Observation of condition of plant growth by image processing system

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1. Introduction

The controlled environment agriculture of today incorporates sensors for a variety of elements such as temperature, humidity, sunlight, and water, and has succeeded at implementing systematic operation. By recording and interpreting the growing environment with sensors, this technology can forecast the future state of crops. However, it is also true that there are many cases which cannot be factored in, such as disease and harmful insects, and management by humans cannot be done away with. On the other hand, as experienced farmers grow high quality produce through a process of judging the state of a crop by observing the leaves, analyzing visual information is expected to facilitate a higher level of agriculture through means such as evaluating the growth state of produce, harvest time forecasting, estimating harvest quantity, early discovery of diseases, and evaluating quality. This kind of analysis also serves as the starting point for agricultural remote sensing.

The goal of this study is to promote the popularization and practical functionality of remote sensing technology. Therein, we have observed the growth status of plants using digital cameras and color tiles available on the market, executed several tests, and reported on the usefulness we encountered in previous reports. After that, we implemented follow-up research regarding issues which remained unsolved at that time. This current study is a report on that follow-up research.

2. Previous studies

Using a colorimeter and reference color plates, we tried determining the harvest period of potato samples by the leaf color changes corresponding to growth stages. The results indicated that in addition to determining the harvest period, it may also be possible to judge water and fertilizer deficiencies and other such changes in the plants during the different growth stages, and to identify constituents that are lacking in the fertilizer.

Simultaneously, in order to actualize the practical application of this method, we also examined the usefulness of consumer digital cameras and the utilization as reference plates of color tiles available on the market. This gave a better level of precision than the current measurement method using colorimeters. However, because a number of issues still had to be worked out, we continued our trials and ran new tests designed to improve precision, the results of which are reported herein.

3. Equipment and materials

We photographed a potted plant called "kodakaraso" (*Bryophyllum Crenatodaigremontianum*) with two Panasonic network cameras (BL-C131). The shots were taken simultaneously at fixed points from above and the side. The image data was saved on a computer. Fig.1 shows examples of the data.

Fig.1 Fixed point photographs of kodakaraso plants

From above

From side

We prepared 10 pots each for three groups with different fertilizer conditions: plant group A (blank plants), made up of kodakaraso plants with no added fertilizer; plant group B (added fertilizer plants), made up of kodakaraso plants raised in the same conditions as the blank plants but with added fertilizer; and plant group C (base fertilizer plants), made up of kodakaraso plants which were grown with a sufficient amount of fertilizer already supplied. We arranged the added fertilizer plants, blank plants, and base fertilizer plants in that order from left to right in the photograph. We included color tiles in the images for comparison while photographing.

We added color tiles of light green (from INAX) and dark green (from TOTO) as new reference plates to the five tiles of white, black, cyan, magenta, and yellow which we had used in the previous study. We found the Lab values for each color using a colorimeter (the "Color and Difference Meter Super Color Model Sp-80" made by Tokyo Denshoku Co., Ltd.).

Table 1 Colorimeter measurement values for the color tiles

Measured color differences for green tiles						
	X	Y	Z	L	a	b
Light green	10.90	23.64	13.83	48.62	−15.69	17.16
Dark green	2.32	3.43	5.07	18.52	−10.05	−3.26

We used graphic software (Adobe Photoshop) for correction and analysis of the images.

4. Study method

At the time of our previous presentation session, it was pointed out in regards to the color difference measurement of the leaves that using reference color tiles that approximate leaf color would be better. We examined the influence on color difference measurement with green color tiles with two different brightness levels as reference colors.

5. Results and discussion

We tried correcting the images based on the values measured with the colorimeter. In order to avoid saturation of color data values due to excessive reflection of light that may cause large fluctuations in value and unmeasurable levels as had been observed in past cases, we analyzed leaf color fluctuation in one day based on data from an overcast day when light is defused. We chose one plant from each of the three groups of kodakaraso plants with different fertilizer conditions and took measurements of a specific sample leaf from each plant. Also, we implemented corrections with black and white reference plates that we had used previously. A comparison of the values can be seen in Fig.2, 3, and 4.

Fig.2 Added fertilizer plants (B)

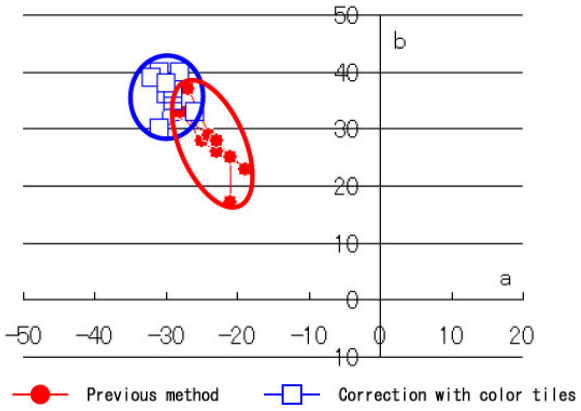


Fig.3 Blank plants (A)

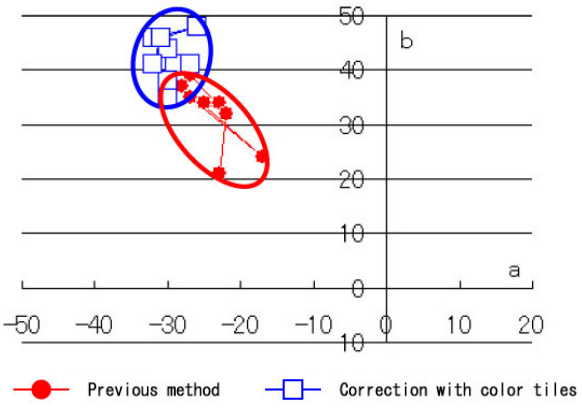
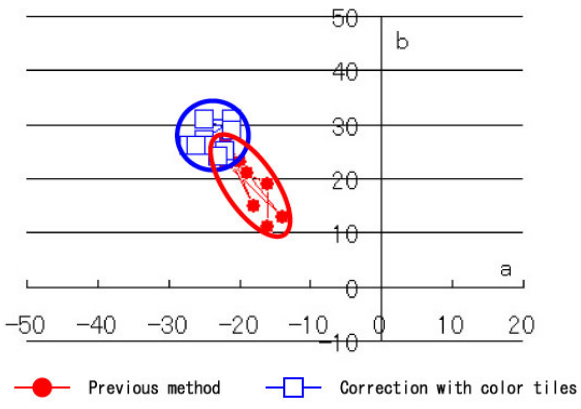


Fig.4 Base fertilizer plants



In spite of the fact that the intensity of light throughout one day does not stay the same, and the angle of incidence also fluctuates, cohesiveness was seen in the values for all three subjects, the data being more favorable than that from analysis through previous

methods. This indicated a possibility of increased accuracy through color measurements using two differing shades of green-based color tiles.

Next, we attempted to assess the fluctuation of leaf color over a span of days. We used samples of kodakaraso plants under the same conditions and analyzed the observed images taken at the same time every day. However, in cases when light reflected strongly (e.g. specular reflection) causing saturation of values and inability to obtain correct measurements, we substituted the image for that day with an image from another time during the same day. The fluctuations of value set a and value set b, which represent the color components of the Lab values, are shown on Fig.5 and Fig.6 respectively.

Fig.5 and 6 indicate improvements in data accuracy, with the dispersion of values being approximately plus or minus 5. The dispersion was approximately plus or minus 10 with the previous method. However, the presence of large fluctuations amongst the raw data is an area that needs to be improved.

Fig.5 Daily fluctuations of value set a

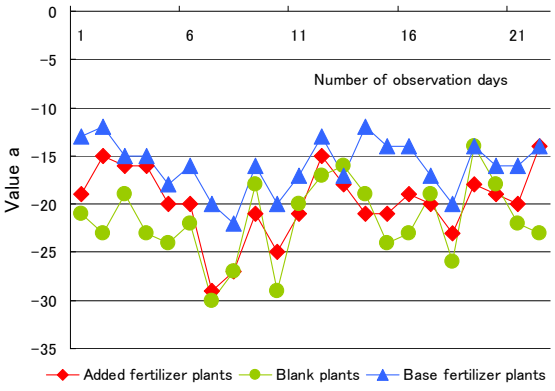
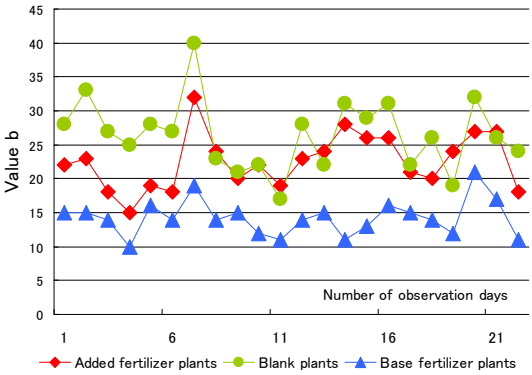


Fig.6 Daily fluctuations of value set b



In the analysis of this current study, our expectation, that the leaf color data of plant group B would change as it moved from the leaf color values of plant group A to approximate the values of plant group C, was not fulfilled. In this regard, reexamination is necessary. On the other hand, with regard to the influence of the fertilizer amount, correlation was observed between the fertilizer amount (plant group A at the lowest, plant group B in the middle, and plant group C at the highest) and both value sets a and b; particularly in value set b, higher fertilizer levels gave correspondingly lower values, confirming a clear difference.

This study indicated increased practicability of color difference measurements using consumer digital cameras and color tiles available on the market, by which we were able to obtain data of sufficiently high accuracy. Following this, we plan to conduct measurements for other plant types. In addition, in order to solve the problem of specular reflection, we are examining the effects on color difference measurements of polarizing filters, by which reflected light can be controlled.