# COMPARISON OF NUTRIENT STRESS DIAGNOSIS OF CUCUMBER PLANT USING VARIOUS PHYSIOLOGICAL INSTRUMENTS

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## ABSTRACT

This paper represents our efforts to diagnose nutrient 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 deficient and controlled plants. From the all over experiments, the stresses could be first diagnosed in the 8th 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 workers 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.

Nilson(1995) reported N deficient stress could be detected in the wavelengths of 531nm and 550nm and water stress in the wavelengths of 531nm and 570nm and Halk(1992) indicated the chlorophyll content reduction of barely with N deficient stress could be detected by chlorophyll a fluorescence. Eiichi(1999) demonstrated that image-processing-based Inductively Coupled Plasma(ICP) could successfully detect nutrient changes in the modified Half-Strength Hoagland solution used for growing hydroponic sweet potato and Saidul Borhan(1999) indicated the unsuitability of the histogram-based

image features(mean, variance average energy and entropy) from red and green leaf images for predicting $NO_3$- content.

The goal of this study is to confirm the possibility for diagnosing nutrient 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 nutrient stresses such as P, Ca, K and Mg deficiencies with that of controlled cucumber plants. The nutrition solution for the experiments was made by excluding each P, Ca, K and Mg from Cooper's nutrient solution for the respective stress. Each two leaves 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, P and Ca deficient experiments were repeated 4 times(chlorophyll fluorescence measurement system repeated twice and stomatal resistance meter performed once), K deficient experiment twice(except for stomatal resistance meter) and Mg deficient experiment once(except for stomatal resistance meter). Above all experiments were performed in plastic green house and growth chamber at Chonnam National University, Gwanju for 3 years from April 1997 to February 2000.

## RESULTS AND DISCUSSION

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**

The chlorophyll meter for diagnosing P and K deficient stresses was ineffective because no difference of chlorophyll content with days after treatment between deficient and controlled plants was found.

In Ca deficient stress, chlorophyll content of the deficient plant tends to be lower significantly with days after treatment than that of controlled plant. Fig. 1 shows the history of chlorophyll content in Ca deficient and controlled plants. As shown in Fig. 1, The Ca deficient stress could be detected first at the 1st day and in other repeated experiments at least on the 7th day with the overall diagnosis rate of about 80%.

The instrument was able to detect Mg deficient stress since chlorophyll content of the deficient plant tends to be lower significantly from the 8th day than that of controlled plant.

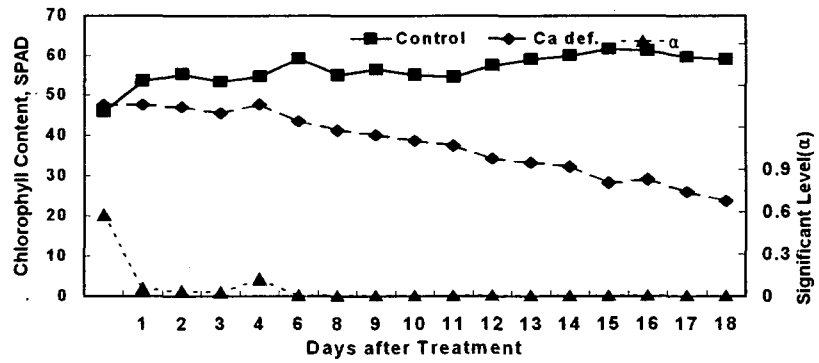


Fig.1 Comparison of chlorophyll content in Ca deficient and controlled cucumber plant

**Chlorophyll fluorescence measurement system**

Fig. 2 represents the result of P deficient experiments using chlorophyll fluorescence measurement system. As shown in Fig. 2, Fv/Fm value of the deficient plant tends to be lower significantly from the 9th day than that of controlled plant. From the experimental result, the overall diagnosis rate was estimated at 50%.

The significant difference of Fv/Fm value between K deficient and controlled plants from 3rd day to 6th day was found although the difference of Fv/Fm was gradually reduced with days. Therefore, the K deficient stress could be detected on the 3rd day and the overall diagnosis rate was estimatiated at 50%.

The instrument was ineffective for diagnosing Ca and Mg deficient stresses because no significant difference between the deficient and controlled plants, despite passing 12 days, was admitted.

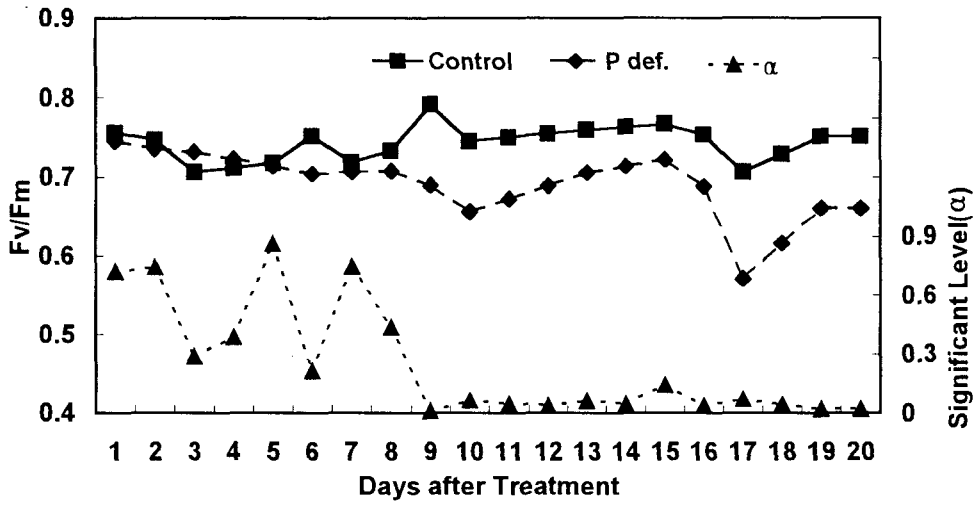


Fig.2 Comparison of photosynthetic eff iciency (Fv/Fm) in P deficient and controlled cucumber plant

**Infrared thermometer**

Fig. 3 shows the difference of atmosphere temperature and leaf temperature between Ca deficient and controlled plants as detected by infrared thermometer. As shown in Fig. 3, the difference of DT between the deficient and controlled plants was found from the 6th day and the leaf temperature closed to the atmosphere temperature with days after treatment. From the repeated experiments, Ca deficient stress could be detected from the 6th to 10th day and the overall diagnosis rate was estimated at 50%.

The diagnoses of P, K and Mg deficient stresses were impossible since no difference of DT with days after treatment between deficient and controlled plants was found.

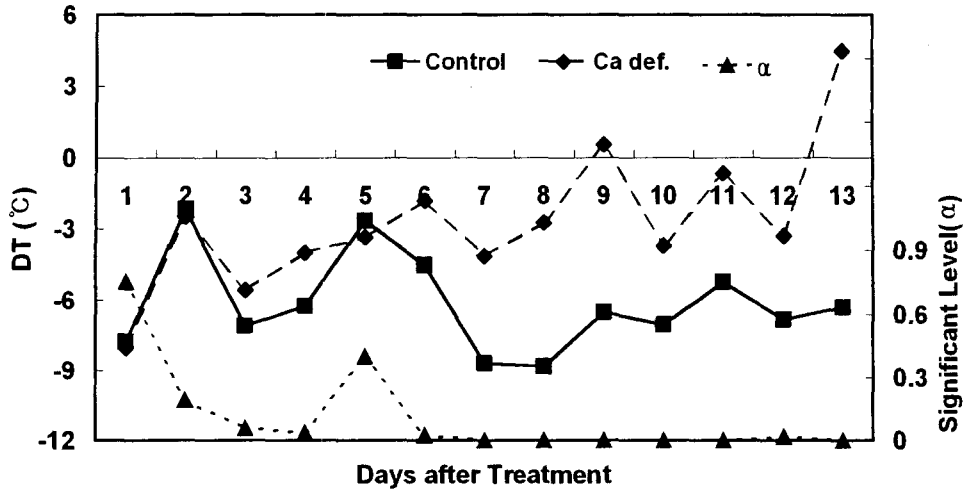


Fig. 3 Comparison of differential temperature (DT) in Ca deficient and controlled cucumber plant

**Stomatal resistance meter**

From the P deficient experiment result measured with stomatal resistance meter, the stress could be detected from the 2nd day with the overall diagnosis rate of about 50%.

The Ca deficient stress could be diagnosed from the 8th day and the overall diagnosis rate was estimated at 50%. Fig. 4 shows the history of stomatal resistance in Ca deficient and controlled plants.

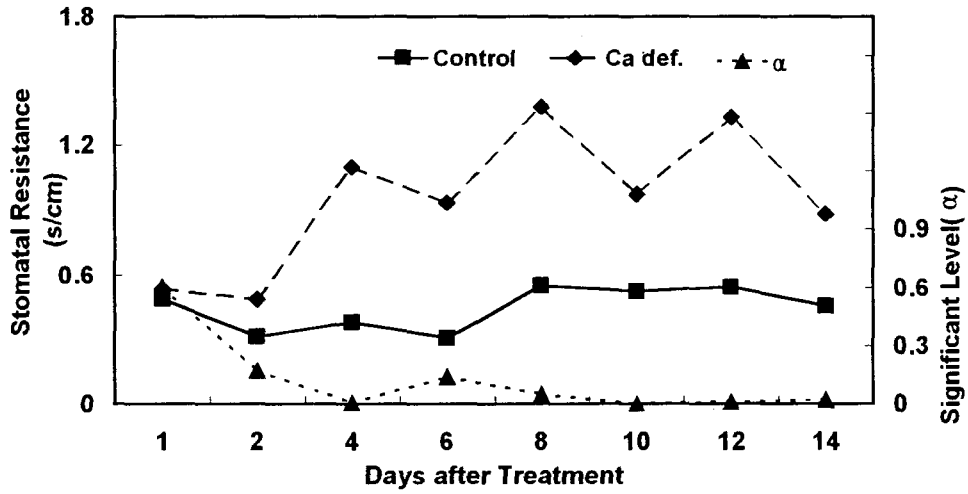


Fig. 4 Comparison of stomatal resistance in Ca deficient and controlled cucumber plant

**Near-Infrared spectrometer**

This study examined appropriate wavelength ranges and center wavelengths by measuring light absorbance of leaves of deficient and controlled plants. Then, the

possibility to detect the stresses was investigated by analyzing light absorbance difference of center wavelengths between deficient and controlled plants. The analysis results of this test are as follows:

Appropriate wavelength ranges for P deficient diagnosis were 460 - 506nm, 508 - 658nm, 660 - 740nm, 1864 - 1916nm and 1946 - 1998nm and the center wavelengths were 480nm, 560nm, 710nm, 1890nm and 1972nm. Although the first day to detect P deficiency was varied with center wavelengths, the stress could be generally detected first at the 4th day and at least in the 10th day at the center wavelengths. The overall diagnosis rate was estimated at 50%.

In Ca deficient diagnosis, sensitive wavelength ranges were 450 - 514nm, 516 - 650nm, 650 - 740nm and 1912 - 1950nm and the center wavelengths were located at 480nm, 560nm, 710nm and 1930nm. The stress could be detected first at the 1st day and at least in the 7th day at the center wavelengths with the overall diagnosis rate of about 50%. Fig. 5 shows the history of light absorbance in Ca deficient and controlled plants at a wavelength of 560nm.

To detect Mg deficient stress, adequate wavelength ranges were 544 - 586nm and 698 - 706nm and the center wavelengths were placed at 560nm and 710nm. The stress could be detected on the 6th day.

The diagnosis of K deficient stress was ineffective since no difference of light absorbance between deficient and controlled plants was found.

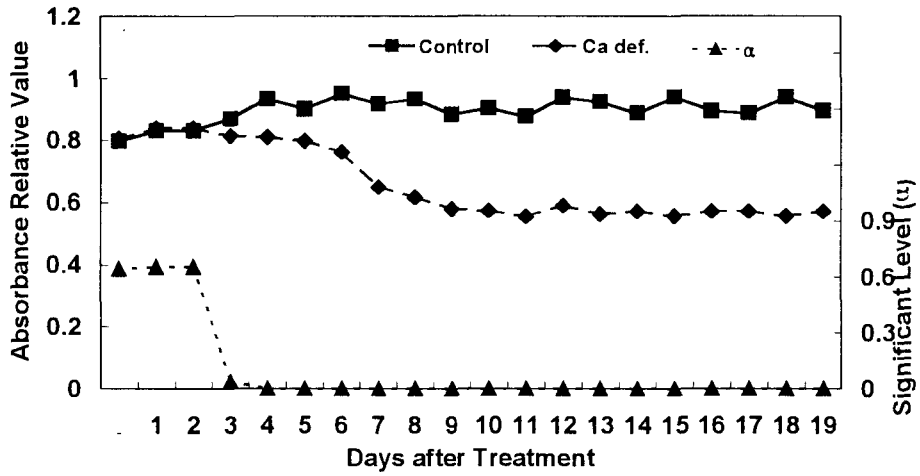


Fig. 5 Comparison of light absorbance in Ca deficient and controlled cucumber plants at a wavelength of 560 nm

## CONCLUSION

The results of experiments to diagnose nutrient stresses such as P, K, Ca and Mg deficient stresses using different measuring instruments are as follows:

1. The useable instruments for diagnosing P deficient stress were chlorophyll

fluorescence measurement system, stomatal resistance meter and Near-Infrared spectrometer and the diagnosis rate of the instruments were estimated at 50%. Stomatal resistance meter could diagnose P deficient stress from the 2nd day with the highest early detection ability, whereas chlorophyll fluorescence measurement had the lowest.

2. The K deficient stress could be diagnosed by only chlorophyll fluorescence measurement system from the 3rd day with the overall diagnosis rate of around 50%.

3. The useable instruments for diagnosing Ca deficient stress were chlorophyll meter, infrared thermometer, stomatal resistance meter and Near-Infrared spectrometer. The diagnosis rate of the instruments were around 80%, 50%, 50% and 50%, respectively. The instruments could detect the stress first at days 1, 6, 8 and 3, respectively.

4. Chlorophyll meter and Near-Infrared spectrometer could diagnose Mg deficient stress first at 8th and 6th day, respectively.

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