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GROWTH OF CUCUMBER PLANTS (*CUCUMIS SATIVUS* L.) UNDER DIURNAL CONTROL OF AIR TEMPERATURE

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YOSHIDA, S., KITANO, M. and EGUCHI, H. *Growth of cucumber plants* (*Cucumis sativus* L.) *under diurnal control of air temperature*. BIOTRONICS 27, 97–102. 1998. Growth of cucumber plants (*Cucumis sativus* L.) was analyzed under three different control regimes of air temperature (i.e., constant-value, two-value and variable-value controls): Desired values were set at 20°C under the constant-value control, at 15°C (night) and 25°C (day) under the two-value control and in a sinusoidal pattern between 15°C and 25°C under the variable-value control. Stem length, leaf area and shoot fresh weight under the two-value control were smaller than those under the constant-value control and the variable-value control, and however percent of dry matter became largest under the two-value control. The largest stem length and leaf area were found under the variable-value control. Thus, it is suggested that the shoot growth can be modified by the control regimes of air temperature, and the variable-value control of air temperature can promote the plant growth.

Key words: cucumber plant; *Cucumis sativus* L.; growth analysis; air temperature; diurnal control; controlled environment.

INTRODUCTION

In plant production under controlled environment, night temperature is often kept lower than day temperature, and this method is known to improve plant growth and yield (3, 5). Furthermore, it has been found that plant growth can be promoted by varying the night temperature (6). Also in day temperature control, it has been found that the air temperature control according to the fluctuating natural light intensity prevents succulent growth of cucumber and lettuce plants (1, 2). From these facts, plant growth could be affected by night and day temperatures through carbon balance such as photosynthesis, translocation and dark respiration. In this study, three different regimes of diurnal control of air temperature were examined in cucumber plant growth. This study may help to understand optimum control of air temperature in plant production.

MATERIAL AND METHODS

Three natural light growth chambers were used for growth analysis under

three different regimes of diurnal control of air temperature, that is, 1) constant-value control, 2) two-value control and 3) variable-value control. In the first chamber for the constant value control, desired value was set at 20°C. In the second chamber for the two-value control, desired values were set at 25°C from 6:00 to 18:00 and at 15°C from 18:00 to 6:00. In the third chamber for the variable-value control, desired values were changed in the sinusoidal pattern with diurnal period between 15°C (0:00) and 25°C (12:00). In all the chambers, daily mean air temperature was 20°C, and relative humidity was controlled constantly at 70%. Signals of these desired values were transmitted from an on-line computer to an air temperature controller with intervals of 1 min and held for 1 min (1, 2). Figure 1 shows time course patterns of controlled variables of

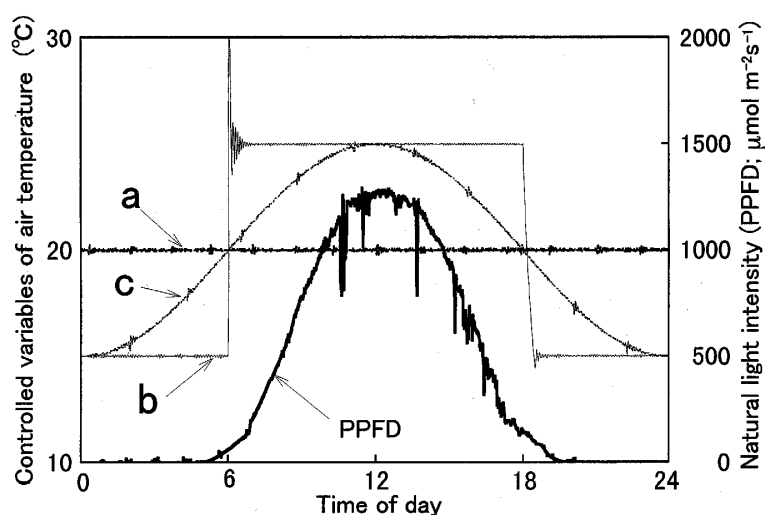


Fig. 1. Time course patterns of the natural light intensity (PPFD) on a fair day and air temperatures in the respective regimes of constant-value control (a), two-value control (b) and variable-value control (c).

air temperature and natural light intensity on a fair day. Air temperature under the two-value control settled after transient oscillation at the time of the stepwise change in the desired values (6:00 and 18:00). In the daytime on a fair day, air temperature under the variable-value control was almost synchronized with the natural light intensity. Thus, accuracy of the air temperature controls in all the chambers appeared to be sufficient for growth analysis.

Cucumber (*Cucumis sativus* L. cv. Chojitsu-Ochiai) seeds were germinated in 14 cm pots with vermiculite, and four pots of cotyledonary plants were grown in each growth chamber. The root medium was moistened enough with a complete nutrient solution (Mg^{2+} , 1.8 mM; Ca^{2+} , 4.2 mM; K^{+} , 7.6 mM; $\text{H}_2\text{PO}_4^{-}$, 1.6 mM; NO_3^{-} , 16.4 mM with iron-EDTA and micronutrients). Stem length, number of leaves and midrib length of each leaf were measured with intervals of a week. Leaf area (LA ; cm^2) of each leaf was evaluated from the midrib length (LL ; cm) by using a LL - LA relationship predetermined empirically as $LA = 1.265 LL^2 - 4.784 LL + 12.79$ (1). The fresh and dry weights were measured in the

matured second leaf of the plants grown for four weeks under the respective control regimes of air temperature.

RESULT AND DISCUSSION

Figure 2 shows photograph of general views of the cucumber plants grown

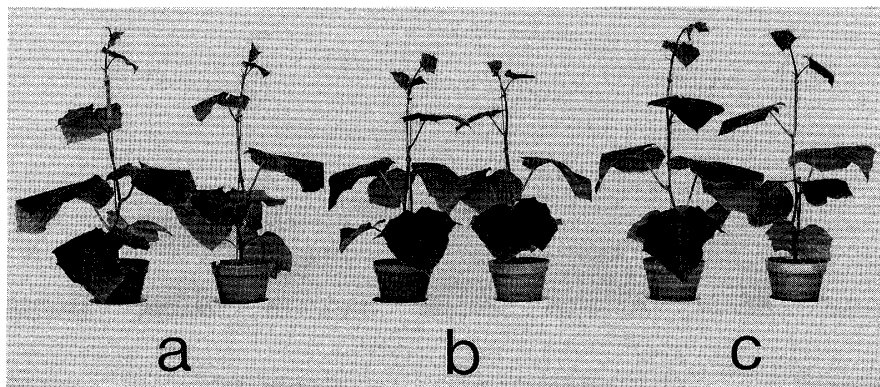


Fig. 2. Photograph of cucumber plants grown for four weeks in the respective regimes of air temperature under constant-value control (a), two-value control (b) and variable-value control (c).

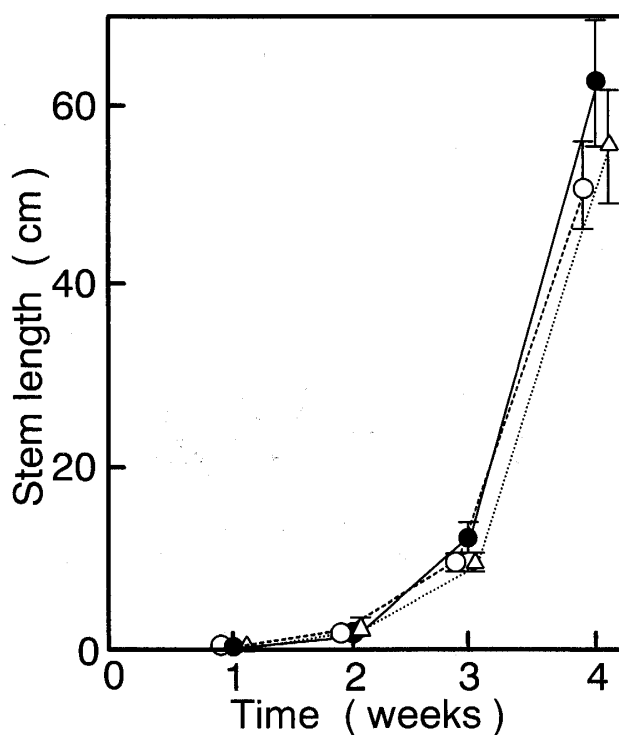


Fig. 3. Time course patterns of stem length of cucumber plants grown in the respective regimes of air temperature under constant-value control (Δ), two-value control (\circ) and variable-value control (\bullet): The means of measured values in four plants were shown with 95% confidence limits.

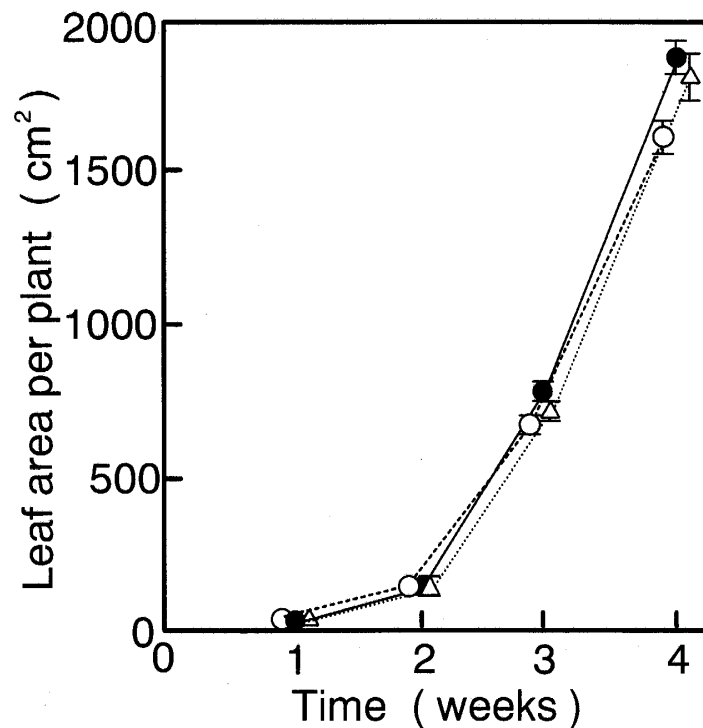


Fig. 4. Time course patterns of leaf area of cucumber plants grown in the respective regimes of air temperature under constant-value control (Δ), two-value control (\circ) and variable-value control (\bullet): The means of measured values in four plants were shown with 95% confidence limits.

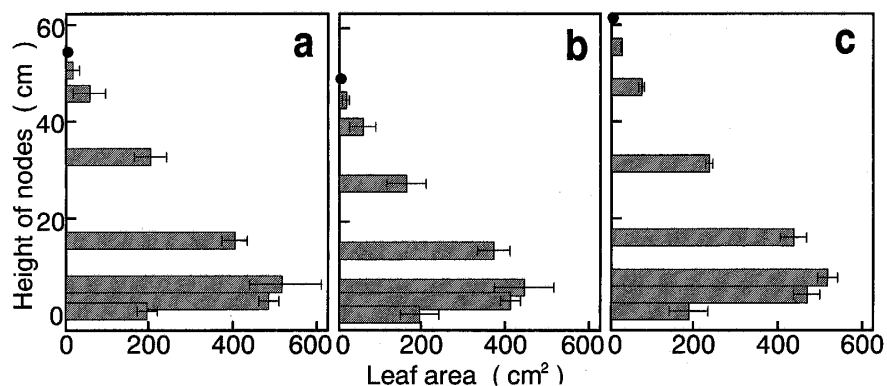


Fig. 5. Distribution of leaf area of each leaf along the stems of cucumber plants grown for four weeks in the respective regimes of air temperature under constant-value control (a), two-value control (b) and variable-value control (c): The means of measured values in four plants were shown with 95% confidence limits.

for four weeks under the air temperature controls. From the fact that all the plants appeared healthy, all the control regimes of air temperature were estimated to be around the optimum temperature. Figure 3 shows time course patterns of stem length. Stem length under the variable-value control was

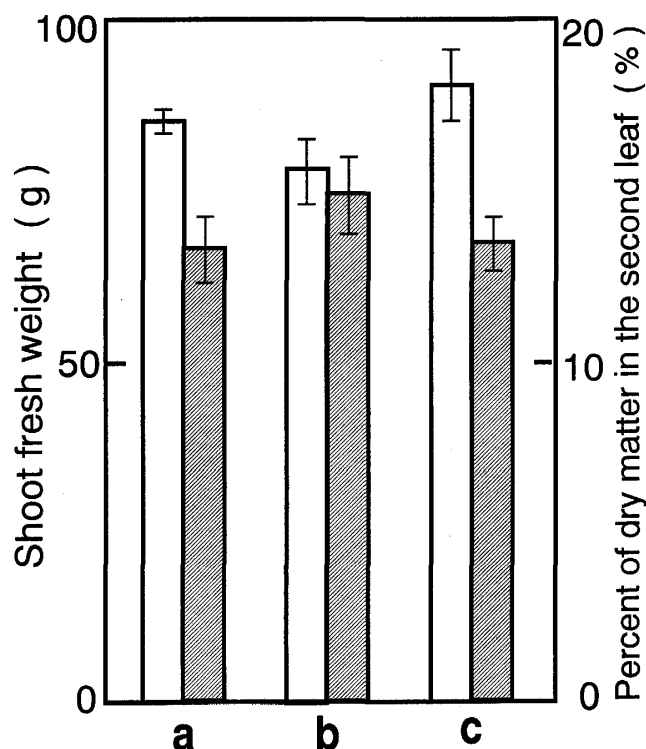


Fig. 6. Shoot fresh weight per plant (\square) and percent of dry matter (\blacksquare) in the second leaf of cucumber plants grown for four weeks in the respective regimes of air temperature under constant-value control (a), two-value control (b) and variable-value control (c): The means of measured values in four plants were shown with 95% confidence limits.

significantly larger than that under the two-value control. Figure 4 shows time course patterns of leaf area per plant. Leaf area increased rapidly under the constant-value control and the variable-value control, and the lower increase rate was found under the two-value control. Figure 5 shows distribution of leaf area along the stem, where area of each leaf was plotted on the height of nodes. Number of leaves under the two-value control was equal to those under the constant-value control and the variable-value control, but area of each leaf under the two-value control became smaller. Under the constant-value control, larger area of each leaf was found at the lower position along the stem. Under the variable-value control, however, larger area of each leaf was found at the higher position along the stem. From the results, stem elongation and leaf expansion were promoted under the variable-value control as compared with the two-value control. It has been considered that the night temperature lower than day temperature can improve plant growth through carbon balance between photosynthesis and dark respiration (3, 5). In the present study, however, the improvement in plant growth was not found under the two-value control as compared with the constant-value control. Figure 6 shows shoot fresh weight and percent of dry matter in the matured second leaf. Shoot fresh weight under the two-value control was smaller than those under the constant-value control

and the variable-value control. The largest percent of dry matter was found under the two-value control where slower leaf growth was found (Fig. 5). This event could be caused by higher accumulation of photosynthate and/or decrease in leaf water content under the two-value control. Hori and Shishido (3) have found that photosynthetic carbon in tomato leaves is translocated to sink organs within two to four hours just after light-off. Toki *et al.* (6) have recommended that the air temperature for a few hours after sunset should be kept higher than the night temperature to maintain active translocation. Thus, it can be estimated that the drastic drop to the night temperature under the two-value control restricts the carbon translocation from source leaves. Furthermore, it is possible that the drastic change in air temperature disturbs physiological processes affecting the leaf expansion. On the other hand, these restriction on the translocation and disturbance of the physiological processes could not be found under the variable-value control where the night temperature after sunset decreased more slowly.

Air temperature in the daytime is considered to affect plant growth through photosynthetic activity which is the light- and temperature-dependent process (4). In the previous papers (1, 2), it has been found that the day temperature control according to the natural light intensity can prevent succulent growth in cucumber and lettuce plants. Thus, it is considered that the improved growth found under the variable-value control can be also attributed to the day temperature synchronized with the natural light intensity on a fair day.

From the results, it is suggested that shoot growth of cucumber plants can be modified by the control regimes of air temperature, and the sinusoidal regimes of temperature control can promote the plant growth.

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