Environment control based on Speaking Plant Approach

—For highly sophisticated intelligent greenhouse—

Background: Current situation of agriculture in Japan

- Decrease in agricultural workforce
  - Rapid aging in the agricultural sector
  - Less number of young people in agricultural sector

- Decrease in self-sufficiency
- Increase in dependence on imported food

Safety and reassurance of foods can not be proved

Agricultural aspect
**Definition of Plant factory in Japan**

- High-performance agricultural production system by controlling the environmental factors such as light, temperature, humidity, CO₂.

Artificial lighting completely closed
Intelligent greenhouse

**Intelligent greenhouse in Japan**

Large scaled food production system utilizing solar energy

This greenhouse produces 40,000 tomatoes a day
Tomato plants in the intelligent greenhouse

Intelligent greenhouse: Tomato cultivation schedule in Japan

### Conventional (Old) greenhouse

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<th>Month</th>
<th>Seeding</th>
<th>Raising seedlings</th>
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Harvest period

### Year-round cultivation in intelligent greenhouse

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Harvest period

Reduced raising seedlings period, extended harvest period.
Intelligent greenhouse: Year-round tomato production

High-performance production system should achieve 4 CONSTANTS, constant interval, constant amount, constant price, constant quality.

“4-constant” food production

Various environmental factors changes depending on the outside weather and climate conditions

- Monitoring (measurement) of plant biological status
- Early detection of plant diseases and dysfunctions
- Appropriate diagnosis
- Early and appropriate treatment
Speaking Plant Approach

The optimal crop cultivation conditions should be achieved by monitoring the physiological status of the plants.

Measurement, Diagnosis, Treatment

Plant health monitoring technique

Chlorophyll fluorescence measurement

Energy distribution in chlorophyll

Precise measurement of Chl fluorescence allows us to evaluate the status of photosynthetic functions without touching.
Automated and robotized Chl fluorescence imaging system - Photos -

Invisible but significant heterogeneity in the health conditions of tomato plants

Effect of night temperature
“Map of Photosynthetic Function Index”

Invisible but significant heterogeneity in the health conditions of tomato plants
Early detection of tomato russet mite damage

Current plant diagnosis techniques

Early detection of damages caused by tomato russet mite is possible.

Water stress detection with thermal imaging technique

Inhibition of transpiration caused by water stress increases the leaf temperature
Detection of water stressed plant under greenhouse condition

In the intelligent greenhouse located at agricultural faculty

Water stressed plant is detectable

Quantification of water stress by monitoring the wilting of tomato plant

Continuous monitoring of the projected area of tomato plants is useful to evaluate the extent of water stress
Irrigation control system for high sugar content tomato production

Moderate water stress increases sugar content in tomato fruits

Total leaf area estimation with 3-D measuring system

By measuring the leaf area of a matured leaflet with the 3-D measuring system, total leaf area can be estimated through a leaf structure model.
Detection of abnormal flowers with neural-network

Detection of abnormal flowers with neural-network (software)

Current plant diagnosis techniques
Autonomously-controlled Plant Diagnosis Robot

Detection of abnormal flowers

Diagnosis of transpiration with leaf temperature measurement

Diagnosis of photosynthetic functions with chlorophyll fluorescence imaging

CCD camera with long-pass (red) filter

Infrared radiation thermometer

Chlorophyll fluorescence imaging system

Blue LEDs

CCD camera for chlorophyll fluorescence imaging

CCD cameras for leaf area measurement and abnormal flower detection

Chlorophyll fluorescence imaging system

CCD camera for chlorophyll fluorescence imaging

Scheme of SPA

SPA based intelligent greenhouse system

Growth

Light, temperature, humidity, CO₂

• Genetic capacity
• Historical log
• Daily operations

• EC, irrigation schedule

Hydroponics

Plant diagnosis

Control

Production management system

Knowledge base

For Intelligent greenhouse
Knowledge base for intelligent greenhouse system

- Quality information (Brix, acidity, shape)
- Yield information
- Plant physiological information (Fluorescence, leaf temperature, color, wilting)
- Environmental information (Temperature, humidity, solar radiation, wind speed)

Outline of RIGS

Research center of Intelligent Greenhouse Systems

- Intelligent greenhouse-A (500m²)
- Intelligent greenhouse-B (1300m²)
- Research and seminar building
Outline of RIGS
Intelligent greenhouse-B (1300m²)

6 m high

Tomato production

Year-round production test

Outline of RIGS
Intelligent greenhouse-B (1300m²)

SPA applicable Environment control system

Water recycle system
Outline of RIGS
Intelligent greenhouse-B (1300m²)

Partial heating and cooling system

High performance heat pump system

Outline of RIGS
Intelligent greenhouse-B (1300m²)

Tomato production in summer:
Growing tip cooling system

Water tank

Infrared radiation thermometer

Spraying water drops onto growing tips

Pump

Heat of evaporation

ON/OFF

Leaf temperature

Controller

Nozzle

Indonesian Universities and Ehime Univ.

Collaboration researches
Tomato production in summer: Root zone cooling system

- Polystyrene foam
- Rockwool cube
- Rockwool slab (Root zone cultivation material)
- Thickness 2cm
- Pipelines for cooled water

Keeping the root zone temperature at 25 °C increases the total yield of tomato fruits

The number of physiological disordered fruit was smallest in the 25 °C treatment