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Enhancement of photosynthesis and growth of tomato seedlings by forced ventilation within the canopy

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Abstract

A forced ventilation system that directs airflow upward or downward within a canopy was developed for plant culture in order to enhance photosynthesis and growth of the plant canopy. Tomato seedling canopies including the seedlings, growing medium, and a plastic tray were used for the experiments. In the upward and downward ventilation systems, air flows upward and downward, respectively, within the plant canopy; this is achieved by blowing and drawing air from holes (0.6 mm) made in plastic pipes positioned on the surface of the growing medium. A horizontal airflow system was used as a conventional system to compare the performance of the experimental ventilation systems. Using the upward and downward ventilation systems, the effects of air directions and air velocities on the CO_2 exchange rate of the tomato seedling canopy and the growth of the seedlings were compared with those observed using the conventional horizontal airflow system. The forced ventilation within the plant canopy enhanced tlie CO_2 exchange rate of the canopy and the dry masses of the seedlings by 1.4-1.5 and 1.2-1.3 times, respectively, as compared to the conventional horizontal airllow. When the leaf area index (LAI) increased front 1.2 to 2.4, there was only a 5% decrease in the CO2 exchange rate per unit leaf area in the downward ventilation system, whereas !here was a 20% decrease in the CO_2 exchange rate per leaf area in the horizontal airflow system. The coefficient of variation for the dry mass of the seedlings was higher in the downward system than in the other systems. These results demonstrate that forced ventilation within the canopy is an effective technique to enhance the gas exchange of the plant canopy and the consequent plant growth.

Keywords: Air velocity: Gas exchange: Net photosynthetic rate: 'tomato: Transplant production

1. Introduction

A closed-type transplant production system with artificial light (Kozai et al., 20(K); Chun and Kozai, 2000; Ohyama et al., 2000) has been recently developed as a high performance production system that can produce high quality transplants regardless of the weather. The air circulation method is essential to control the micrometeorological environment around the transplants and their consequent gas exchange. It is relatively easy to design a ventilation system that provides the required air circulation in a closed-type system than in a greenhouse. Therefore, the selection of an appropriate type of ventilation system is essential to control the environment in a closed-type system. If an insufficient air velocity is present above the canopy, it results in the thickening of the boundary layer (Kim et ahis., 1996a). Thus, the gas exchange of the transplants is limited (Kitaya et al., 2003; Shihuya and Kozai, 2001) due to the decrease in the CO_2 concentration and air velocity around the leaf (Kim et al., 1996b; Kitaya et al., 1998). Along with the air velocity, the airflow direction is equally important for controlling the gas exchange' of a plant canopy, particularly for a high-density canopy. This is because the

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