GAS-EXCHANGE MEASURING SYSTEM WITH ADAPTIVE CLIMATE CONTROL

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KRUG H. and FINK M. *Gas-exchange measuring system with adaptive climate control.* BIOTRONICS **16**, 71–74, 1987. Concentration and function of a gas-exchange measuring unit with CO_2 control by the compensation method and an adaptive control algorithm for temperature, humidity, irradiance and CO_2 concentration is described. It allowes to measure CO_2 uptake or CO_2 release, plant weight, leaf area and pattern area of plants and diameters of plant organs almost continuously.

Keywords: gas-exchange measurement; adaptive climate control.

INTRODUCTION

Analysis of plant growth in "natural" environments, which means under fluctuating weather conditions, can be supported by experiments under controlled artificial conditions. Therefore in addition to climate controlled greenhouses, a set of walk in growth chambers (*2, 3*) and a gas-exchange measuring device with time-constant set-points (*4*), a smaller unit for gas-exchange measuring was installed. This is capable for controlling a wide range of time courses of input factors. CO_2 uptake and release as well as fresh weight and morphogenetic parameters can be measured almost continuously. By use of this unit, fluctuating climatic growth factors can be simulated and corresponding plant reactions can be observed.

CONSTRUCTION, FUNCTION AND EFFECTIVENESS

The setup is shown in Fig. 1*. It consists of a cuvette (a) with the size of 0.4 m $\times$ 0.6 m $\times$ 0.8 m $=$ 0.19 m^3 placed a top of an air conditioning unit (b) to reduce the total air volume (0.4 m^3). This cuvette is made of double-sheet acrylic plates in order to prevent condensation on the walls. Incoming air is first dispersed by a turbulator, streams then more or less in horizontal direction through the cuvette and the plant and is finally exhausted by a tangential fan at the outlet on the opposite side. Air velocity can be controlled up to 0.3 m s^{-1}.

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* We are grateful to Prof. Dr. H. J. Daunicht for his valuable suggestions (see also *1*). The cuvette and the air conditioning unit were built by Weiss Umwelttechnik GmbH, Federal Republic of Germany.

The maximum air temperature is more than 40°C, the minimum air temperature and the dewpoint temperature are lower than −15°C. The temporal temperature variation is ±0.2°C, whereas the spatial temperature variation is ±0.5°C. The temperature can be increased by about 8°C min^{-1} and decreased by about 0.5°C min^{-1} at maximum.

The air conditioner (b) contains a brine-fed heat exchanger for cooling and dehumidification and an electric heater (2×1.5 kW). Humidification results from plant transpiration. This unit is placed in a temperature-controlled room.

The brine temperature is controlled by an air-cooled refrigerating machine (1 kW) and an electric heater (d).

The CO_2 concentration is controlled and the CO_2 consumption is measured by the compensation method and by infrared gas analysers (Binos, Leybold Heraeus), which is provided with a device for atmospheric pressure compensation. The CO_2 dosage unit (e) is built according to Daunicht (unpublished). The pressure of the CO_2 coming from a bottle is reduced to 50 hPa. For measuring a tube (volume about 1 ml) between two solenoid valves is filled by opening the inlet valve. After closing the inlet valve the outlet valve opens and releases the CO_2, which is led through a pipe to the turbulator at the inlet of the cuvette. Thus the inside CO_2 concentration is kept constant±1 mg l^{-1}. The quantity of the CO_2 applied correlates linearly to the number of pulses.

CO_2 release by respiration is determined by the increase of CO_2 concentration. In order to avoid high concentration the cuvette can be flushed automatically with surrounding air. It is possible to install a constant-rate CO_2 adsorber and compensate the CO_2 deficit by the dosimeter.
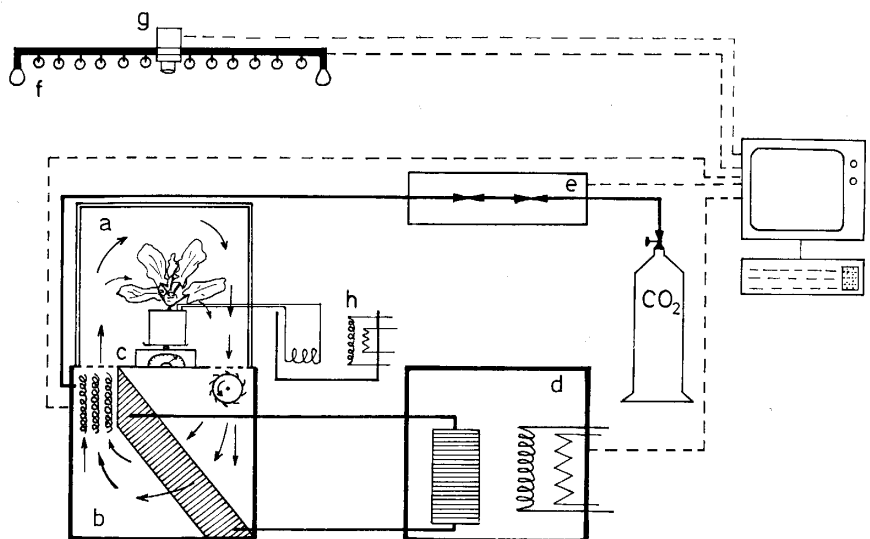

Fig. 1. Set of gas exchange measuring unit with flexible climate control. Double wall cuvette (a) placed atop, an air conditioning unit (b), electric balance (c), brine refrigerating machine (d), CO_2 dosage unit (e), set of fluorescent and incandescent lamps (f), videocamera for digital image analysis (g), temperature controlled nutrient solution circulation unit (h), microcomputer for climate control and data storage (i).

The plants are irradiated by 28 Sylvania High Pressure Cool White Fluorescent Tubes (58 W) in combination with 10 incandescent lamps (100 W) (f) to maintain a light quality comparable to that in the growth chambers where the plants are grown before, or where measurements under constant conditions are made for comparison. Irradiance is measured by a photo cell. It is roughly controlled by the light frame height, the number of lamps in operation and balanced by a potentiometer for 8 tubes. Thus light intensities up to 20 klx inside the cuvette can be achieved.

The plants are grown in hydroculture with a temperature controlled nutrient solution (h). As pots and plants are placed on an electric balance (c), the pipes for nutrient solution circulation must be smooth and have to be installed in a way that weighing is not distorted.

Data registration and climate control are performed by a microcomputer (i). Air and dewpoint temperatures, CO_2 concentration, number of pulses for CO_2 influx and irradiance are measured every 15 seconds. These values or corresponding means can be stored on a disc. Additional data can be registered as well, as for example:
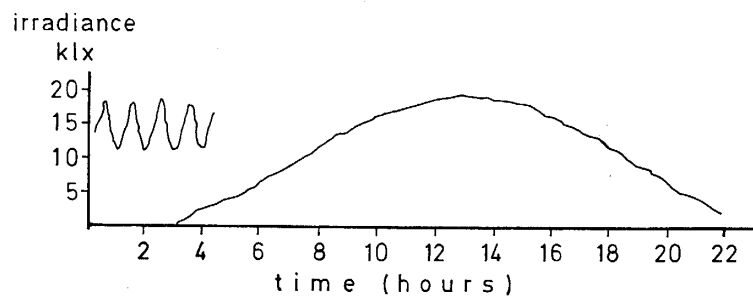

Fig. 2. Observed values of irradiance with oscillating set points of different frequencies.
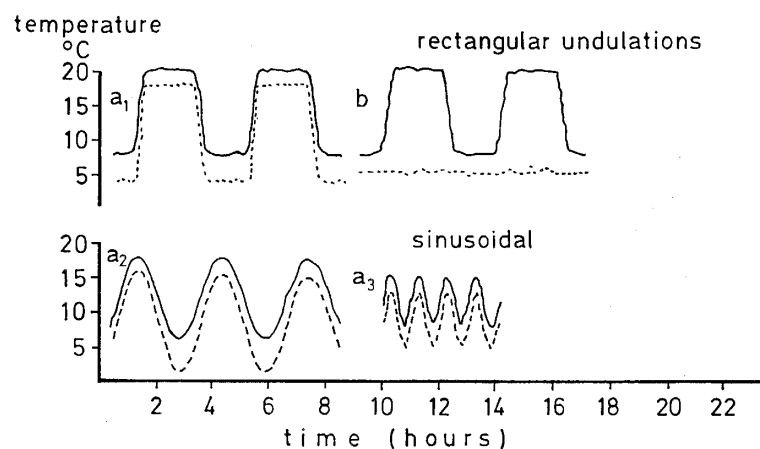

Fig. 3. Observed values of air (——) and dewpoint (------) temperature with controlled oscillating set points. a) oscillating air temperature and dewpoint temperature, constant water vapour deficiency. b) oscillating air temperature, constant dewpoint temperature with corresponding oscillating water vapour deficiency.

—plant fresh weight measured by the electric balance

—leaf area and pattern area, respectively, measured by digital image analyses (g)

—diameter of tubers, stems or fruits measured by linear voltage displacement transducer

Of main importance is the adaptive control algorithm developed by Tantau (unpublished data). In combination with the microcomputer it allows to work with sinusoidal or rectangular time courses of different frequencies and amplitudes for irradiance (Fig. 2) as well as air temperature or dewpoint temperature (Fig. 3). The effectiveness and limits of on-line measuring of plant weight, leaf growth and diameters as well as modeling plant growth will be published later.

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