Effect of high consentrated dissolved oxygen on the plant growth in a deep hydroponic culture under a low temperature

A. Suyantohadi*, T. Kyoren*, M. Hariadi**,**
M.H. Purnomo, T. Morimoto*****

* *Agricultural Technology Faculty, University of Gadjah Mada (UGM)*
Sosioyustisia, Bulaksumur, Jogjakarta, Indonesia.
** *Dept of Electrical Engineering, Institut Teknologi Sepuluh November Surabaya (ITS)*
Keputih Sukolilo, Surabaya - Indonesia
*** *Dept of Biomechanical Systems, Ehime University, Tarumi, Matsuyama, Japan*

Abstract: In this study, the effect of high concentrated dissolved oxygen on the lettuce plant growth in a deep hydroponic culture under a low greenhouse temperature has been investigated. The nutrient solution containing 20-30 mg/*l* dissolved oxygen was made using an Oxygen Enricher. From the Henry's law, the solubility of oxygen in the air mainly depends on water temperature and the partial pressure of oxygen in the air. This high concentrated dissolved oxygen is made by passing the nutrient solution in the high-pressure pure oxygen gas (95% O_2). The study aimed to improve lettuces plant growth grown in hydroponic under a low temperature condition by applying the high concentrated dissolved oxygen to the nutrient solution at winter seasons from December to January. The average temperature of the nutrient solution was 12°C and the electric conductivity was 1.0 mS/cm. There is no heating treatment of the nutrient solution. Image processing techniques are used for measuring the leaf areas ratio on the lettuce plant growth. In the result, the lettuce plant growth treated by the high concentrated dissolved oxygen (23mg/*l*) is about 2.1 fold larger than that treated by the fully aeration of room air. Thus, it was found that the high concentrated dissolved oxygen (20-30 mg/*l*) supply was effective to improve the lettuce plant growth under a low greenhouse temperature in a deep hydroponic culture.

Keywords: High concentrated dissolved oxygen, deep hydroponic culture, growth improvement, image processing.

1. INTRODUCTION

The nutrient solution and its management are the cornerstone for a successful hydroponics system. The function of a hydroponics nutrient solution is to supply the plant roots with water, oxygen and essential mineral elements in soluble form. Hydroponic system has been concentrated on a cultivation technique for growing plants in highly oxygenated, nutrient enriched water rather than soil (Huttner and Barzvi 2003; Suhardiyanto et al. 2009). Nutrient solutions in the water for plant in hydroponic has conducted to supply the plant roots with water, oxygen and essential mineral elements in soluble form. Dissolved oxygen (DO) in plant growth indicated essential to root formation and root growth (Soffer and Burger 1988). On tomatoes plant, the high oxygen treatment could increase in plant growth as measured by shoot and root weights (Cherif et al. 1997).

In this study, the effect of high concentrated dissolved oxygen (20-30mg/*l*) on the lettuce plant growth in a deep hydroponic culture under a low greenhouse temperature is investigated using an oxygen enricher (Ehime Sanso, OD-110) and a pure high-pressured oxygen gas (95% O_2). In the oxygen enricher, the high concentrated dissolved oxygen is made by passing the nutrient solution in the high-pressure pure oxygen gas. The dissolved oxygen made by this method was also compared to other methods such as micro bubble and air pump techniques.

2. MATERIALS AND METHODS

Lettuce plants (*Lactuca sativa L.* cv. Legacy) grown in a deep hydroponic culture were used for experiment. They had been transferred on hydroponic conditions after 22 days and separated into two treatments: (A) high concentrated dissolved oxygen of 20-30 mg/*l*, obtained using an oxygen enricher (Ehime-sanso, OD-110) with a compressed pure oxygen gas (95% O_2), (B) normal dissolved oxygen of 7-8 mg/*l* as a control, obtained by the aeration of greenhouse air using an air pump. Micro bubble technique (Win corp., B-02) was also used for comparing to the efficiency of the Oxygen Enricher. The nutrient solution was made by mixing Otuska fertilizer NO.1 and NO.2 in a ratio of 3:2. The size of the deep hydroponic container for cultivation is W34×L50×H30cm. The nutrient concentration of the solutions was increased from 0.8 to 1.0 mS/cm according to the plant growth. The experiment has been done in the greenhouse, the department of Bio-mechanical System, Ehime University

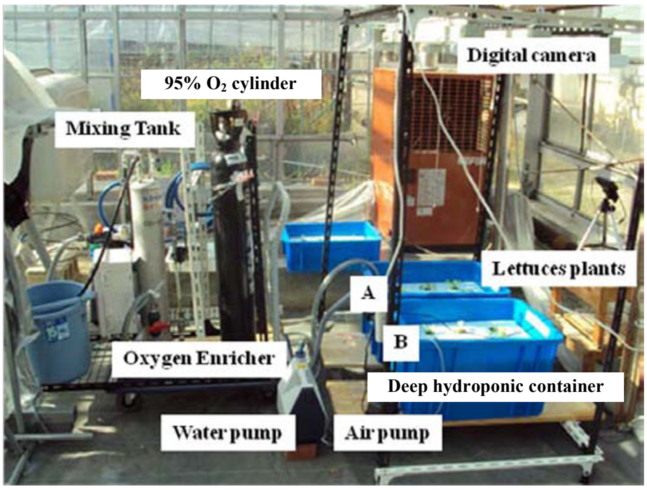

Fig. 1. Experimental apparatus. Oxygen Enricher, deep hydroponic lettuces and measuring system for plant growth.

A: High concentrated dissolved oxygen of 23 mg/*l*,
B: Control (Normal dissolved oxygen of 8.5 mg/*l*)

during a low temperature in winter season from November to January. The average temperature was 12°C. The water temperature was also low because of winter season. The average temperature in the greenhouse was about 12°C without controlling air temperature.

The high concentrated dissolved oxygen ranging from 20 to 30 mg/*l* was made using an oxygen enricher and a pure high-pressured oxygen gas (95% O_2). From the Henry's law, the solubility of oxygen in the air mainly depends on water temperature and the partial pressure of oxygen in the air. This high concentrated dissolved oxygen is made by passing the nutrient solution in the high-pressure pure oxygen gas. The high concentrated dissolved oxygen was measured using a DO meter (HANNA, HI-9147) which allows the measurement of DO ranging from 0 to 50 mg/*l*. The high concentrated dissolved oxygen has been maintenanced and supplied using an oxygen enricher during the experimental study in laboratory of greenhouses.

The lettuce plant growth has been obtained by measuring the leaf area using a digital camera and image processing system which is rarely low cost and also easy to use. Personal Computer and digital camera was used for capturing images on plant (Andersson 1998). The digital camera was positioned in the top of the hydroponic container to measure the lettuce plant growth. By source images captured with digital camera in 480×640 of pixels, the measurement by image processing includes the plant images, the detection of boundaries images, segmentation and calculated of areas of the plant. Digital video and camera can provide digital output, in progressive scan, delivering sequences of images that are readily processed. (Nixon and Aguado 2008). Image processing analysis for measuring areas of plant growth is used by toolbox of image processing Matrix Laboratory (Matlab) software. Image processing toolbox is power collection of functions that extend the capability make many image-processing operations easy to write in a compact, clear manner providing for the solution of image processing problems (Gonzales et al. 2004).

Figure 1 shows the experimental apparatus for this experiment. Oxygen enricher mainly consists of a pure (95%) O_2 cylinder and the mixing tank to dissolve the high concentrated oxygen in the nutrient solution. Two deep hydroponic containers for cultivation were set. One is used for control and the other for the treatment of high concentrated dissolved oxygen. The digital camera was positioned in the top of the hydroponic tray to measure the lettuce plant growth.

3. RESULTS AND DISCUSSION

Fundamental responses of the dissolved oxygen of the nutrient solution in the deep hydroponic container were investigated. Figure 2 shows responses of the dissolved oxygen obtained using three types of aeration methods. The closed circles, closed triangles and open circles are cases of oxygen enricher with the 95% O_2 gas, micro bubble with the 95% O_2 gas and air pump with greenhouse air (21% O_2), respectively. The oxygen enricher with the 95% O_2 gas was the most superior compared to two methods. It increased the dissolved oxygen to 23-25 mg/*l* in about 5 minutes.

Figure 3 shows the responses of decreasing the dissolved oxygen after stopping aerations. The bold solid, dotted, and fine solid lines show cases of the oxygen enricher, micro bubble and air pump, respectively. The oxygen enricher kept the dissolved oxygen at a high level for about 12 hours even after stopping aeration. On the other hand, the micro bubble method significantly decreased the dissolved oxygen at 2 hours after its stop. Thus, it is found that the oxygen enricher is effective to maintain the dissolved oxygen of the solution for a long term.

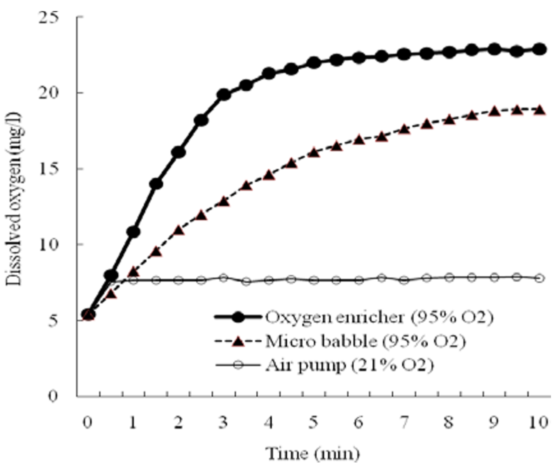

Fig. 2. Increases in the dissolved oxygen of the nutrient solution after applying three types of aerations.

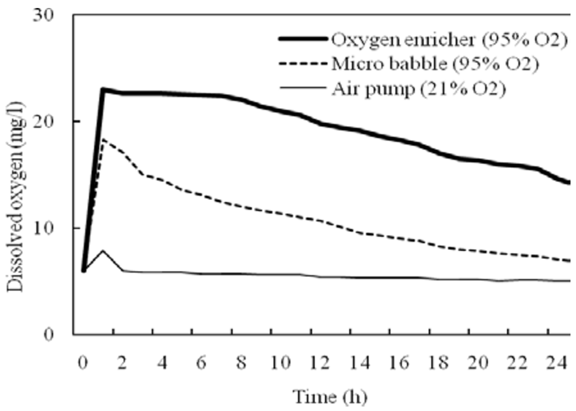

Fig. 3. Decreases in the dissolved oxygen of the nutrient solution after stopping three types of aerations.

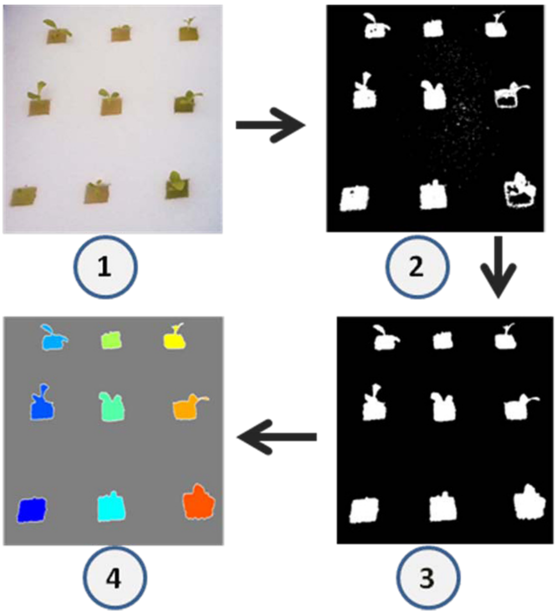

Fig. 4. The leaf areas of plant measuring using image processing software.

1. Source of Crop Images Dimension on 480×640 Pixels
2. Image detection of threshold of boundaries
3. Image segmentations
4. Calculate the percentage of plant growth areas

The areas of plant growth were obtained by digital camera and image processing system. The digital camera was positioned in the top of the box of hydroponic on lettuce plant growth. By source images captured with digital camera in dimension of 480×640 pixels, the measurement by image processing includes initially the crop of source images, the detection of boundaries images, the image segmentation for removing the noise and the result was calculated the percentage areas of plant. Figure 4 shows the processing of image for measuring of areas of lettuce plant growth by using image processing toolbox software of matlab.

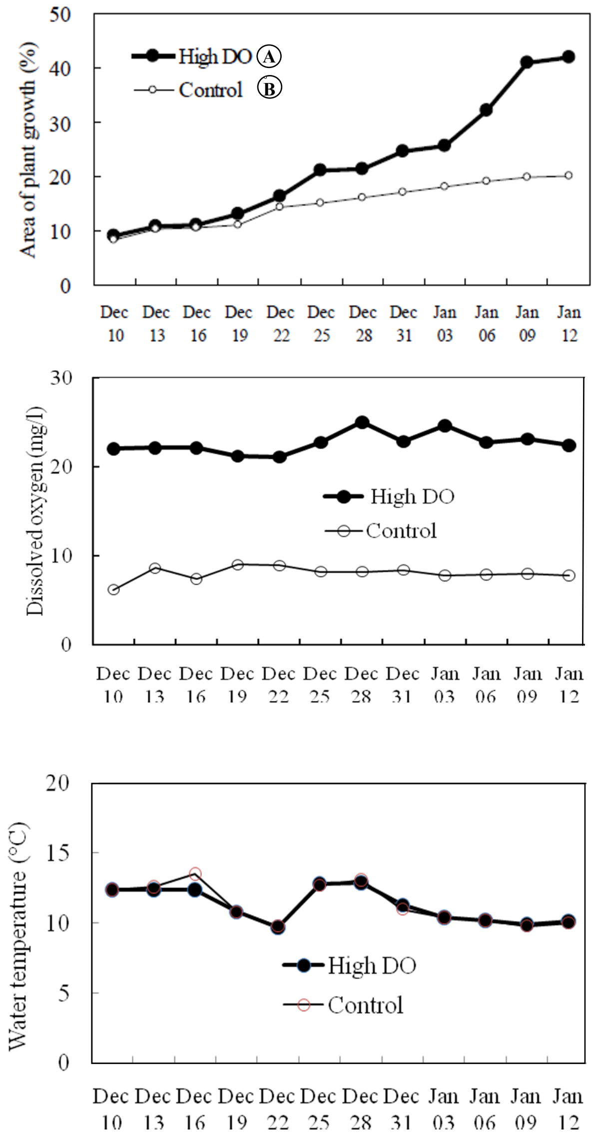

Fig. 5. Time course changes in the water temperature, dissolved oxygen of the nutrient solution and the leaf areas of lettuces plant growth between the high concentrated dissolved oxygen (A) and control (B).

Figure 5 shows time course changes in the dissolved oxygen of the hydroponic solution and the area (%) of plant growth. The high concentrated dissolved oxygen was kept constant by periodic manual operation of the oxygen enricher. The bold line with closed circle shows the plant growth grown in the high concentrated dissolved oxygen and the fine line with open circle shows that grown in normal dissolved oxygen. It is clear that the plant growth grown in the high concentrated dissolved oxygen was much larger than that grown in the normal dissolved oxygen.

Figure 6 show the ratio of plant growth. The values were obtained by dividing the plant growth in the high concentrated dissolved oxygen by that in the normal dissolved oxygen. It was found that the plant growth

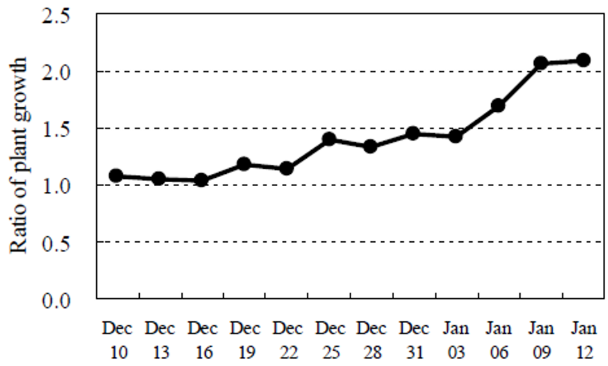

Fig. 6. Time course change in the ratio of lettuces plant growth between high concentrated dissolved oxygen and control.

grown in the high concentrated dissolved oxygen was 2.1 fold larger than that grown in the normal dissolved oxygen. These results indicated more effective for plant growth for comparing for them.

Figures 7 and 8 shows the photographs of lettuce plant growth on 46 and 60 days after transplanting in a low water temperature (12°C). The root system was also checked. Figure 9 shows the root conditions in both cases. No physiological disorders were observed in the shoot and roots in both cases.

From these figures, it is clear that the plant growth in the case of the high concentrated dissolved oxygen is markedly larger than that of the normal dissolved oxygen.

The dry weights of lettuce plant growth were also measured and compared. Figure 10 shows the comparison of the dry weight of lettuce plant growth in the high concentrated dissolved oxygen and control. The dry weight in the case of the high concentrated dissolved oxygen was 2.3 fold larger than control. This result suggests that the high concentrated dissolved oxygen of 20-30 mg/*l* is effective to promote the lettuce plants grown in deep hydroponic system. A and B of lettuces plant growth under hydroponic conditions is caused by the dissolved oxygen.

From the present study, it is effective by supply of high concentrated oxygen under hydroponic condition for plant growth. In these study, the focused for treatment on the experiment is by using the high oxygen concentrated supply to make the effect on the plant growth and the concentrated nutrition solutions regularly maintain on average 1.0 mS/cm by measuring with EC meter. The other factors such as temperature, humidity and intensity of light are with no controlling treatment (no heating and other treatment environments). The high concentrated oxygen supply in hydroponic plant growth after harvesting compared on the control is more differences between the roots and the leaf of lettuce plant growth.

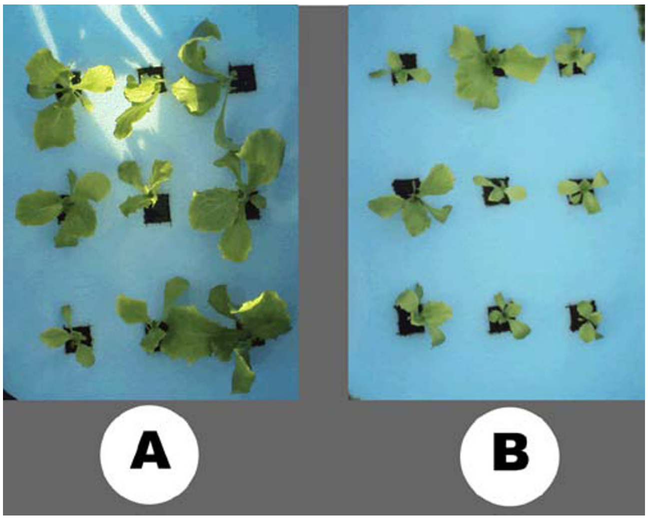

Fig. 7. The lettuce plant growth on 46 days after transplanting in a low water temperature (12°).

A: High concentrated dissolved oxygen of 23 mg/*l*,
B: Control (Normal dissolved oxygen of 8.5 mg/*l*)

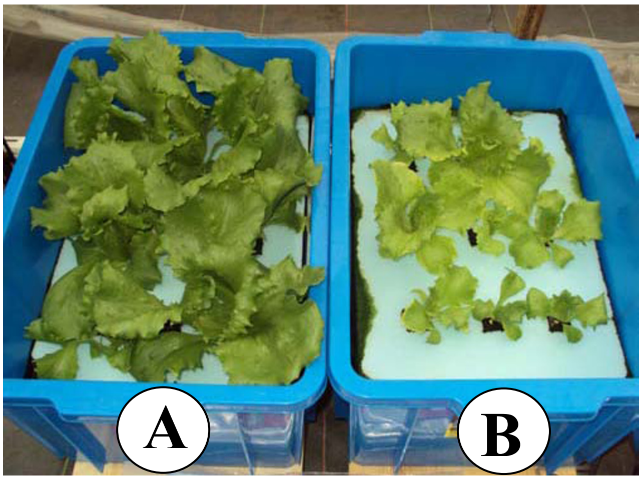

Fig. 8. The lettuce plant growth on 60 days after transplanting in a low water temperature (12°).

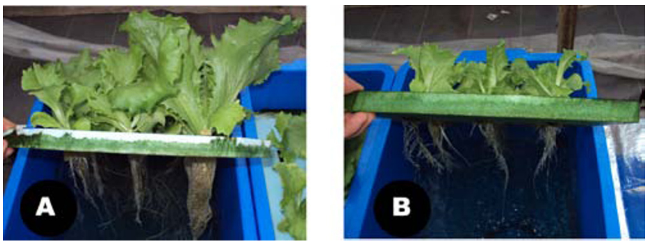

Fig. 9. The leafs and roots of lettuces plant growth on 60 days after transplanting in a low water temperature (12°) under hydroponic conditions.

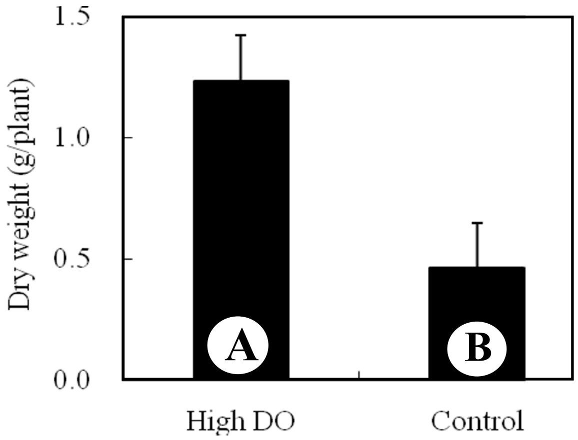

Fig. 10. Comparison of the dry weight of lettuce plant growth.

4. CONCLUSIONS

The lettuce plant growth treated by the high concentrated dissolved oxygen on A treatment that treated by the fully aeration of room air on B treatment showed the more big of areas for plant growth on the root, dry weight and the leaf of lettuces. It was found that the high concentrated dissolved oxygen by using in 20-30 mg/*l* supply was effective to improve the lettuce plant growth under a low greenhouse temperature in a deep hydroponic culture. The image processing was conducted in these study could be applied for measuring of leaf areas and ratio of lettuce plant growth during initial stage of plant to result on harvesting. This study is still focused for analysing on the effect of the treatment of high concentrated dissolved oxygen on monitored of the lettuces plant growth under hydroponic under a low temperate. The result has been investigated and more been developed using the control technology and more experimental design for improving study.

REFERENCES

Andersson, M. (1998). Weed and Crop Classification by Automated Digital Image Processing. Master Thesis, Department of Applied Electronics, Chalmers University of Technology.

Cherif, M., Y. Tirilly and R.R.B. Elanger (1997). Effect of oxygen concentration on plant growth, lipidperoxidation, and receptivity of tomato roots to *Pythium* F under hydroponic conditions. *European Journal of Plant Pathology,* 103, 255–264.

Gonzales, R.C., R.E. Wood and S.L. Edding (2004). *Digital Image Processing Using Matlab*, Pearson Prentice-Hall, New Jersey.

Huttner, D. and D. BarZvi (2003). An Improved, Simple, Hydroponic Method for Growing Adabidopsi thaliana. *Plant Molecular Biology Reporter,* 21, 59-62, *International Society Plant Moleculer Biology*, Canada.

Nixon, M.S. and A.S. Aguado (2008). *Feature Extraction and Image Processing, Second Edition*, Academic Press, London

Soffer, H. and D.W. Burger (1988). Effects of Dissolved Oxygen Concentrations in Aero-hydroponics on the Formation and Growth of Adventitious Roots. *Journal of the American Society for Horticultural*

Suhardiyanto, H. C. Arif and B.I. Setiawan (2009). Optimization of EC values of nutrient solution for tomato fruits quality in hydroponics system using artificial neural network and genetic algorithm, *ITB*.