a doubling of CO_2 concentration (Kimball *et al.*, 1993). Baker et al (1992) conducted experiments to determine the effects of CO_2 and temperature on rice (Oryza sativa L., cv. IR–30). Rice plants were grown season-long in outdoor, naturally sunlit, controlled-environment, plant growth chambers in temperature regimes ranging from 25/18/21°C to 37/30/34°C (daytime dry bulb air temperature/night-time dry bulb air temperature/paddy water temperature)and [CO_2] of 660 μmol CO_2 mol1 air. These results indicate that while future increases in atmospheric [CO_2] are likely to be beneficial to rice growth and yield, potentially large negative effects on rice yield are possible if air temperatures also rise.

The glass-topped chambers have externally mounted microwave powered light sources providing minimum PAR at canopy level of 1000 $\mu m \cdot m^{-2} \cdot s^{-1}$. Major gases ($CO_2$, O_2) were monitored. Other environmental variables relevant to plant production (humidity, temperature, nutrient solution) were monitored and controlled continuously (Dixon, 1999)

Effect of elevated temperature on rice growth

One cultivated and two wild rice varieties have been grown in a temperature and humidity-controlled growth chamber to find the variation in photoperiod and light quality by daily exposure of the seedlings at the four-leaf stage to 8 h of natural daylight followed by white incandescent, red, green or blue light for 2,4 or 8 h (Sarkar and Sircar, 1975). The treatments caused marked differences in growth and reproduction between the cultivated and wild rice. The cultivar Dudkalmi showed extensive tillering after far-red exposure. Earliest flowering was observed with a 16-h dark period both in the cultivated and wild rice. Failure of flowering with 8-h day and 8-h artificial light of different wavelengths could be overcome by red or far-red of 1-h duration.

Mark R. Schmitt and Gerald E. Edwards grow the C_3 species wheat and rice and the C_4 species maize for 2–3 weeks in controlled environment growth chambers at 20 or 30 °C day and 15 °C night temperatures. These results that C_4 species may make more efficient use of their nitrogen, soluble protein, and RuBP carboxylase protein than C_3 species under atmospheric CO_2 conditions. This may be due in part to the C_4 cycle and CO_2-concentrating mechanism in C_4 photosynthesis.

The effects of high temperature (32/23°C max/min; 27.5°C daily mean temperature), which is common in August in Fukuyama city, Japan, on the grain weight and the grain quality of rice plants were examined. Air temperature was controlled artificially in growth chambers. The grain weight at 32/23°C was lower at high temperature. The decrease in grain weight at high temperature accompanies the decrease in grain thickness (Morita Satoshi, 2000).

Effect of light intensities on crop growth

In another experiment the effects of interruption of the dark period by a light period of 2 h after from 4–12 h of darkness in a 24-h cycle were studied in the two wild rice varieties grown in humidity-controlled growth chamber. Light of different wavelengths interposed in the dark period caused variation in tiller number and stem length in comparison to an uninterrupted dark period of 16 h. The effect at the beginning of the dark period advanced flowering but flowering was delayed by interruption at 4 h and after 8 h and accelerated after a 10- to 12-h dark period ((Sarkar and Sircar, 1975).

The measurement of water fluxes from canopy and soil surfaces is performed in sunlight controlled environment chambers by measuring condensate draining from cooling coils in a constant humidity environment (Dennis Timlin, 2007). Rowland-Bamford et al (1999) conducted a study on long-term effects of CO_2 concentration and temperature on carbohydrate partitioning and status in rice (*Oryza sativa* L. cv. IR-30) where the plants were grown season-long in sunlight, controlled-environment chambers with CO_2 concentrations of 330 or 660 $\mu mol\ mol^{-1}$, and daytime air temperatures of 28, 34 or 40°C. Elevated CO_2 had no effect on carbohydrate concentration in the grain at maturity; however, grain total non-structural carbohydrate total non-structural carbohydrate concentration was significantly lowered by increasing temperature. An artificial light growth chamber is for simulating a specific climate of a lowland rice field at a local area in Japan. Daily changes in air temperature, relative humidity, wind velocity and light intensity were simulated using an artificial light growth chamber for investigating the disease symptoms and its process (Watanabe, 2001).

Climate Control Chamber at TNAU, Coimbatore.

The Climate Control Chamber facility has been established at Agro Climate Research Center, Tamil Nadu Agricultural University, Coimbatore, under the **ClimaRice** project, funded by the Ministry of Foreign Affairs, Norway. This Climate Control Chamber has the facility to control air temperature and atmospheric CO_2 to carry out studies and to study the impact of change in climatic parameters on crops. The chamber also has the facility to record the following weather parameters at periodical (5 minutes) intervals.

- Air temperature
- Relative Humidity
- Global radiation
- Soil Temperature
- Soil Moisture

The Climate Control Chamber is connected online with gas chromatographic facility, which would help in estimating various green house gases such as methane and nitrous oxide inside the chamber. Besides, this facility can also be used to estimate green house gas emission rates from different water management systems and rice cultivars in farmers' field.

Research Activities in the Climate Control Chamber at TNAU

- To study the effects of increased temperature on the penology of different rice cultivars
- To study the effects of increased temperature on the yield of popular rice cultivars of delta region
- To study the impact of increase in temperature on soil enzymes and biogeochemical processes
- To study the combined effects of increased temperature and CO_2 on rice grain quality
- To study the effect of elevated night temperature on rice penology and yield
- To conduct Carbon sequestration studies under elevated temperature
- To study the effects of increased temperature on nitrogen fixation and other biological processes

References

A.J. Rowland-Bamford, J.T. Baker, L.H. Allen Jr and G. Bowes, 1996. Interactions of CO_2 enrichment and temperature on carbohydrate accumulation and partitioning in rice. Environmental and experimental botany. 36(1):Pages 111-124.

Baker. J. T., L. H. Allen, JR and K. J. Boote, 2005. Temperature Effects on Rice at Elevated CO_2 Concentration. Journal of Experimental Botany 43(7):pp. 959-964.

Cheng W, Yagi K, Sakai H, Kobayashi K. 2003. Effects of elevated CO_2 on CH4 and N2O emissions from submerged rice soil: a pot experiment. 2003 ASA-CSSA-SSSA Annual Meetings, 2- 6 November 2003, Denver, Colorado, USA. CD-ROM.

Dennis Timlin, David Fleisher, Soo-Hyung Kim, Vangimalla Reddy and Jeffrey Baker. 2007. Evapotranspiration Measurement in Controlled Environment Chambers: A Comparison between Time Domain Reflectometry and Accumulation of Condensate from Cooling Coils. Agronomy Journal, 99:166-173.

Dixon M. A., B. Grodzinski, R. Côté and M. Stasiak.1999. Sealed environment chamber for canopy light interception and trace hydrocarbon analyses. Advances in Space Research.24(3), 271-280.

Horie. T., H. Nakagawa, J Nakano, K. Hamotani, H. Y. Kim.2006.Temperature gradient chambers for research on global environment change. Iii. A system designed for rice in kyoto, japan. Plant, cell & environment,18(9): 1064 – 1069.

Kimball. B. A., J. R. Mauney, F. S. Nakayama and S. B. Idso. 1993.Effects of increasing atmospheric CO_2 on vegetation, Plant Ecology,104-105 (1):65-75.

Mark R. SchmitT [1] and Gerald E. Edwards. Photosynthetic Capacity and Nitrogen Use Efficiency of Maize, Wheat, and Rice: A Comparison Between C_3 and C_4 Photosynthesis. Journal of Experimental Botany. 32 (3) pp. 459-466.

Morita Satoshi.2000. Effects of High Air Temperature on Ripening in Rice Plants. Analysis of ripening performance in growth chamber experiments. Japanese Journal of Crop Science. 69(3):391-399.

Sarkar K. K and S. M. Sircar.1975. Control of Growth and Reproduction in Cultivated and Wild Rice by Light Quality and Dark Period *Annals of Botany* 39: 1063-1070.

Watanabe. T., k. Toh4, j. Ohwaki2, y. Naga02, m. Fujiyama1, A. Tsurunaga3 and s. Yoshida, 2001. Environment control in an artificial light Growth chamber for simulating a specific Climate of a lowland rice field at a local area in japan. *Biotronics* 30, 115-118, 2001.

Weiguo cheng, Kazuyuki Yagi and Kazuyuki Inubushi. Impact of rising atmosphere Co_2 on CH_4 emmission from rice paddies. Climate change and rice production.

ClimaRice II Project (2009-2011)

ClimaRice II is an integrated project that aims to test and validate climate change adaptation techniques related to rice production, in close co-operation with farmers and local agencies in two study areas in the Cauvery River Basin, Tamil Nadu, and Krishna River Basin, Andhra Pradesh, in India.

The overall goal is to contribute to the regional and national adaptation strategies to sustain rice production and ensure food security amidst changing climate. The partners are:

- Bioforsk - Norwegian Institute for Agricultural and Environmental Research (Project Co-ordinator)
- Tamil Nadu Agricultural University, Coimbatore, India
- International Pacific Research Institute, Hawaii, USA
- International Water Management Institute, Hyderabad, India

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