COMPARISON OF ENVIRONMENTAL STRESS DIAGNOSIS OF CUCUMBER PLANT USING VARIOUS PHYSIOLOGICAL INSTRUMENTS

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ABSTRACT

This paper represents our efforts to diagnose environmental stresses using physiological instruments in cucumber plants. The stresses could be detected by measuring and analyzing the difference of chlorophyll content, photosynthetic efficiency(Fv/Fm), differential temperature(DT), stomatal resistance and light absorbance values between treated and controlled plants. From the all over experiments, the stresses could be first diagnosed on the 1st to 5th day after treatment and the overall diagnosis rate was estimated at more than 50%.

Key Word : plant stress, stress diagnosis, cucumber plant

INTRODUCTION

There has been much effort in developing sensors for detecting plant stresses. Contact and non-contact instruments to measure chlorophyll content, leaf temperature, stomatal resistance, light absorbance and sap flow have been widely used. Contact sensors need a lot of time and worker for detecting stresses and limited samples and especially can cause stress against growing although they provide direct bio-information about plant stress. Non-contact sensors, however, are not limited by these problems. Therefore, Non-contact and plant-response-based measurements for detecting plant stresses are preferred and recommended as a future sensing technology.

Buschmann(1994) reported the optical characteristics of plant leaf were useful tools for detecting plant stresses and Gregory(1995) analysed the difference between reflectance and thermal image of plant for early detection and indicated the most sensitive wavelengths in reflectance image for detecting plant stresses were 694± 3nm. Evans(1998) used Dual-wavelength liquid crystal tuneable filter for measuring NDVI(Normalized difference Vegetation Index) to monitor plant stress and Kurata(1996) reported the water stress of tomato plant groups could be detected by machine vision.

Murat Kacira(1999) used crop water stress index(CWSI) to quantify the level of the water stress and top projected canopy area(TPCA) information obtained from CCD monochrome camera to monitor plant growth and movement and indicated it was able to identify water-stressed plants when CWSI was 0.22 for New Guinea Impatiens.

The goal of this study is to confirm the possibility for diagnosing environmental stresses in cucumber plants using physical instruments and to select suitable instrument for early detection of each stress.

MATERIALS AND METHODS

MATERIALS

Cucumber(Cucumis sativus L.) seeds were sown in carbonized chaff. When the 2nd true leaves were just visible, cucumber seedlings of similar sizes were transferred into 4-L pots of nutrient solution. In each 4-L pot filled with Cooper's(1975) nutrient solution and 3rd distilled water, three plants were allocated and grown. Then, as the 4th true leaves were found, the plants were used for the experiments after acclimatizing to the circumstances.

Vigorous aeration was supplied by air pump to maintain uniform environment of nutrient solution in pots. The nutrition solution was regularly replaced at 2-3 day intervals since the composition of nutrition solution can be changed with days after treatment owing to the plants' unbalanced absorption of nutrients.

INSTRUMENTS

In this study, various physiological instruments were used to diagnose cucumber plant stresses such as 1) chlorophyll meter(Minolta Co. Ltd., Japan, model SPAD-502) to measure chlorophyll content; 2) chlorophyll fluorescence measurement system(Morgan Scientific Inc. USA, Model CF-1000) used to measure photochemical efficiency(Fv/Fm, Fv : variable fluorescence, Fm : maximal fluorescence) and Fm/2 increasing time($t_{1/2}$); 3) infrared thermometer (Everest Interscience, Inc. USA, model 510B) to display difference between atmosphere and leaf temperatures; 4) stomatal resistance meter(LI-COR, Inc., LI1600) to measure transpiration and stomatal resistances; 5) Near-Infrared spectrometer(Perstorp Analytical, Inc., Model NIRS 6500) for scanning spectrum data of light absorbance of plant leaves in the range of 400nm to 2500nm in 2nm increments.

METHODS

The experiments were peformed by comparing bio-information of cucumber plants treated by environmental stresses such as salinity, low light intensity, low temperature and herbicide with that of controlled cucumber plants. For salinity stress, the nutrition solution includes 4 times Nacl over Cooper's nutrient solution. A shading curtain(blocking 60% of light) was installed in the upper part of plants for low light intensity stress. The temperature of nutrient solution also was maintained at 10℃ for low temperature stress. Herbicide stress was carried out by adding herbicide(Kyeongnong Co.,

Ltd, Goul) to nutrient solution with diluting rate of 50% of density(50 ㎖/20ℓ) recommended by manufacturing company. Each two leaves of plants grown for 10 - 15 days were selected for the experiments at 3 plants per pot. Then, the bio-information of the leaves was measured using the physiological instruments. The data were collected for 2 hours from 10:00 to 12:00 in the morning for 12 - 20 days.

To increase diagnosis precision, salinity, low light intensity and low temperature experiments were repeated 4 times(chlorophyll fluorescence measurement system repeated twice and stomatal resistance meter performed once) and herbicide experiment twice(except for stomatal resistance meter). Above all experiments were performed in a plastic green house and a growth chamber at Chonnam National University, Gwanju for 3 years from April 1997 to February 2000.

RESULTS AND DISCUSSIONS

In order to distinguish the stressed and the controlled plants, a two-sample T-test was performed. On the test, we regarded the plant maintaining T-test result of less than 5% significant level during over continuous 3 days within the 12th day after treatment as the stressed plant. In the stressed plant, we investigated the first day to detect stresses and the diagnosis precision(value considering the ratio of the number of experiment for detecting stresses to experiment trial numbers, significant level and continuous diagnosis days). The diagnosis results of the instruments are as follows.

Chlorophyll meter

To confirm the possibility to diagnose salinity using chlorophyll meter, the history of chlorophyll contents of highly salinized and controlled plants is shown in Fig. 1. The instrument was able to detect chlorophyll content indicating that in highly salinized plant the amount was increased, compared to that of controlled plants few days after treatment, as shown in Fig. 1.

Statistical analysis shows that the instrument was able to detect significant difference in chlorophyll content on the 6th day and the overall diagnosis rate of chlorophyll meter was about 50%.

Effect of low light intensity could be detected first at 6th to 10 day and the diagnosis rate was approximately 50%. In this study, however low temperature stress could not be detected since the difference between treated and controlled plants was not found.

The herbicide stress resulted in reduction of chlorophyll content at 3rd to 4th day and could be detected first at the 1st day and in the 5th day at least. Plants treated by herbicide withered and died at 5th to 7th day after treatment.

Chlorophyll fluorescence measurement system

To detect salinity, low light intensity and low temperature stresses, the chlorophyll fluorescence measurement system was ineffective as the difference of Fv/Fm value

between treated and controlled plants was not found.

The herbicide stress could be detected from the 5th day as shown in Fig. 2. Fv/Fm value was rapidly reduced below 0.4 from the 6th day and the overall diagnosis rate was almost 100%.

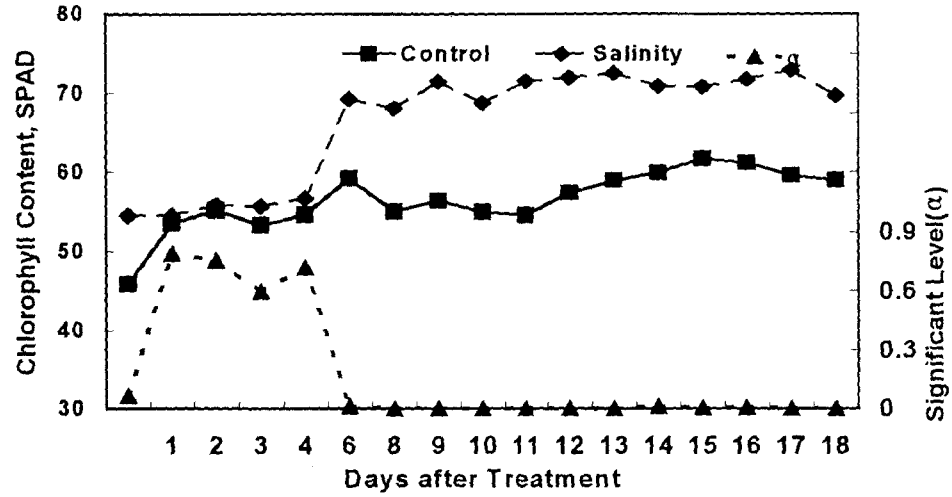

Fig.1 Comparison of chlorophyll contents in highly salinized and controlled cucumber plants.

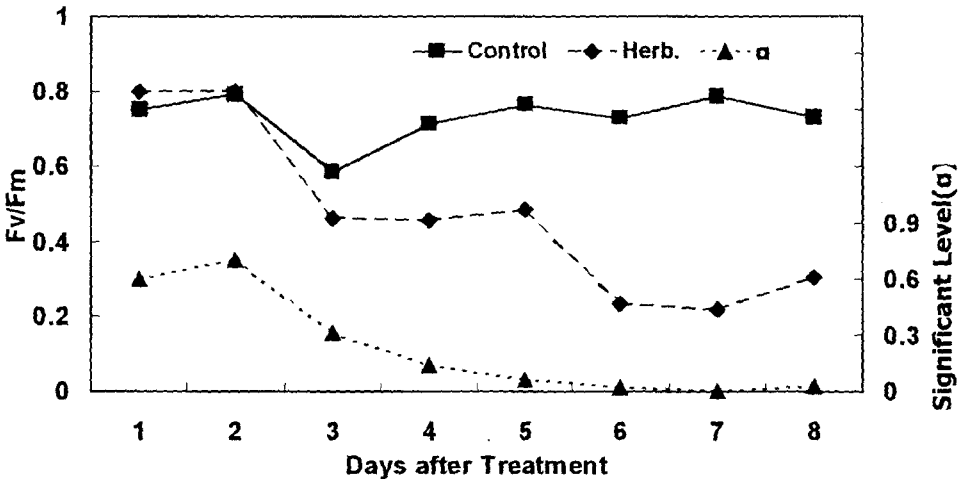

Fig.2 Comparison of photosynthetic efficiency (Fv/Fm) of herbicide treated and controlled cucumber plants.

Infrared thermometer

Fig. 3 shows the difference of atmosphere temperature and leaf temperature

between highly salinized and controlled plants as detected by infrared thermometer. As shown in Fig. 3, salinity could be detected from the 7th day with the overall diagnosis rate of about 45%.

The low light intensity stress was detected on the 3rd day in only one experiment among 4 trials and the overall diagnosis rate was about 25%.

In measuring the differential temperature(DT) of plants treated by low temperature and controlled, significant difference was not admitted although temperature of treated plants tends to be higher than that of controlled. Hence, the diagnosis of low temperature stress was impossible.

Herbicide could be detected at the 1st to 3rd day with the overall diagnosis rate of around 50%.

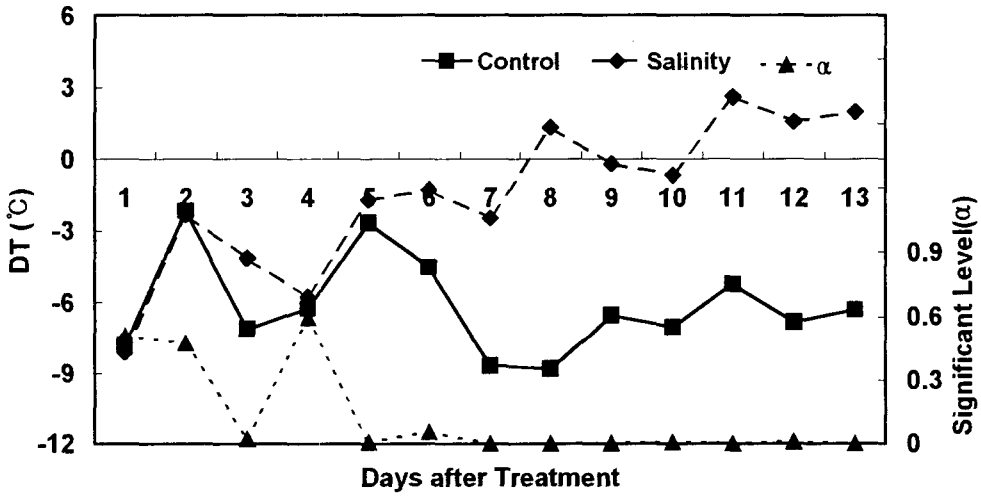

Fig. 3 Comparison of differential temperature (DT) of highly salinized and controlled plants.

Stomatal resistance meter

The diagnosis of salinity stress using stomatal resistance meter was impossible because no significant difference between treated and controlled plants was admitted.

In low light intensity stress, the stomatal resistance of treated plant began to be higher significantly than that of controlled plant from the 5th day as shown in Fig. 4. Like low light intensity, low temperature stress could be detected from the 3rd day.

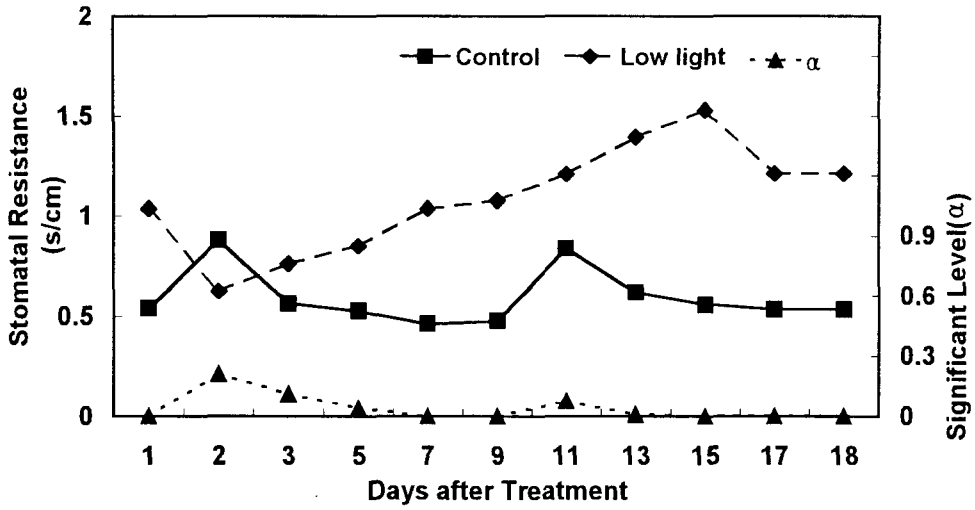

Fig. 4 Comparison of stomatal resistance of low light intensity and controlled plants.

Near-Infrared spectrometer

This study examined appropriate wavelength ranges and center wavelengths by measuring light absorbance of leaves of treated and controlled plants. Then, the possibility to detect the stresses was investigated by analyzing light absorbance difference of center wavelengths between treated and controlled plants. The analysis results of this test are as follows:

Appropriate wavelength ranges for salinity diagnosis were 520 - 654nm and 688 - 756nm and the center wavelengths were 560nm and 710nm. The salinity stress could be detected first at the 3rd day and at least in the 10th day at the center wavelengths. The overall diagnosis rate of Near-Infrared spectrometer was estimated at 70%.

The low light intensity stress could be detected at the wavelength ranges of 450 - 520nm, 582 - 692nm and 1326 - 2000nm and the center wavelengths were located at 480nm, 630nm and 1664nm. The stress could be detected at 10th to 12th day in 480nm and 630nm with the overall diagnosis rate of about 50%. Also at 1664nm, the stress could be detected first at the 3rd day and at least in 6th to 10th day with the diagnosis rate of about 45% .

For low temperature stress, sensitive wavelength ranges were 450 - 1098nm and 1346 - 2000nm and the center wavelengths were not important due to very wide wavelength ranges. The stress could be detected first at 1st to 3rd day and at least in the 10th day. The overall diagnosis rate for detecting the stress was estimated at 70%.

To detect herbicide stress, adequate wavelength ranges were 506 - 542nm, 554 - 714nm, 1392 - 1420nm and 1432 - 1876nm and the center wavelengths were placed at 520nm, 630nm, 1406nm and 1654nm. The stress could be detected on the 4th day at the center wavelengths.

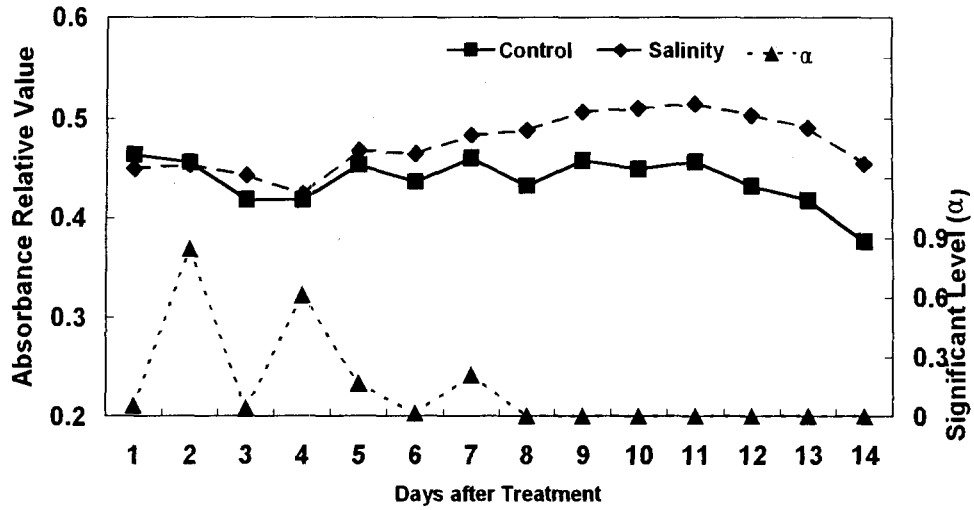

Fig. 5 Comparison of light absorbance of highly salinized and controlled plants at a wavelength of 560 nm.

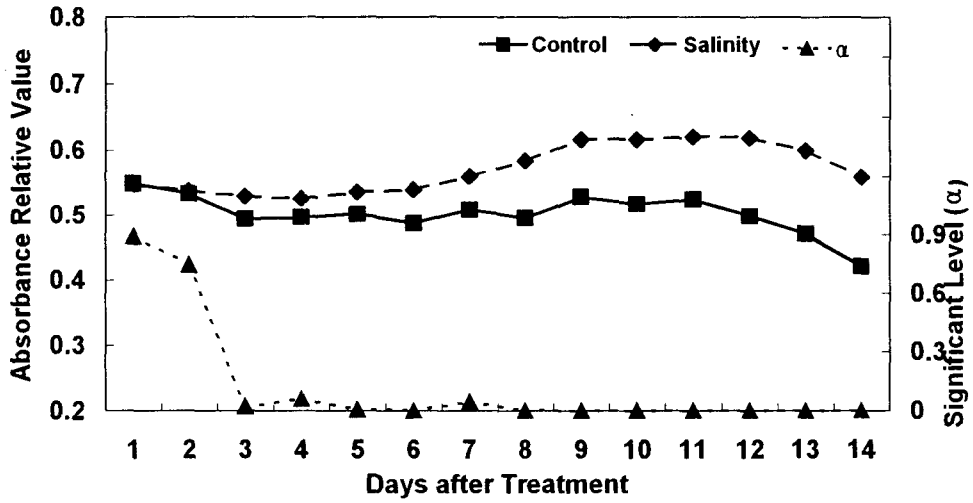

Fig. 6 Comparison of light absorbance of highly salinized and controlled plants at a wavelength of 710 nm.

CONCLUSION

The results of experiments to diagnose environmental stresses such as salinity, low light intensity, low temperature and herbicide using different measuring instruments are as follows:

1. The useable instruments for diagnosing salinity stress were chlorophyll meter, infrared thermometer and Near-Infrared spectrometer. The overall diagnosis rate of the instruments were about 50%, 45% and 70%, respectively. The instruments could detect the stress first at the 6th, 7th and 3rd day, respectively.

2. Chlorophyll meter, infrared thermometer, stomatal resistance meter and Near-Infrared spectrometer could detect low light intensity stress with diagnosis rate of around 50%, 25%, unknown and 50%, respectively. The stress could be first detected on the 9th, 3rd, 5th and 3rd day for the respective instrument.

3. The usable instruments for diagnosing low temperature stress were stomatal resistance meter and Near-Infrared spectrometer. The diagnosis rate of Near-Infrared spectrometer was approximately 70%. The instruments could detect the stress first at 1st to 3rd day.

4. All instruments used for the experiments could diagnose herbicide stress. The diagnosis rate was about 50% for infrared thermometer and almost 100% for other instruments. Chlorophyll meter, chlorophyll fluorescence measurement system, infrared thermometer and Near-Infrared spectrometer could detect herbicide first at 1st, 5th, 1st and 4th day, respectively.

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