

# 学位論文要旨

## Dissertation Abstract

氏名 : Diyah Yumeina  
Name

学位論文題目 : Modelings and optimal controls of plant responses of tomato plants to  
Title of environmental factors in hydroponics  
Dissertation (水耕トマトの環境要因に対する植物応答のモデル化と最適制御)

学位論文要旨 :  
Dissertation Abstract

Hydroponic culture is possibly the most intensive method of crop production in today's agricultural industry. Nowadays, various hydroponic culture techniques are used in advanced greenhouses and plant factories. These techniques were developed to optimize greenhouse environmental variables. To develop this optimization, shoot zone environment and root zone environment were chosen as plant control variables. The present work has focused on the optimal control of the root-zone environment, because controlling the root-zone environment is much easier, more efficient, and cost-effective.

Nevertheless, it is difficult to achieve the optimal control of root-zone environment, because interactions between plant responses and environmental factors are difficult to understand due to the complexity of physical and physiological processes. Intelligent control techniques have been proved that they are effective for controlling such complex process as physiological responses of the plant. In practice, measurement and identification (modelling) of plant responses and monitoring the physiological status of the plant, and then using this physiological information in making a decision on optimal strategy, are effective for optimizing cultivation processes.

A new intelligent control system was developed by Morimoto in 2000. It consists of a decision system and a feedback control system. The decision system determines the optimal set point of the root-zone environment using neural networks and genetic algorithms. In the system, neural networks are used for identifying (learning) plant responses to environmental factors and dynamic models are built. Then, genetic algorithms are used for searching for optimal set points of environmental factors which optimize the plant responses through simulation of the identified neural-network models. Finally, the optimal set points are applied to the set point of the feedback control system.

In this study, an intelligent control technique was applied to two optimization problems. One optimization was meant to promote initial plant growth of tomatoes in hydroponics, by controlling solution nutrient concentration. In this technique, the manipulating factor (control input) is the solution nutrient concentration whereas the controlled output is the growth rate of plant height in tomato cultivation. The estimated responses obtained from model simulation showed that the growth rate of plant height increased with nutrient concentration. However, the growth rate of plant height decreases

with nutrient concentrations in the range above  $0.9 \text{ dSm}^{-1}$ . The optimal 6-step set points of nutrient concentration was 1.0 for 1<sup>st</sup> step, 0.5 for the 2<sup>nd</sup> step, 0.8 for the 3<sup>rd</sup> step, 0.9 for the 4<sup>th</sup> step, 1.1 for the 5<sup>th</sup> step, and  $1.2 \text{ dSm}^{-1}$  for the 6<sup>th</sup> step during the initial growth stage. Afterwards, there was a significant reduction ( $0.5 \text{ dSm}^{-1}$ ) in nutrient concentration in the second step and this significant reduction corresponds to nutrient stress. In optimal control performance of plant growth, the growth rate of plant height was about 1.12 times higher with optimal control than with conventional control, and the fresh weight was also about 1.15 times larger with optimal control than with conventional control.

The other is optimization problem maximizes the leaf water content of tomatoes by controlling water temperature. The manipulating factor is water temperature and the controlled factor is the leaf water content of the tomato in hydroponics. The leaf water content was estimated from the leaf thickness. Moreover, the control length is short-term; less than 10 hours. Furthermore, the estimated responses obtained from model simulation showed that the leaf water content increased until the water temperature reached approximately  $35^{\circ}\text{C}$ , and then decreased with increasing water temperature. The optimal 5-step points of water temperature were  $\{40, 15, 40, 22, 30^{\circ}\text{C}\}$  under the constraint of  $10\text{-}40^{\circ}\text{C}$ . A combination of the sudden rise to  $40^{\circ}\text{C}$  and drops it to  $15^{\circ}\text{C}$  had showed a tendency to increase the leaf water content of the plant, compared to when the water temperature was maintained at the suitable level ( $30^{\circ}\text{C}$ ) over the control process. Applying this optimal manipulation to a real system increased leaf water content by 1.3 times.

Thus, this dissertation demonstrates that a control method that changes flexibly and optimally, based on plant responses is a better way to promote plant growth during the initial growth stages than a conventional control method. Through manipulating the root-zone environment, these two studies indicate that applying environmental stress such as moderate nutrient stress and temperature stress to the plant, for instance raising to the maximum level and decreasing to the minimum level of the root-zone environment, successfully accelerated the physiological responses and promoted plant growth. The actual results also showed the same results. This means that the intelligent control technique combined with a neural network and genetic algorithms is suitable for optimizing such complex system as the plant responses to environmental factors in a hydroponics system.