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PLANT SPEAKING APPROACH FOR AUTOMATIC FERTIGATION SYSTEM IN GREENHOUSE

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ABSTRACT

Nowadays, many vegetables are grown inside greenhouses in which environment is controlled and nutrition can be supplied through water supply using electrical pump, namely fertigation. Dosage of nutrition in water for many vegetable plants are also known so that by controling water supply all the needs for the plants to grow are available. Furthermore, water supply can be controlled using electrical pump which is activated according to the plants condition.

In order to supply water and nutrition in the right amount and time, plants condition can be observed using a CCD camera attached to image processing facilities. In this study, plants development during their growing periode are observed. Three populations of tomato plants, with less, enough, and exceeded nutrition in water, are captured using a CCD camera every three days, and the images were analyzed using a developed computer program for the height of plants. The results showed that the development of the plants can be monitored using this method. After that, the respon of plant growth in the same condition was monitored, and the respon was used as input for the fertigation system to turn electrical pump automatically on and off, so the fertigation system could maintain the growth of the plants.

Keywords: *tomato plant, fertigation system, image processing*

BACKGROUND

Vegetables are very important as source of vitamins and fibers. To increase vegetables production, technology in vegetables cultivation is continually improved. Such a technology is growing vegetables in relatively controlled space in a greenhouse or screenhouse. Even, some materials for constructing greenhouse are modified so the greenhouse can be optimzed to trap only a certain of wavelength from sunlight for specific purposes (Wilson dan Rajapakse, 2001).

Nowadays, in Indonesia many vegetables are grown in a well controlled environment such as in greenhouse and screenhouse. The vegetables are grown on a normal sterilized medium like soil and paddy husks charcoal, sand, small rock, carbon, or zeolit, as long as they are sterilized (Wardi et al., 1998).

Some experiments for determining dosage of nutrition needed for specific plants were also conducted. For strawberry, the suggested dosage are 30 lb/a of nitrogen, until 100 lb/a of phosphate depends on the soil condition, until 100 lb/a of potassium depends on the soil condition, 15 lb/a of sulphate, 20 lb/a of magnesium, and small amount of boron (Hart et al., 2000). Rahman et al. (2004) reported that mixing of nitrogen, phosphate, potasium, magnesium and zing then applied them to potato gave a better result. For red chilli, recommended dosage for optimum result is 100 kg/ha nitrogen, 90 kg/ha phosphate, 90 kg/ha potasium, 20 kg/ha sulphate, and 2 kg/ha zing (Sarker et al., 2003). For tomato, recommended dosage for optimum result is 175 kg/ha urea, 350 kg/ha TSP, dan 200 kg/ha KCl (Ferziana, 2001). Other work reported that nutrition needed to grow tomato is 8-10 g/plant for urea and 10-15 g/plant for TSP (Marr, 1996).

Plant nutrion for horticulture commercially available both in solid and liquid forms. Nowadays, liquid form is preferable because of simple and easy to apply, especially for vegetables, ornamental, and some kinds of fruits. It is believed that more than 100 different brands are commercially available in Indonesia with primary and secondary nutrition as well as micro compounds (Susilowati, 2002). Every brand has its own unique formula for several plants which is determined by nutrition composition and consentration.

Supply of plant nutrition in water can be done continuously by flowing the water into the medium where the plants are growing, but this method will consume a lot of electrical power to run the pumps all the time. Besides, some amount of plant nutrition in water drain will be released to the surrounding and this affect the environment and increase the production cost. One method to avoid this is by giving the nutrition in water only when the plants need it, not all the time. And the plants might need different amount of plant nutrition and water from day to day during the growing period since they might exeprience different micro climate in the greenhouse as a factor of external climate changes. We might be able to predict when and how much plant nutrition and water is needed by the plants if we know respon of the plants to micro climate changes, or normal growth rate of the plants during growing period. One possibility to observe normal growth rate of the plant is by taking its images during its growing period and take some parameter as a series of data using image processing technique. Also, to know respon to the micro climate changes, the plant can be placed in different conditions and take its images, analize them and compare the data to the optimal condition.

Whatever the medium is, this method of cultivation needs plant nutrition that can be supplied through watering by using electrical pumps, namely fertigation system. Hence, plant nutrition supply through fertigation system for vegetables grown in the greenhouse is very important to obtain good produces. For this purposes, dosage of nutrition for some vegetable plants are known, and the formula is already developed for each plant. What we have to do is to put some amount of plant nutrition into a gallon of water for example, stir and distribute it to the plants. If the nutrition in water is given in a right amount and time during the growing period, the plants will grow and produce whatever we want from them in a normal period of time, with a good yield and quality. To accomplish this task, application of automatic control would be very helpful, which is sometimes referred as biosystems, meaning that automatic application using computer technology and electronic (Grift, 2003).

Automation in agricultural activities is considered necessary based on the following reasons; 1) many taks are still laborious and monotonous which are not suitable for human, but require certain intelligence to perform, 2) the availability of farming workforce is decreasing at an alarming rate in many countries, 3) the problem of labor shortage frequently result in rising in labor cost, and 4) the market demand for product quality has becaome an important factor in bioproduction (Kondo and Ting, 1998). Image processing is a technology to get information from images by manipulating images and produces the desired information to be used for taking action. If image processing is employed and collected information is used to operate a device such as electrical pump, it is called machine vision (Jain et al., 1995).

Image processing has been developed and tested in many agricultural activities; for example in automatic cherry tomato harvester in greenhouse (Kondo et al., 1996), mushroom picker to find and locate mushroom when it is ready to harvest (Reed et al., 1995), and melon harvester to find watermelon and judge it for harvest criteria (Tokuda et al., 1995). Color images processing was used to predict ripeness level of Gedong mango in a sorting and grading machine (Ahmad, et al., 2004).

Development of control system based on the feedback from the plants is called plant speaking system. To develop a plant speaking system, growth characteristics of the plant and its relationship with nutrition and water should be studied first (Hashimoto, 1985). Growth rate of groups of lettuces grown in different light condition were captured and analyzed to determine the optimum environment (Murase et al. 1994).

The objective of this preliminary research is to observe the growth rate of plants population growing in the greenhouse in different fertigation formula, using image processing technique. Another objective is to develop a real-time monitoring system using a CCD camera that can be used for automatic fertigation system.

METHODOLOGY

The research was conducted in experimental field of Agricultural Engineering Department, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University, Bogor. The research was started on June 2008, and data (images) collecting was accomplished on August 2008. After that, the images were analyzed using a developed computer program.

Material used in this research were tomato seeds, paddy husk charcoal as medium to grow the plants, polybag, and commercially available plant nutrition for tomato. Equipments used were a greenhouse, a set of drip irrigation system with a water tank and elastic pipes. A digital camera was used for image acquisition, which was taken every three days during the growing period, and a computer with image processing program to analyze the images.

First, the tomate seeds were grown in a tray in shade to produce seedlings. After two weeks, the seedlings were placed into polybags filled with charcoal of burned paddy husk. Before that, the charcoal was sterilized by soaking it into water with disinfectant. The polybags with seedlings then were placed in the greenhouse and their images were taken individually every three days. There were three groups of plants grown in the greenhouse, every group consist of 20 plants. Different formula in consentration was applied to the three groups, one group with under-fertilized (1.0–1.5 mS or mili Siemens, a unit for concentration measurement through the electrical conductivity), one with normal-fertilized (2.5–5.0 mS), and one with over-fertilized (10.0–12.5 mS).

Since they were placed in the greenhouse, their images were taken every three days from the same distance using a digital camera, with a red pannel placed as a background. When the plant grew bigger and taller so that camera could not cover the whole plant from the same distance, the distance was adjusted. Later, in image processing, distance factor was considered so that the data resulted from image processing can be compared from day to day.

Respon of the plant for deficiency in fertigation was also studied from the images. For this purpose, width of the plant in image captured at time t is compared with width of the plant in image captured at time $t+\Delta t$ because plant tends to wilt when experiencing water deficiency. Therefore, it is important to determine water deficiency condition by finding the right ratio value of width comparison. Ratio of plant's width for current condition and plant's width of normal condition might be useful for wilt determination using image processing.

RESULTS AND DISCUSSION

A number of tomato seedlings were grown in polybags after two weeks of nursery and placed in the greenhouse. Image of every plant was taken using a digital camera (Fig. 1). The captured images of tomato plants during their growing period were then analyzed using a developed image processing program. Prior to analysis, the images were collected and stored in a harddisk, separated into their groups respectivlely. From the collected images height of every plant was calculated. Data obtained from image processing were processed to get average of height. The average height data then were plotted into a graph to see the growth rate (Fig. 2).

Figure 1. Image acquisition of tomato plant

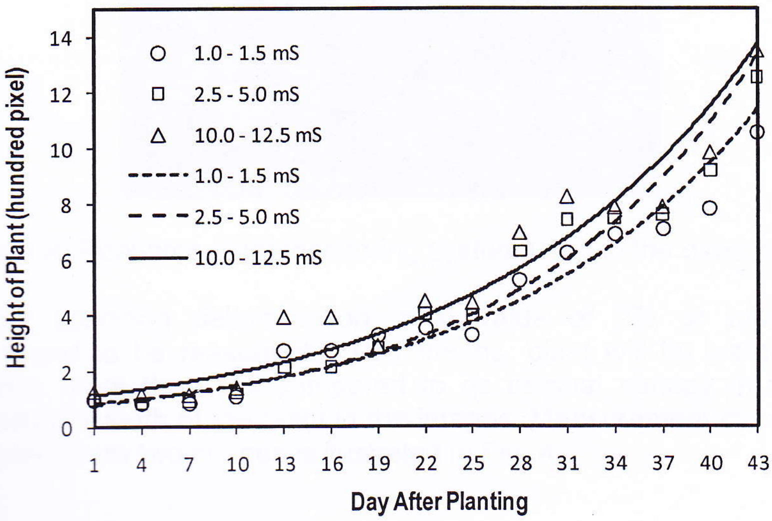

Figure 2. Plant height development obtained from image

The plants were actually grown until they produced fruits, around 75 days after planting. However, due to small space in the greenhouse, after 43 days the plant could not be captured individually since there were leaves overlapping among the plants. Overlapped leaves in image were difficult to analyzed because the developed program was desinged to analyze tomato plant image as it is taken individually.

From Fig. 2, we can see that group of tomato plant with under-fertilized (1.0–1.5 mS), experienced the slowest growth rate compare to the other two groups, the plants with normal-fertilized (2.5–5.0 mS) and the plants with over-fertilized (10.0–12.5 mS). Group of plants with over-fertilized showed the fastest height increment, followed by group of plants with normal-fertilized and group of plants with under-fertilized. Change in image quality due to change of sunlight intensity during image acquisition time, caused some fluctuation data, indicated by decreased values at some points (normally, the height of plants increases from day to day). We can see also that the graph is non-linear, meaning that the tomato plants growth was increasingly faster from day to day. More attention should be taken especially when the plants were very small for the first two weeks after planting. Lack of nutrition in this period will cause abnormal growth where the plants are still tiny and weak in roots system, and might produce less fruits later.

Automatic fertigation was attempted by applying real-time monitoring using a CCD camera and plant wilt determination was developed in the computer program to turn pump ON and OFF. For this experiment, a one month tomato plant was observed by real-time image processing system, and other 10 plants were used to apply watering action (Fig. 3). The plant that observed by the camera was placed in front of a red cloth to get contrast background with the plant in image. The camera connected to a laptop with interfacing facility to control an electrical pump, that will pump the fertilized water into all the plants. When the result of image processing meets the criteria of wilt condition, the program will turn ON the pump for 5 seconds, then OFF again.

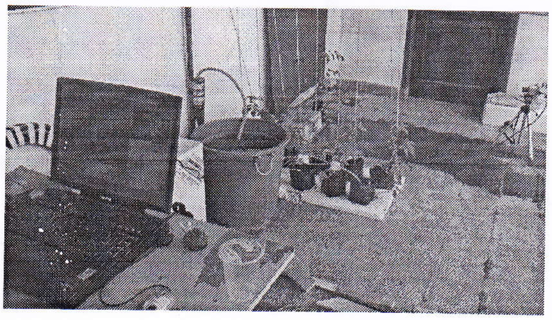

Figure 3. Real-time plant monitoring system used in the experiment

For wilt condition determination, ratio value of 2% or more for width comparison found to be reasonable. This means, plant will be watered when its canopy shrinks more than 2% compared to its original canopy in the morning, measured from the width of the plant in the images. Measurement of comparison of width of the plant from two images is ilustrated in Fig. 4.

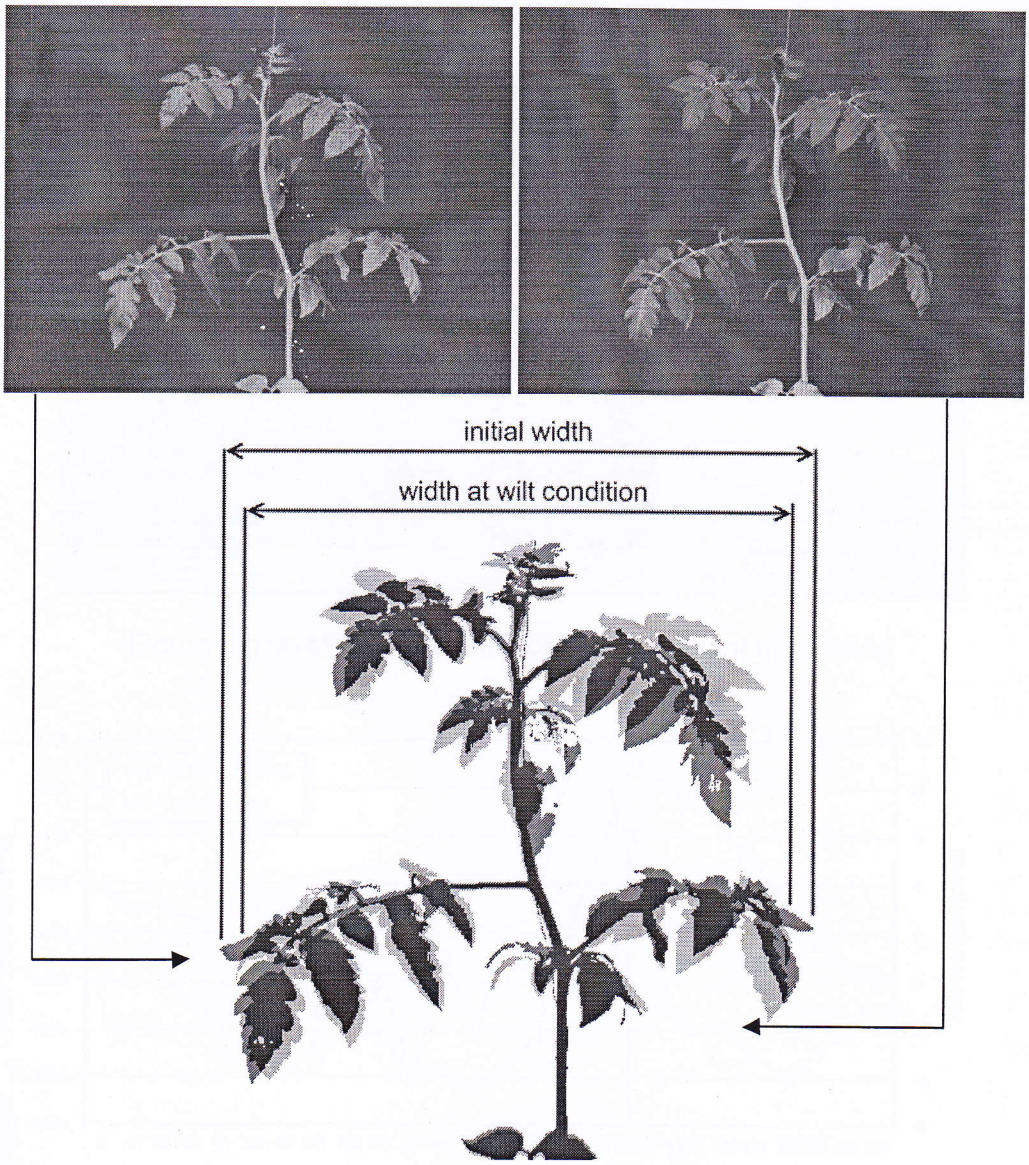

Figure 4. Measurement of comparison of width of the plant in image. (Dark gray is original condition, light gray is wilt condition, and black is overlapped part of the two images)

After determining the ratio value for width comparison, we need to apply a second rule in wilt definition, to avoid system from watering again in the next action since the condition will not change much in a short time, thus the ratio value may be still bigger than 2%. However, if a small change in wilt condition is noticed (or wilt gradient changes its value from positive to negative) , it will help to be used as a second rule for wilt condition definition. It was found that the plant will stop shrinking, or at least slow down the process, 10-15 minutes after watering. This respon was used as a second rule, so the rules for watering (turn the pump ON for 5 seconds, then OFF again) are:

```
if (wilt_degree > 0.02 and previous_width > width)
then pump=ON;
```

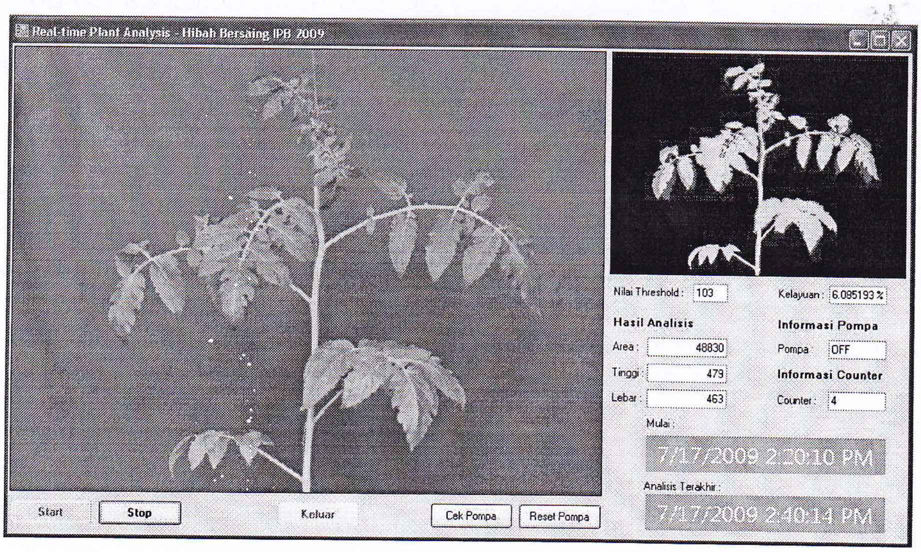

Figure 5. Developed program for real-time plant monitoring

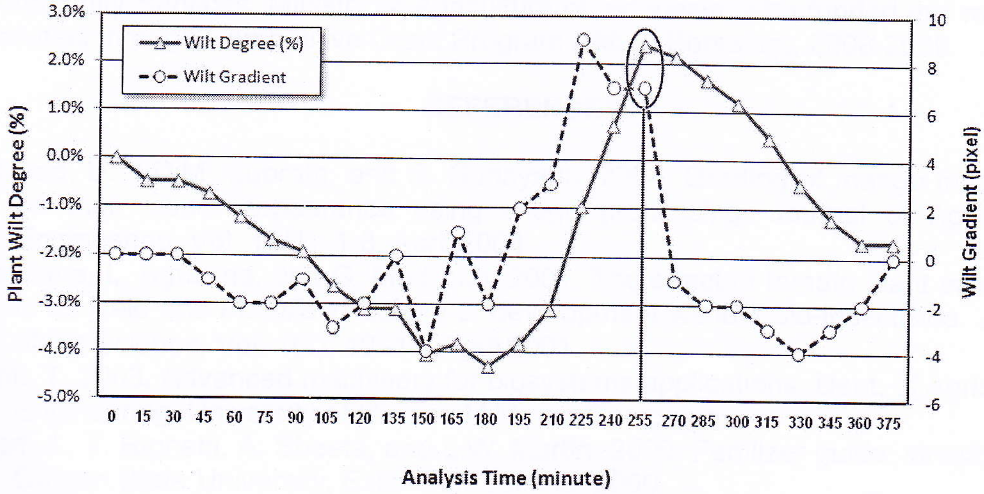

Figure 6. The record for 6 hours and 15 minutes real-time monitoring

The above rules will avoid the automatic fertigation system from watering again in the next action since the condition of the plant will stop wilting and probably get more fresh condition if compared with the last condition just before watering, so that width of plant increasing, not decreasing just like before watering. The image analysis and rules checking were conducted using a developed real-time image processing program (Fig. 5). The program was set up to capture and analysis an image, in 640 by 480 pixels resolution, every 15 minutes. The record for 6 hours and 15 minutes real-time monitoring was shown in Fig. 6. From the figure, it can be noticed that the system only turn on the pump once, after 4 hours and 15 minutes of monitoring (at 255th minute), when the wilt ratio value was more than 2% and the wilt gradient was positive. This time, we only tested that the automatic fertigation system was working and able to flow the water with plant nutrition in it, based on the determined wilt condition which was still very simple. In the next step, determination of wilt condition of the plant being monitored using some other parameters is very important to obtain the real condition of the plant that need watering.

CONCLUSIONS

From this research, some important information has been obtained and can be cocluded as follows:

1. The results showed that plant growth can be monitored by analyzing a series of images of the plants during their growth period using image processing
2. For more accurate results as well as longer period of observation, condition for image acquisition should be optimized so that leaves over-lapping among the plants can be avoided.
3. In the real-time image analysis, width of the plant can be used to determine wilt condition by comparing current condition with the original condition when the plant was still fresh.

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