# Speaking Plant Approach for Highly Sophisticated Intelligent Greenhouse©

**Seiichi Arima**
Research Center of Intelligent Greenhouse Systems, Faculty of Agriculture, Ehime University, 3-5-7, Tarumi, Matsuyama, Ehime 790-8566, Japan
Email: sarima@agr.ehime-u.ac.jp

## INTRODUCTION

Japanese agricultural sector has a serious problem in the workforce area. The population engaged in agricultural sector has decreased in the last 50 years because of rapid aging, i.e., people over 65 years old occupy 61% of the current agricultural workforce. This situation results in a decrease in self-sufficiency and increase in the dependence on imported food, and threatens the safety and reassurance of food in Japan. As a solution for this problem, the plant factory system attracts much attention as a prospective agricultural production system in Japan. However, at this moment, the plant-factory system does not always produce commercial success. So, further technological development is required.

In April 2011, we established the Research Center of Intelligent Greenhouse Systems (RIGS) in Ehime University, which was supported by the Ministry of Economy, Trade, and Industry and the Ministry of Agriculture, Forestry, and Fisheries of Japan. In RIGS, we are promoting research based on the concept of the "speaking plant approach" (SPA). The SPA concept defines that the optimal crop cultivation conditions should be based on the physiological status of the plants and the concept has attracted a great deal of attention as a highly sophisticated strategy for environmental control in greenhouses. To establish the SPA, we are focusing on information and communication technology (ICT) and robot technology. Our goal is to achieve a stabile supply of high quality agricultural products with SPA technologies.

## SPEAKING PLANT APPROACH FOR HIGHLY SOPHISTICATED INTELLIGENT GREENHOUSES

There are two types of plant factories defined in Japan. One is artificial lighting completely closed and the other is intelligent greenhouse. Both are high-performance agricultural production systems, which control environmental factors such as light, temperature, humidity, and $CO_2$. At RIGS we are especially focused on the intelligent greenhouse. The difference between the conventional and the intelligent greenhouses is characterized by their harvest periods. In the intelligent greenhouse, the environmental factors are intensively controlled to keep the plants healthy based on the SPA concept and it allows year-round production.

## INTELLIGENT SYSTEMS FOR SPEAKING PLANT APPROACH GREENHOUSE

The first and important step of the SPA concept is the measurement of plant physiological information and the diagnosis of the plant health status based on that information. Therefore, the "plant health monitoring technique" is very important step in the SPA concept. The SPA basically consisted of three steps: (1) measurement of plant biological information, (2) diagnosis of plant physiological status, and (3) control of environmental conditions optimally. So, we focus on the research topics as follows:

1) Chlorophyll fluorescence measurement to evaluate the photosynthetic functions (Fig. 1). The photosynthetic reaction and chlorophyll fluorescence emission are competitive reactions, so precise measurement of chlorophyll fluorescence allows us to evaluate the status of photosynthetic functions without touching the plant. Figure 1 is a map of the "photosynthetic function index" of an experimental RIGS greenhouse. Tomato plants in the western area of the greenhouse, i.e., non-heating area, showed lower values compare with the plants in the eastern area. This result suggests that significant heterogeneity in the health conditions of tomato plants is detectable by using the chlorophyll fluorescence imaging system.
2) Detection of water-stressed plants under greenhouse conditions. Generally, leaf temperature is relatively low because of the transpiration, i.e., latent heat of evaporation. But, the leaf temperature goes up when the plant is exposed to water stress and the temperature increase of the leaves is detectable with thermal cameras.
3) Quantification of water stress by monitoring the wilting of tomato plants. By taking color images of tomato plants form the top of the canopy, the extent of the water stress can be evaluated as changes in the projected area of the plant. We applied this technique for the irrigation control to produce high-sugar-content tomato fruits.
4) Autonomously controlled plant diagnosis robot (Fig. 2). This robot has CCD camera for detection of abnormal flowers, infrared radiation thermometer for diagnosis of transpiration by measuring the leaf temperature and chlorophyll fluoresce imaging system for diagnosis of photosynthetic functions.

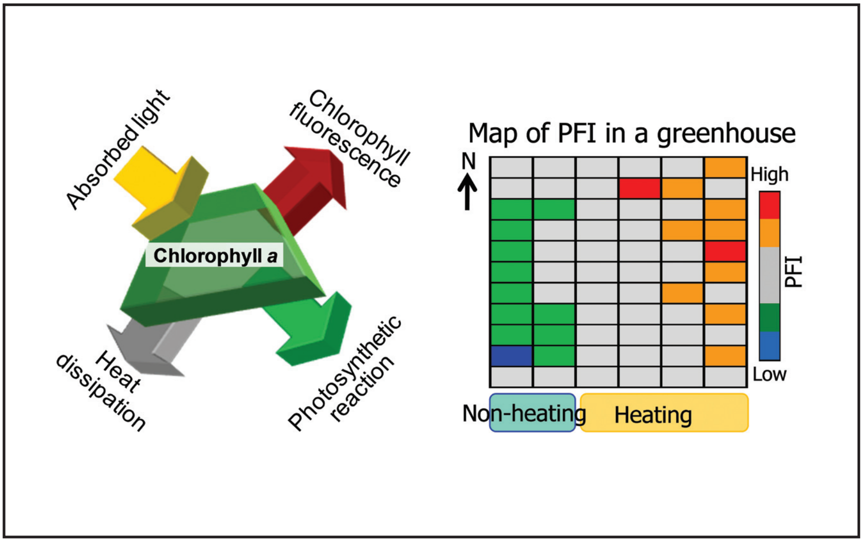


**Figure 1.** Chlorophyll fluorescence measurement to evaluate the photosynthetic functions and map of PFI.

**Figure 2.** Plant diagnosis robot.

5) Mapping system of diagnosis information.
6) Root zone and growing tip cooling system, etc.

By using such a plant diagnosis robot, we are developing SPA-based intelligent greenhouse systems. Though the plants are cultivated under strictly controlled environmental conditions, their growth can be varied by not only the genetically based variations but daily operations. Such a destabilized growth is also detectable with the plant health monitoring techniques and the plant health status is able to be evaluated (plant diagnosis). Based on the result of the plant diagnosis, the production management system automatically modifies the settings of the environmental factors. At this step, a knowledge base — which is an accumulation of information on growth, plant diagnosis, and historical log of the environmental control — plays an important role to optimize the control procedure.