

## GROWTH OF LETTUCE PLANTS (LACTUCA SATIVA L.) UNDER CONTROL OF DISSOLVED O<sub>2</sub> CONCENTRATION IN HYDROPONICS

Yoshida, Satoshi  
Biotron Institute Kyushu University

Kitano, Masaharu  
Biotron Institute Kyushu University

Eguchi, Hiromi  
Biotron Institute Kyushu University

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## GROWTH OF LETTUCE PLANTS (*LACTUCA SATIVA* L.) UNDER CONTROL OF DISSOLVED O<sub>2</sub> CONCENTRATION IN HYDROPONICS

S. YOSHIDA, M. KITANO and H. EGUCHI

*Biotron Institute, Kyushu University 12, Fukuoka 812-8581, Japan*

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YOSHIDA, S., KITANO, M. and EGUCHI, H. *Growth of lettuce plants (Lactuca sativa L.) under control of dissolved O<sub>2</sub> concentration in hydroponics*. BIOTRONICS 26, 39-45 1997. The effect of dissolved O<sub>2</sub> concentration on growth of lettuce plants (*Lactuca sativa* L.) was analyzed in hydroponics. The plants were grown for 7 days under different dissolved O<sub>2</sub> concentrations controlled at 0.01, 0.10 and 0.20 mM. Number of leaves was scarcely affected by the dissolved O<sub>2</sub> concentration, but leaf expansion was depressed at 0.01 mM where leaf water content became lower. Furthermore, the fresh and dry weights of leaves and roots were clearly reduced at 0.01 mM. On the other hand, difference in plant growth between 0.10 and 0.20 mM was scarcely found. These results suggest that growth of the lettuce plants at the lowest dissolved O<sub>2</sub> concentration of 0.01 mM is depressed through leaf turgor loss caused by decrease in root water uptake.

**Key words:** lettuce plants, *Lactuca sativa* L.; dissolved O<sub>2</sub> concentration; hydroponics; leaf expansion; plant growth; root function.

### INTRODUCTION

Decrease in dissolved O<sub>2</sub> concentration in poor-aerated nutrient solution in hydroponics causes inhibition of root cell division and decrease in root elongation (1, 3). Furthermore, decline in leaf water potential and reduction in stomatal conductance have been found at lower dissolved O<sub>2</sub> concentrations (5, 7). These effects of dissolved O<sub>2</sub> concentration can be considered to relate to root physiological functions such as respiration and water uptake. In the previous studies (9, 10, 11), water uptake and growth in cucumber plants were analyzed under control of dissolved O<sub>2</sub> concentration, and it has been found that decrease in water uptake at lower dissolved O<sub>2</sub> concentrations reduces leaf growth through plant water status. Chun and Takakura have reported that root respiration in lettuce plants is depressed at lower dissolved O<sub>2</sub> concentrations (2). The present paper deals with growth analysis of lettuce plants under control of dissolved O<sub>2</sub> concentration in hydroponics.

## MATERIAL AND METHODS

### Plant materials

Lettuce plants (*Lactuca sativa* L. cv. Okayama-Saradana) were hydroponically grown at air temperature of 23°C and relative humidity of 70% in photoperiod of 12 h (8:00–20:00). The composition of nutrient solution was  $\text{Mg}^{2+}$ , 1.86;  $\text{Ca}^{2+}$ , 4.10;  $\text{K}^+$ , 7.63;  $\text{H}_2\text{PO}_4^-$ , 1.69;  $\text{NO}_3^-$ , 15.42;  $\text{NH}_4^+$ , 1.61 with iron-EDTA and micronutrients. Five-leaf-stage plants were used for growth analysis under control of dissolved  $\text{O}_2$  concentration, where streptomycin of 0.25 mM was applied to the nutrient solution for preventing microbial propagation.

### Control of dissolved $\text{O}_2$ concentration

Figure 1 shows schematic diagram of a hydroponic system developed for controlling dissolved  $\text{O}_2$  concentration (9). A material plant was transplanted in a stainless-steel pot which was filled with the nutrient solution. The pot was air-sealed by using rubber stoppers and Vaseline for setting the plant. For control of dissolved  $\text{O}_2$  concentration in the pot, air-saturated nutrient solution in an aeration tank was supplied to the pot according to respiratory  $\text{O}_2$  uptake in roots. Flow of the air-saturated nutrient solution into the pot was regulated with on-off action of a peristaltic pump by using a feedback signal of the dissolved  $\text{O}_2$  concentration measured by a polarographic  $\text{O}_2$  sensor (DO-4, Tokyo Rikakikai Co., LTD). The nutrient solution overflowing from the pot was returned into the aeration tank. The dissolved  $\text{O}_2$  concentration was controlled at the respective set values of 0.01, 0.10 and 0.20 mM with an accuracy of  $\pm 0.005$  mM. Controlled values of the dissolved  $\text{O}_2$  concentration were

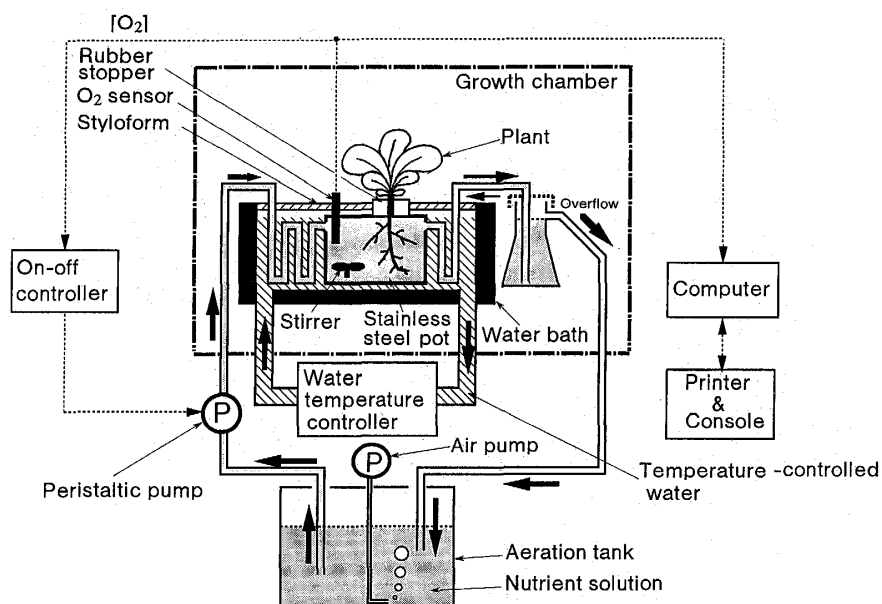


Fig. 1. Schematic diagram of a control system of dissolved  $\text{O}_2$  concentration in hydroponics.

transmitted to a computer. In the root environment, temperature of the nutrient solution was kept 23°C in a temperature-controlled water bath. For control of the aerial environment, the hydroponic system was installed in an artificial light growth chamber with air temperature of 23°C and relative humidity of 70%, PPFD of 300  $\mu\text{mol m}^{-2}\text{s}^{-1}$  and photoperiod of 12 h (8 : 00–20 : 00).

#### Growth analysis

Leaf area ( $LA$ ;  $\text{cm}^2$ ) in the plants grown at the respective dissolved O<sub>2</sub> concentrations was evaluated at intervals of 2 days: Length ( $LL$ ; cm) and width ( $LW$ ; cm) of each leaf were measured non-destructively, and  $LA$  of each leaf was calculated on the basis of the predetermined relationship of  $LA = 0.7 \times LL \times LW - 2.4$ . After growing for 7 days, fresh and dry weights per plant were measured in leaves and roots of the plants.

### RESULTS AND DISCUSSION

Figure 2 shows time course patterns of number of leaves in lettuce plants grown at 0.01, 0.10 and 0.20 mM of dissolved O<sub>2</sub> concentrations. Differences in number of leaves among these dissolved O<sub>2</sub> concentrations were not significant at 5% level. Thus, increase in number of leaves was scarcely affected by the dissolved O<sub>2</sub> concentration. Figure 3 shows time course patterns of leaf area per plant. The leaf areas at 0.10 and 0.20 mM rapidly increased, but slower increase

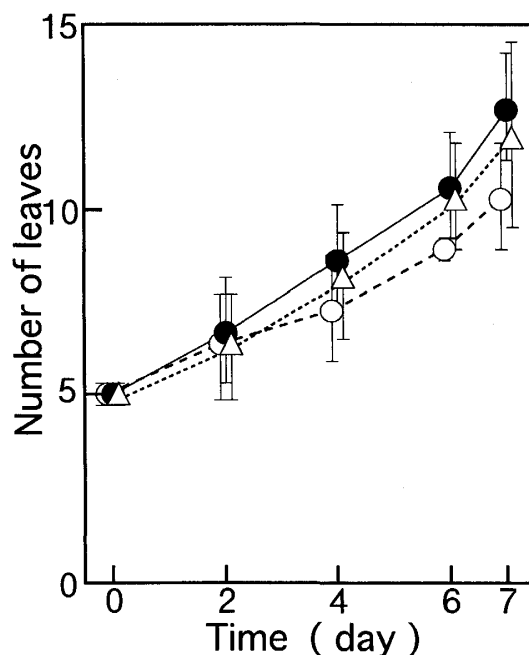


Fig. 2. Time course patterns of number of leaves in lettuce plants grown at dissolved O<sub>2</sub> concentrations of 0.01 (○), 0.10 (△) and 0.20 (●) mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

was clearly found at 0.01 mM. By using the lettuce plants grown for 7 days, characteristics of the plant growth was examined in detail. Figure 4 shows distribution of area of each leaf along the stem. The leaf area at 0.01 mM was smaller than those at 0.10 mM and 0.20 mM. Thus, expansion of each leaf was depressed at 0.01 mM, and this fact resulted in the reduced leaf area per plant.

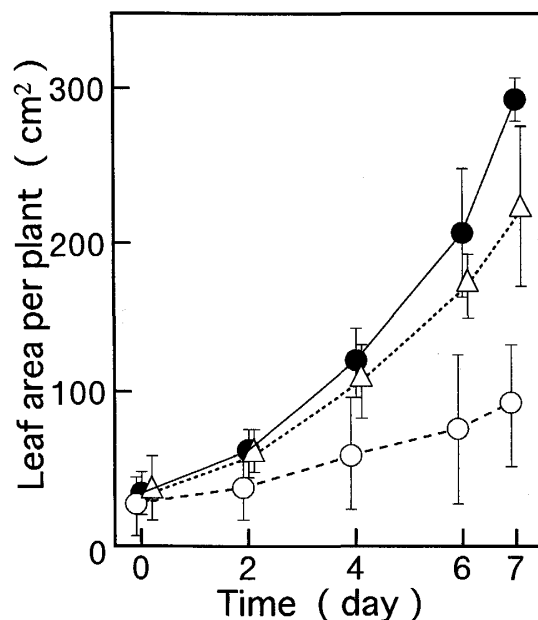


Fig. 3. Time course patterns of leaf area in lettuce plants grown at dissolved  $O_2$  concentrations of 0.01 ( $\circ$ ), 0.10 ( $\triangle$ ) and 0.20 ( $\bullet$ ) mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

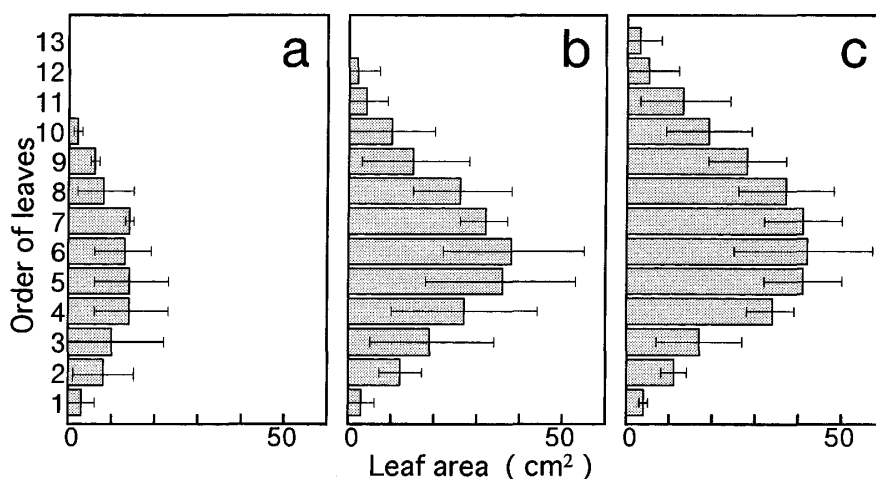


Fig. 4. Distribution of area of each leaf in order of leaves in lettuce plants grown for 7 days at dissolved  $O_2$  concentrations of 0.01 (a), 0.10 (b) and 0.20 (c) mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

Figure 5 shows fresh weight, dry weight and water content in leaves. The fresh and dry weights at 0.01 mM became lower than those at 0.10 and 0.20 mM. Leaf water content at 0.01 mM, where the leaf expansion was clearly depressed, was lower than those at 0.10 and 0.20 mM, and the differences were significant at 5% level. Figure 6 shows fresh weight, dry weight and water content in roots. The fresh and dry weights of roots at 0.01 mM became lower than those at 0.10 and 0.20 mM, but the differences between 0.10 and 0.20 mM were not found significantly. The root water content was not affected by the dissolved O<sub>2</sub> concentration. Thus, growths of leaves and roots were clearly depressed at the lowest dissolved O<sub>2</sub> concentration of 0.01 mM.

Figure 7 shows photographs of lettuce plants grown for 7 days under the controls of dissolved O<sub>2</sub> concentration. Even at 0.01 mM where the growths of leaves and roots are depressed, symptoms of chlorosis and root rot were not found in the general view of the plant. In cucumber plants grown in O<sub>2</sub>-deficient nutrient solution, it has been found that O<sub>2</sub> in the aerial environment is transported through leaves for root respiration (8). Therefore, it is possible in the lettuce plants that the transported O<sub>2</sub> can contribute to the root respiration to some extent. At 0.10 mM, the plant was grown vigorously, and the significant difference in plant growth between 0.10 and 0.20 mM was not found. This fact suggests that the root respiration sufficient for active root functions is maintained even at 0.10 mM which is equivalent to 38% of the dissolved O<sub>2</sub> concentration in air-saturated solution at 23°C.

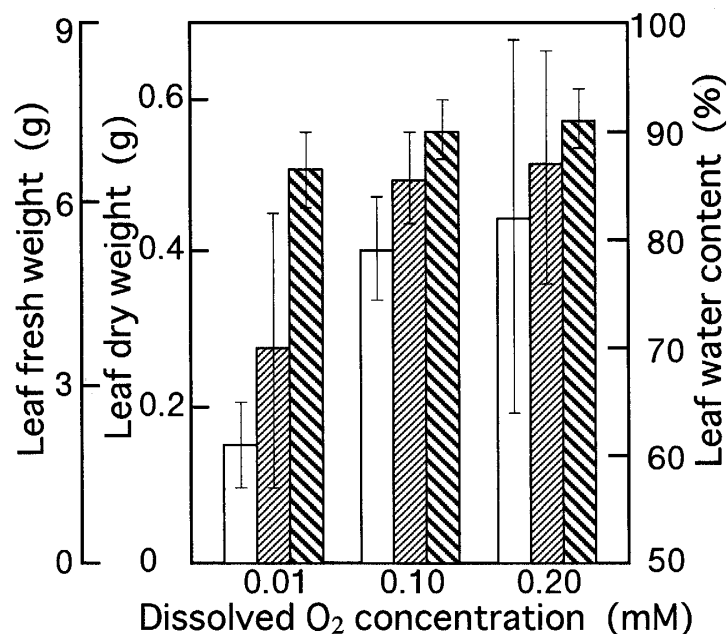


Fig. 5. Fresh weight (□), dry weight (▨) and water content (▩) of leaves in lettuce plants grown for 7 days at dissolved O<sub>2</sub> concentrations of 0.01, 0.10 and 0.20 mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

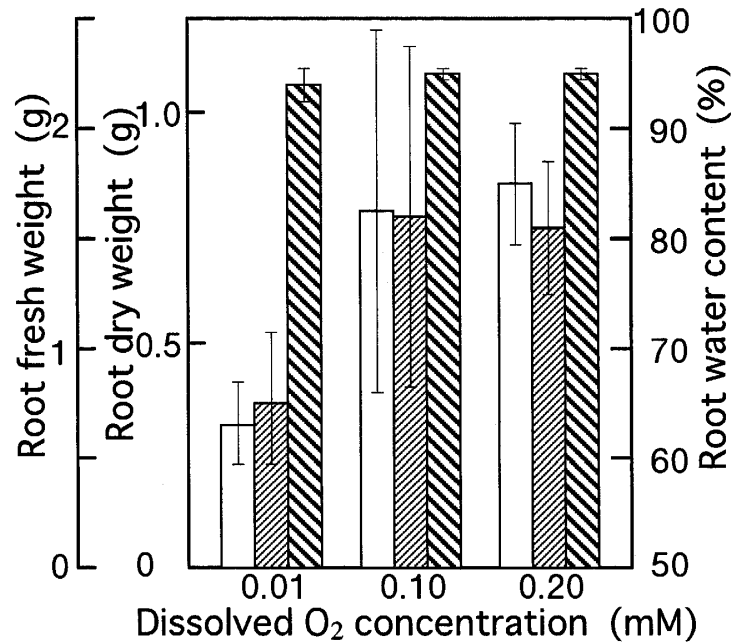


Fig. 6. Fresh weight (□), dry weight (▨) and water content (▩) of roots in lettuce plants grown for 7 days at dissolved O<sub>2</sub> concentrations of 0.01, 0.10 and 0.20 mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

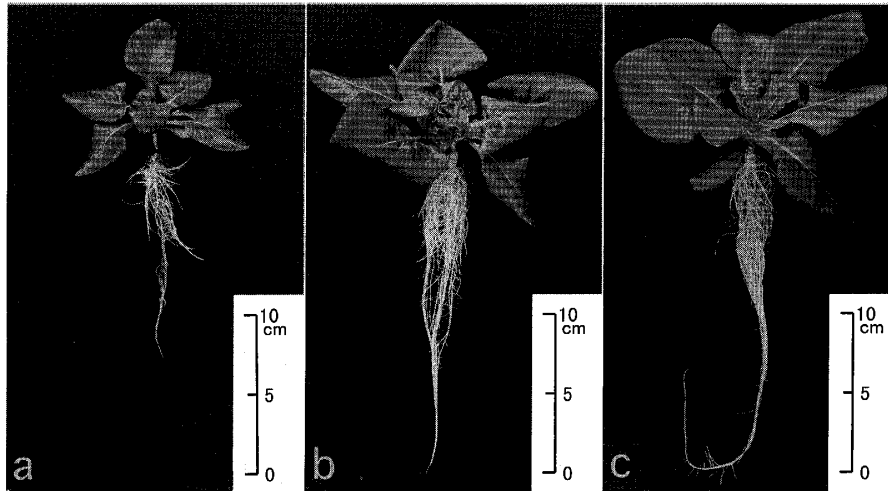


Fig. 7. Photographs of lettuce plants grown for 7 days at dissolved O<sub>2</sub> concentrations of 0.01 (a), 0.10 (b) and 0.20 (c) mM.

Root respiration in lettuce plants is reduced in O<sub>2</sub>-deficient nutrient solution (2). It has been found that root water uptake in cucumber plants is depressed at lower dissolved O<sub>2</sub> concentrations (9). The root water uptake is limited mainly by radial hydraulic resistance which depends on water transport across cell membrane in roots (4). These facts suggest that water permeability of the cell membrane is reduced at lower dissolved O<sub>2</sub> concentrations through

respiration-dependent processes. It can be considered that the depressed root water uptake at lower dissolved O<sub>2</sub> concentrations results in leaf turgor loss which causes decrease in leaf expansion (6). In cucumber plants, depression of root water uptake, lower leaf water content and decrease in leaf expansion have been found at lower dissolved O<sub>2</sub> concentrations (9, 10, 11). In the present study, growth and water content of the lettuce leaves were clearly reduced at the lowest dissolved O<sub>2</sub> concentration of 0.01 mM. From the results, it is suggested that growth of the lettuce plants at 0.01 mM is depressed through leaf turgor loss caused by decrease in root water uptake.

#### REFERENCES

1. Atwell, B. J., Thomson, C. J., Greenway, H., Ward, G. and Waters, I. (1985) A study of the impaired growth of roots of *Zea mays* seedlings at low oxygen concentrations. *Plant Cell Environ.*, 8: 179-188.
2. Chun, C. and Takakura, T. (1994) Rate of root respiration of lettuce under various dissolved oxygen concentrations in hydroponics. *Environ. Control in Biol.* 32: 125-135.
3. Giménez-Abian, M. I., De La Torre, C. and López-Sáez, J. F. (1987) Growth and cell proliferation in *Allium* roots at different oxygen tensions. *Environ. Exp. Bot.* 27: 233-237.
4. Nagano, T., Ishida, T. and Morita, S., (1993) Internal plant-water-status and its control (4): Resistances to water flow through some root systems (Japanese with English summary). *Environ. Control in Biol.* 31: 147-153.
5. Neuman, D. S. and Smit, B. A. (1991) The influence of leaf water status and ABA on leaf growth and stomata of *Phaseolus* seedlings with hypoxic roots. *J. Exp. Bot.* 42: 1499-1506.
6. Lockhart, J. A. (1965) An analysis of irreversible plant cell elongation. *J. Theor. Biol.* 8: 264-275.
7. Smit, B., Stachowiak, M. and Van Volkenburgh, E. (1989) Cellular processes limiting leaf growth in plants under hypoxic root stress. *J. Exp. Bot.* 40: 89-94.
8. Yoshida, S. and Eguchi, H. (1994) Environmental analysis of aerial O<sub>2</sub> transport through leaves for root respiration in relation to water uptake in cucumber plants (*Cucumis sativus* L.) in O<sub>2</sub>-deficient nutrient solution. *J. Exp. Bot.* 45: 187-192.
9. Yoshida, S., Kitano, M. and Eguchi, H. (1996) Water uptake in cucumber plants (*Cucumis sativus* L.) under control of dissolved O<sub>2</sub> concentration in hydroponics (Japanese with English summary). *Environ. Control in Biol.* 34: 53-58.
10. Yoshida, S., Kitano, M. and Eguchi, H. (1996) Growth analysis of cucumber plants (*Cucumis sativus* L.) under control of dissolved O<sub>2</sub> concentration in hydroponics (Japanese with English summary). *Environ. Control in Biol.* 34: 223-229.
11. Yoshida, S., Kitano, M. and Eguchi, H. (1996) Water uptake and growth of cucumber plants (*Cucumis sativus* L.) under control of dissolved O<sub>2</sub> concentration in hydroponics. *Acta Hort.* 440: 199-204.