GROWTH OF LETTUCE PLANTS (LACTUCA SATIVA L.) UNDER CONTROL OF DISSOLVED O_2 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_2 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_2 concentration in hydroponics*. BIOTRONICS **26**, 39–45 1997. The effect of dissolved O_2 concentration on growth of lettuce plants (*Lactuca sativa* L.) was analyzed in hydroponics. The plants were grown for 7 days under different dissolved O_2 concentrations controlled at 0.01, 0.10 and 0.20 mM. Number of leaves was scarcely affected by the dissolved O_2 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_2 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_2 concentration; hydroponics; leaf expansion; plant growth; root function.

INTRODUCTION

Decrease in dissolved O_2 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_2 concentrations (*5, 7*). These effects of dissolved O_2 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_2 concentration, and it has been found that decrease in water uptake at lower dissolved O_2 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_2 concentrations (*2*). The present paper deals with growth analysis of lettuce plants under control of dissolved O_2 concentration in hydroponics.

MATERIAL AND METHODS

Plant materials

Lettuce plants (*Lactuca sativa* L. cv. Okayama-Saradana) were hydroponically grown at air temperature of 23℃ and relative humidity of 70% in photoperiod of 12 h (8:00–20:00). The composition of nutrient solution was Mg^{2+}, 1.86; Ca^{2+}, 4.10; K^{+}, 7.63; $H_2PO_4^{-}$, 1.69; NO_3^{-}, 15.42; NH_4^{+}, 1.61 with iron-EDTA and micronutrients. Five-leaf-stage plants were used for growth analysis under control of dissolved O_2 concentration, where streptmycin of 0.25 mM was applied to the nutrient solution for preventing microbial propagation.

Control of dissolved O_2 concentration

Figure 1 shows schematic diagram of a hydroponic system developed for controlling dissolved 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 O_2 concentration in the pot, air-saturated nutrient solution in an aeration tank was supplied to the pot according to respiratory 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 O_2 concentration measured by a polarographic O_2 sensor (DO-4, Tokyo Rikakikai Co., LTD). The nutrient solution overflowing from the pot was returned into the aeration tank. The dissolved O_2 concentration was controlled at the respective set values of 0.01, 0.10 and 0.20 mM with an accuracy of ±0.005 mM. Controlled values of the dissolved O_2 concentration were

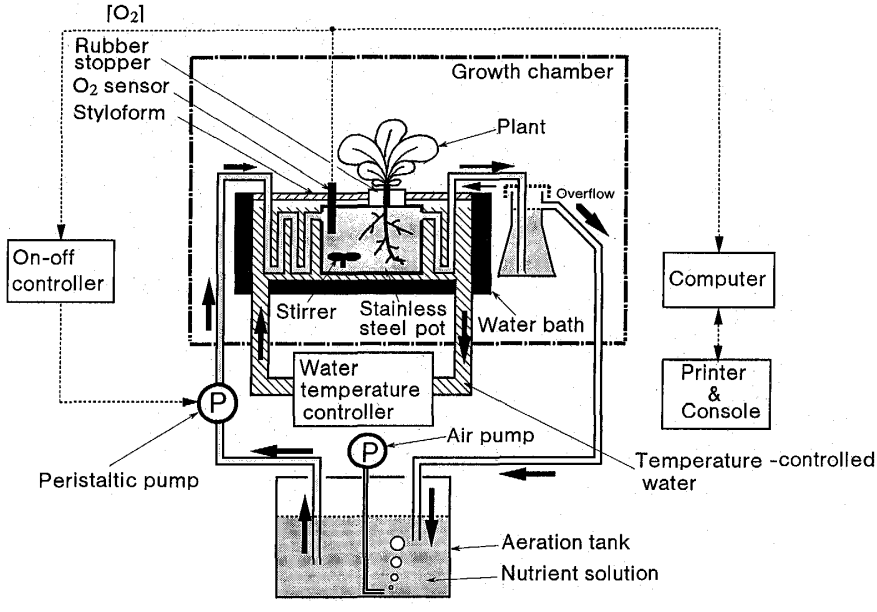

Fig. 1. Schematic diagram of a control system of dissolved O_2 concentration in hydroponics.

transmitted to a computer. In the root environment, temperature of the nutrient solution was kept 23℃ 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℃ and relative humidity of 70%, PPFD of 300 μmol $m^{-2}s^{-1}$ and photoperiod of 12 h (8 : 00–20 : 00).

Growth analysis

Leaf area (LA; cm^2) in the plants grown at the respective dissolved O_2 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_2 concentrations. Differences in number of leaves among these dissolved O_2 concentrations were not significant at 5% level. Thus, increase in number of leaves was scarcely affected by the dissolved O_2 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

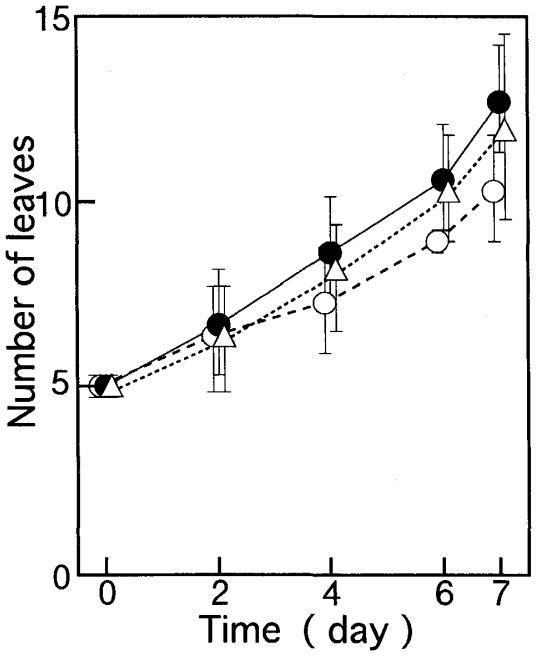

Fig. 2. Time course patterns of number of leaves in lettuce plants grown at dissolved O_2 concentrations of 0.01 (○), 0.10 (△) and 0.20 (●) mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

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.

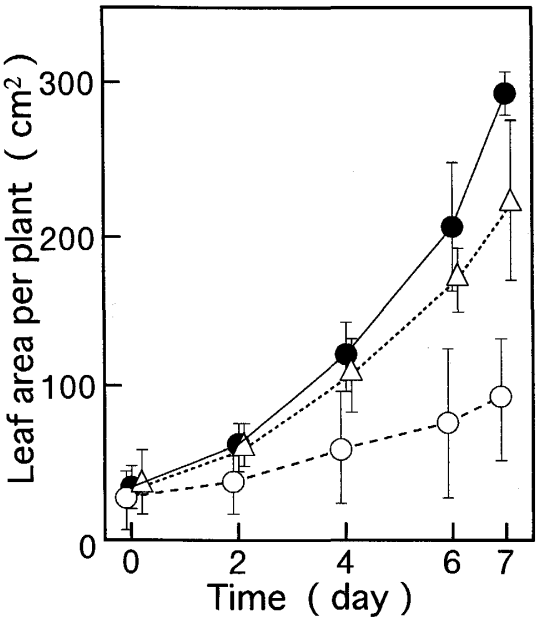

Fig. 3. Time course patterns of leaf area in lettuce plants grown at dissolved O_2 concentrations of 0.01 (○), 0.10 (△) and 0.20 (●) mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

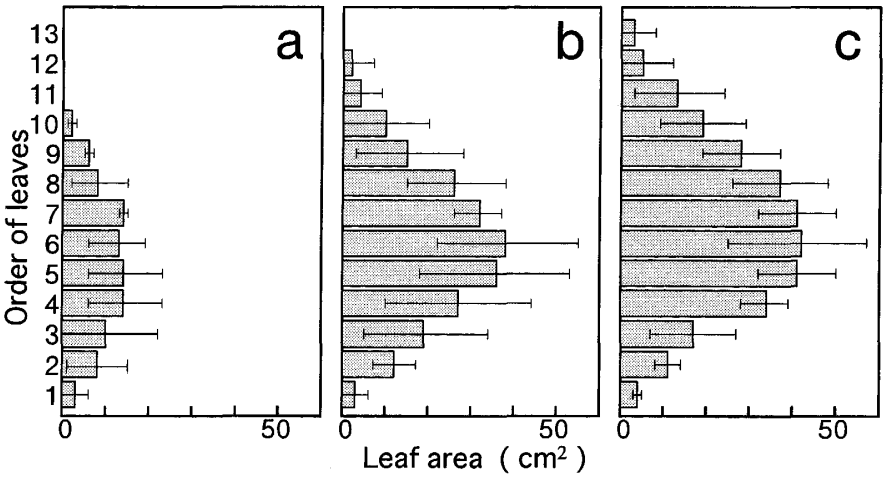

Fig. 4. Distribution of area of each leaf on order of leaves in lettuce plants grown for 7 days at dissolved O_2 concentrations of 0,01 (a), 0.10 (b) and 0.20 (c) mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

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_2 concentration. Thus, growths of leaves and roots were clearly depressed at the lowest dissolved O_2 concentration of 0.01 mM.

Figure 7 shows photographs of lettuce plants grown for 7 days under the controls of dissolved O_2 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_2-deficient nutrient solution, it has been found that O_2 in the aerial environment is transported through leaves for root respiration (*8*). Therefore, it is possible in the lettuce plants that the transported O_2 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_2 concentration in air-saturated solution at 23℃.

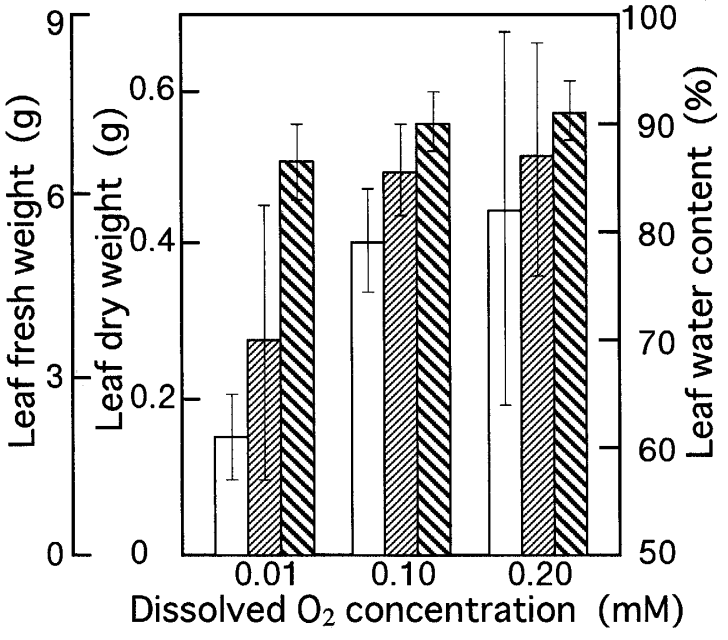

Fig. 5. Fresh weight (□), dry weight (▨) and water content (▩) of leaves in lettuce plants grown for 7 days at dissolved O_2 concentrations of 0.01, 0.10 and 0.20 mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

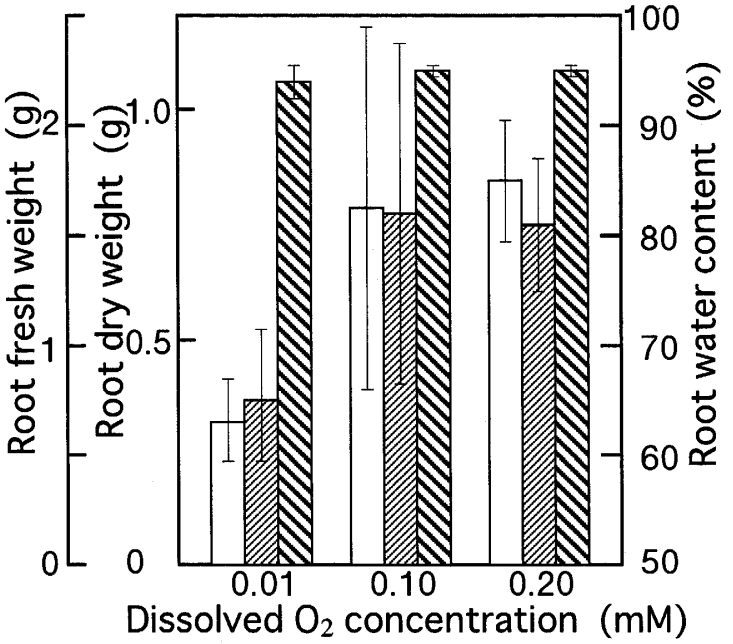

Fig. 6. Fresh weight (□), dry weight (▨) and water content (▩) of roots in lettuce plants grown for 7 days at dissolved O_2 concentrations of 0.01, 0.10 and 0.20 mM: The means of measured values in 3 plants are plotted with the respective 95% confidence limits.

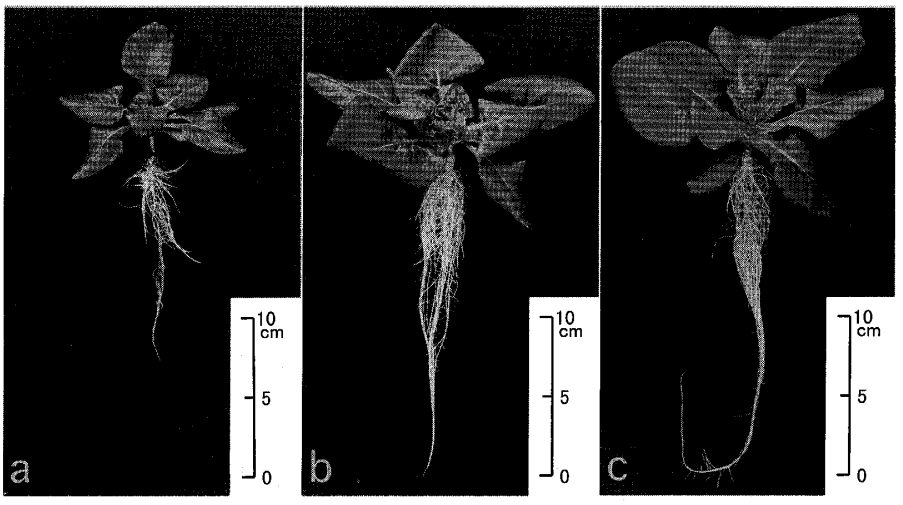

Fig. 7. Photographs of lettuce plants grown for 7 days at dissolved O_2 concentrations of 0.01 (a), 0.10 (b) and 0.20 (c) mM.

Root respiration in lettuce plants is reduced in O_2-deficient nutrient solution (*2*). It has been found that root water uptake in cucumber plants is depressed at lower dissolved O_2 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_2 concentrations through

respiration-dependent processes. It can be considered that the depressed root water uptake at lower dissolved O_2 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_2 concentrations (*9, 10, 11*). In the present study, growth and water content of the lettuce leaves were clearly reduced at the lowest dissolved O_2 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.

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