ANALYSIS OF ENVIRONMENTAL CHARACTERISTICS IN URBAN-TYPE PLANT FACTORY

J. E. Son, J. S. Park and H. Lee

Department of Horticulture, College of Agriculture and Life Sciences
Seoul National University, Suwon , Kyunggi-Do 441-744, Korea
E-mail: sjeenv@snu.ac.kr

ABSTRACT

The characteristics of CO_2 exchange between plant and human modules, absorption rate of NO_2, and growth of lettuce were examined in an urban-type plant factory(UPF). With 150 lettuce plants, CO_2 concentrations of plant module were 600~700μmol·mol^{-1} at average leaf weight of 130g·plant^{-1} and 900~1100μmol·mol^{-1} at 75g·plant^{-1} for one and two persons' stay in the human module, respectively. When the air of 0.13, 0.30 and 0.45 μmol·mol^{-1} NO_2 in a human module was circulated ON/OFF 10/20min between the human and plant modules, NO_2 decrement in the chamber during 10 min was 0.040, 0.109, and 0.149 μmol, respectively. The lettuces grown at 0.45 μmol·mol^{-1} NO_2 during experimental period showed no significant differences in growth factors such as leaf width, leaf length, leaf area and fresh weigh, and in the quality between treated and control.

Key words: urban-type plant factory, air purification, CO_2 utilization, NO_2

INTRODUCTION

Environments of building have been worse and concerns about air pollution have been increased. Utilization of surplus CO_2 generated in the building for crop production and purification of indoor air by crops would be effective to the human in terms of food production and environmental improvement. Generally CO_2 concentrations in the building were 400-1300 μmol·mol^{-1} at cooling season and 600-1500 μmol·mol^{-1} at heating season (Son and Park, 1996). Especially CO_2 concentration in the office was the lowest at 8:30 a.m. before people arrived at work and the highest at10:00 and 15:00 during the day. The pattern of CO_2 change in a day coincided with the photosynthesis cycle for plants during the daytime (Park *et al.*, 1994; Son

and Park, 1996). It was suggested that the surplus CO_2 could be applied to the plant and the O_2 emitted from plants could be used for the human by exchanging air between plant and human modules (Daunicht, 1996; Gitelson and Okladnikov, 1996; Son *et al.*, 1999). In this study, the characteristics of CO_2 exchange between plant and human modules, absorption rate of NO_2, and growth of lettuce were examined in an ecologically semi-closed plant production system like the urban-type plant factory.

MATERIAL AND METHODS

Urban-type plant factory (UPF) sytem. A system consists of human and plant module of $32m^3$ each, and designed to use the carbon dioxide from human module for plant growth and to return the cleaned air to human module. Time constant, presenting controlled characteristics of the system, was 3.5min. Ventilation numbers were $0.407hr^{-1}$ with air circulation and $0.086hr^{-1}$ without in two modules. CO_2, ranging 600~1200 $\mu mol \cdot mol^{-1}$ was added to the human module with a CO_2 changing pattern occurring in the office. Two fans always agitated the air in the chamber.

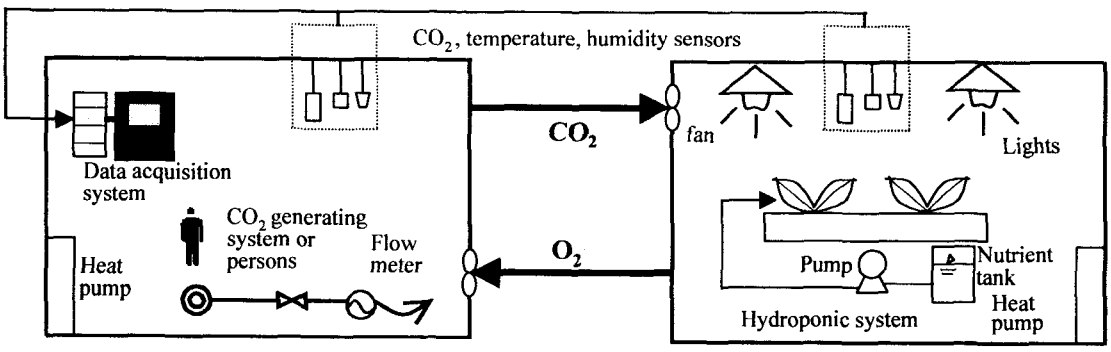

Fig. 1. Schematic diagram of the urban-type plant factory system constructed for the experiment.

Plant materials. 'Chungchima' leaf lettuce (*Lactuca sativa L.*) seeds were germinated on polyurethane cubes moistened with tap water and grown hydroponically in PE house with controlled temperature. The photosynthetic photon flux density (PPFD) was 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at the top of the plants. The light period was 12 hours per day. Air temperature in the plant module was maintained at 25±1C° during daytime and 18±1C° during nighttime.

NO_2 fumigation. The set values of NO_2 concentrations in the human module were 0.15, 0.3 and 0.45 $\mu mol \cdot mol^{-1}$. These values were controlled by a controller with an electric-luminescent NO_2 analyzer (Mapo industry Co., HS 1000, KO), which has output signals. The air in two modules

was circulated by diaphragm ON/OFF 10/20 min during the daytime with maintaining 0.15, 0.3 and 0.45 $\mu mol \cdot mol^{-1}$ NO_2 in each human module.

Measurement. The photosynthetic rate of the lettuces was measured with photosynthesis analyzer (LI-COR, 6400, USA) attached standard CO_2 gas. After the experiment, differences in leaf width, leaf length, leaf area and fresh weight of lettuce between NO_2 treatment and control were compared. Sensors were interfaced with a CR-23 digital and analog input/output controller (Campbell Co, CR-23, USA). This signal conversion relay system communicated with a dedicated control computer over a RS-232 communication link

RESULTS AND DISCUSSION

CO_2 was supplied to human module and the changes of CO_2 concentration in the plant and human modules under 30 min's fan-on and 30 min's fan-off conditions were observed. With the fan ON, the air of plant module and human module started to be circulated between two modules, and CO_2 concentration in both module rapidly reached to same level within 7-8min. After the fan OFF, CO_2 concentrations gradually increased in the plant module by photosynthesis and decreased in the human modules by CO_2 supply equal to the respiration rate (Fig. 2). In this system, different ventilation numbers of $0.407hr^{-1}$ with air circulation and $0.086hr^{-1}$ without in two modules were used, respectively.

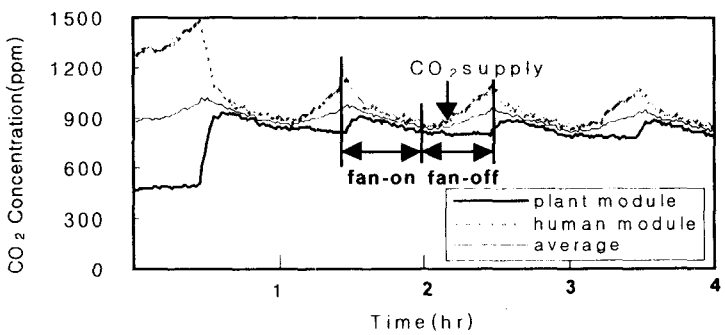

Fig. 2. Change of CO_2 concentration in the plant and human module with intermittent CO_2 supplies.

The UPF's CO_2 characteristics satisfying CO_2 condition of an office in the city were executed in the system. We assumed attendance time to be 8:00, lunchtime from 12:00 to 13:00 and leaving time to be 18:00 in the experiment (Fig. 3). CO_2 concentrations of plant module in

which 150 lettuce plants were grown, were 600~700μmol·mol^{-1} at average leaf weight of 130g·plant^{-1} and 900~1100μmol·mol^{-1} at 75g·plant^{-1} for one and two persons' stay in the human module, respectively. Moreover, the increment of oxygen was 1500μmol·mol^{-1} in plant module due to photosynthesis at average leaf weight of 85g·plant^{-1}.

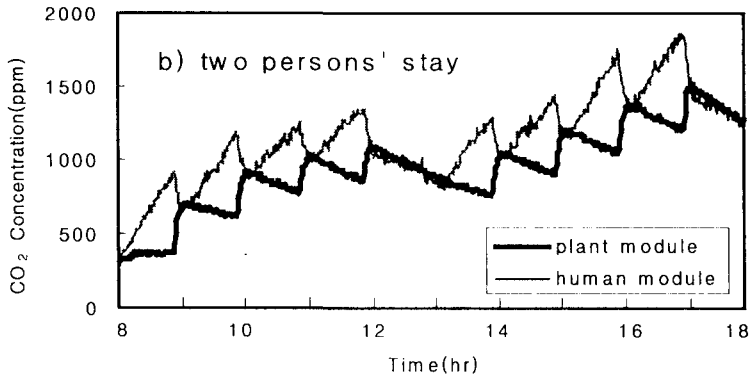

Fig. 3. Changes of CO_2 concentrations without plants in the plant and human modules under 10 min's fan-on and 50 min's fan-off conditions.

Photosynthetic rate of lettuce was measured at 15:00 every day for 5 days. The photosynthetic rate at 0.45 μmol·mol^{-1} NO_2 was lower than control at 4th and 5th days, but no significant difference showed at 0.30 μmol·mol^{-1} NO_2 or less . It is possible that the lettuce treated with 0.45 μmol·mol^{-1} concentration will become a little injured time passes. After the experiment, significant differences in the leaf width, the leaf length, the leaf area and the fresh weigh of the lettuces also were not found (Table 1).

Table 1. Leaf width, length, weight and area of lettuce grown at different NO_2 concentration during 5 days.

NO_2 conc. (ppm)	leaf width (cm)	leaf length (cm)	leaf weight (g)	Leaf area (cm^2)
Control	8.2±0.20[x]	14.2±0.28	15.1±1.77	424±35.9
0.15	8.4±0.10	14.7±0.39	14.4±0.76	413±12.1
Control	9.0±0.62	15.7±0.53	15.1±0.68	459±11.1
0.30	8.6±0.65	15.0±0.56	13.8±1.43	413±25.6
Control	8.9±0.33	17.9±0.40	14.2±1.66	449±41.4
0.45	9.3±0.12	16.7±0.20	14.6±0.29	452±9.9

[x]Means±SE, n=3.

CONCLUSION

An urban-type plant factory (UPF) consisting of human and plant module was designed to use the carbon dioxide from human module for plant growth and to return the cleaned air to human module. The pattern of CO_2 change in the UPF system similar to the photosynthesis cycle for plants during the daytime was realized. The lettuce in the plant module was well grown in the system using the CO_2 generated from the human module. And also the lettuce purified NO_2 gas generated from the human module The growth of lettuce had no difference between NO_2 treatment and control and showed no visible injury in either. It is, therefore, concluded that the urban-type plant factory can accomplish the function of plant production and ambient purification at the same time.

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