Climatic Evaluation of Semi-Closed Greenhouses

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Abstract

In the Netherlands the development of semi-closed greenhouses is going on for eight years. Increased carbon dioxide levels, reduced pesticide use, and energy saving are the main benefits of semi-closed greenhouses. Companies have developed several concepts with the goal to reduce the ventilation with outside air which mainly have been built at commercial tomato and *Phalaenopsis* growers. The goal of the project is to monitor the greenhouse climate at these nurseries in a uniform way so the concepts can be compared and to help growers to control the development of the crop in the best way. The climate is analyzed by measuring temperature and relative humidity on three heights: at the top of the canopy, in between the top and the root system, and near the full grown tomatoes. All system parameters regulating the greenhouse climate are registered which includes the air treatment unit used in the semi-closed greenhouse. Additional measurements are done to determine the local climate as a result of the air treatment units. Three concepts include air ducts below the hanging gutters which distribute outside air and/or cooled greenhouse air. Two concepts have air treatment units hanging above the canopy used for cooling. Only one concept is without windows and therefore completely relies on the systems for cooling. The systems with an air duct under the hanging gutters all show in a vertical temperature gradient with cold air near the root system and warm air near the top of the canopy. This gradient is not present in conventional greenhouses. The horizontal temperature distribution is rather homogenous during cooling with air ducts. Heating using the air ducts gives a lower temperature near the sides of the greenhouse than at the center of the greenhouse increasing the risk of botrytis. Coolers hanging above the crop give a homogenous climate during cooling. A disadvantage of these top coolers is the fact that they reduce the light level near the crop.

INTRODUCTION

In the Netherlands the development of semi-closed greenhouses is going on for eight years (Heuvelink et al., 2007). Increased carbon dioxide levels, reduced pesticide use, and energy saving are the main benefits of semi-closed greenhouses (Bakker et al., 2006; De Zwart, 2007). Companies have developed several concepts with the goal to reduce the ventilation with outside air. Mechanical cooling for climate control in greenhouses is a difficult task (De Zwart and Kempkes, 2007). All the solar radiation being absorbed in the greenhouse has to be removed if the greenhouse is kept completely closed. This enormous cooling capacity should be installed with a minimum amount of light interception for the canopy. These restrictions have let to various systems which will affect the greenhouse climate differently. The goal of the project is to monitor the climate in a uniform way for each greenhouse, so the systems can be compared. All these commercial companies have at the same location a conventional greenhouse where the climate is regulated by ventilation and heating. The climate in these compartments is measured in the same way so a comparison between the conventional and the semi-closed greenhouse can be made for every grower. The knowledge gained in this project will be

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used to develop alternative systems which further optimize climate control. The greenhouses under evaluation grow tomato.

MATERIALS AND METHODS

The climate is monitored at four commercial tomato growers. The installed system varies for every grower. The main variations are listed in Table 1. Three growers have air ducts below the hanging gutters which distribute the conditioned air in the greenhouse (Fig. 1). Two growers apply high pressure fogging to increase the humidity. Two growers have coolers installed near the cover of the greenhouse which can locally cool the greenhouse air (Fig. 1). One grower does not have any windows in its cover meaning he cannot use natural ventilation to condition his greenhouse.

The climate is analyzed in the conventional and semi-closed greenhouse by measuring temperature, and relative humidity level on three heights: at the top of the canopy, in between the top and the root system, and near the full grown tomatoes. The air temperature and relative humidity are measured using the instruments equal to the ones used by the climate control computer being ventilated sensors. The measurement is done half way between the side of the greenhouse and the path located centrally in the greenhouse. All system parameters regulating the greenhouse climate are registered which includes the air treatment unit used in the semi-closed greenhouse. Based on this information the comparison between the traditional greenhouse and the semi-closed greenhouse and various concepts is made.

Besides these standard measurements additional climate measurements are done. These measures give more inside on the influence of air treatment units on the local climate. These measurements are done using wireless sensors which register temperature and relative humidity (SOWNET Model HT100). The sensors are used to determine the climate along the air duct at company 1 at three heights and in a repeatable area at company 4. The used sensors have been compared in terms of temperature and relative humidity reading in a climate chamber. The relative difference between the sensors is less than 0.3 K.

RESULTS AND DISCUSSION

The temperature at three heights in the semi-closed and conventional greenhouse for a 24-hour period for the month July is depicted in Figure 2. Company 1 uses a different climatic strategy for the semi-closed greenhouse as compared to the conventional one. The fact that the carbon dioxide concentration is maintained at a higher level in the semi-closed greenhouse is the reason for this. The companies (1, 2 and 3) where air ducts below the gutters are used to cool the greenhouse clearly show a lower temperature in the lower part of the greenhouse during the day. Cold air weighing more than warm air causes this. In the conventional greenhouse the vertical temperatures do not differ much. The effect of the top coolers installed at company 3 does not influence the vertical temperature distribution when compared to the other companies. The temperature profiles for company 4 which uses only top coolers to cool, do not differ for the conventional and semi-closed greenhouse. Cooling from above with coolers resembles more the conventional way of cooling.

All semi-closed greenhouses have a higher humidity than in the conventional greenhouse (Fig. 3). Less ventilation causes the humidity to increase. Companies 1 and 2 where the air is conditioned by a heat exchanger and cold water, shows a higher humidity in the lower section of the greenhouse than at company 3 where the air is coming from outside.

The temperature profile along the air duct at company 1 during a period of 3 hours when heating was applied, is depicted in Figure 4. This company is the only company that applies low temperature water for its heating. The temperature at the side of the greenhouse is lower than at the centre of the greenhouse. As a result the relative humidity is high at the side of the greenhouse, increasing the chance of botrytis infection. The temperature profile during cooling (Fig. 5) is more homogenous in the horizontal direction. Vertically the same profile can be seen as in Figure 2. The fact that the horizontal profile is less homogenous during heating is caused by the fact that the air cools down as it flows back to the heat exchanger located near the side of the greenhouse. This cold air moves downward causing a lower temperature near the crop at the side of the greenhouse. This does not occur during cooling since the air is warmed up in this case, not affecting the air temperature near the crop.

The temperature profile during cooling with top coolers at company 4 is depicted in Figure 6. The arrows in the figure indicate the direction of the out flowing air from the heat exchanger (Fig. 1. right). Out coming temperature of the coolers is 5 degrees colder than the greenhouse air temperature. The temperature difference near the crop is less than 1 degree. So the cold air is distributed evenly by the fans of the heat exchanger. The fact that the heat exchangers hang 2 m above the crop is also beneficial for the climate.

CONCLUSIONS

Cooling from beneath in a tomato crop results in a vertical temperature gradient where the cold air remains near the air ducts. As a result the ripening fruits are hanging in a lower temperature than the rest of the plant. This does not affect the quality of the product but it does prolong the ripping of the fruit causing the plant to have more tomatoes thereby increasing its load. Air ducts designed for cooling do not give a homogenous climate when used for heating. The flow pattern is dependent on the temperature of the out flowing air which influences the climate distribution. Coolers installed near the cover of the greenhouse give a good temperature distribution as long as the out coming air is turbulent so it mixes with the greenhouse air before reaching the crop. Another beneficial fact of the top coolers is that the air is distributed without using air ducts which reduces the electricity use of the fans. A disadvantage of these top coolers is the fact that they reduce the light level near the crop and thereby the production. Also the top coolers are not used to heat the greenhouse since this would increase the energy use when the heat is distributed so near the greenhouse cover. The application of low temperature water for heating remains a challenge to be solved for the concept of a semi-closed greenhouse.

ACKNOWLEDGEMENTS

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Tables

Table 1. The main characteristics of the various systems.

System	Air ducts	Fogging	Top coolers	Windows
1	yes	yes	no	yes
2	yes	no	no	yes
3	yes	no	yes	no
4	no	yes	yes	yes

Figures

Fig. 1. Picture of a greenhouse with air ducts positioned beneath the hanging gutters (left) and a picture of a greenhouse where the coolers are hanging above the crop near the cover of the greenhouse (right).

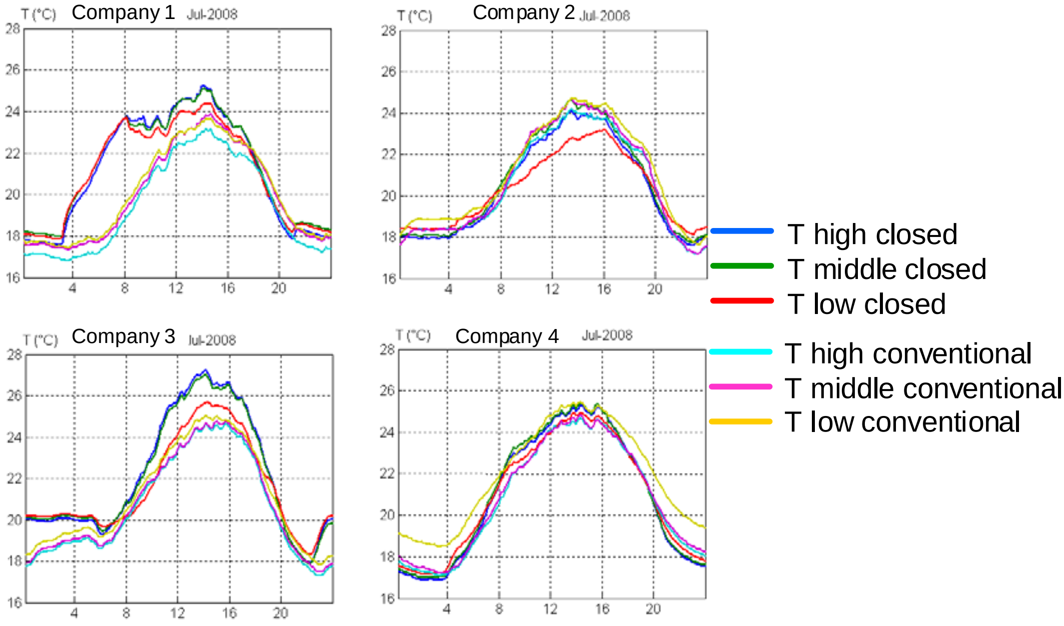

Fig. 2. Temperature at three different heights in the semi-closed greenhouse and the conventional greenhouse at four companies on a 24 hours cycle mean averaged period for the month July 2008.

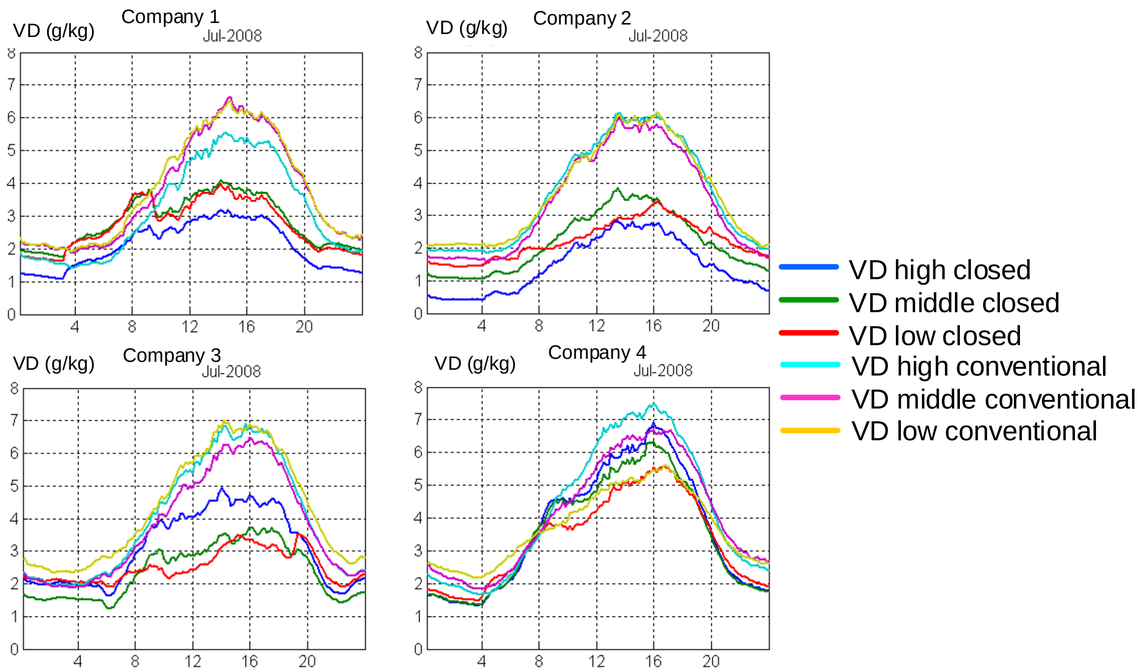

Fig. 3. Vapor deficit in g/kg at three different heights in the semi-closed greenhouse and the conventional greenhouse at four companies on a 24 hours cycle mean averaged period for the month July 2008.

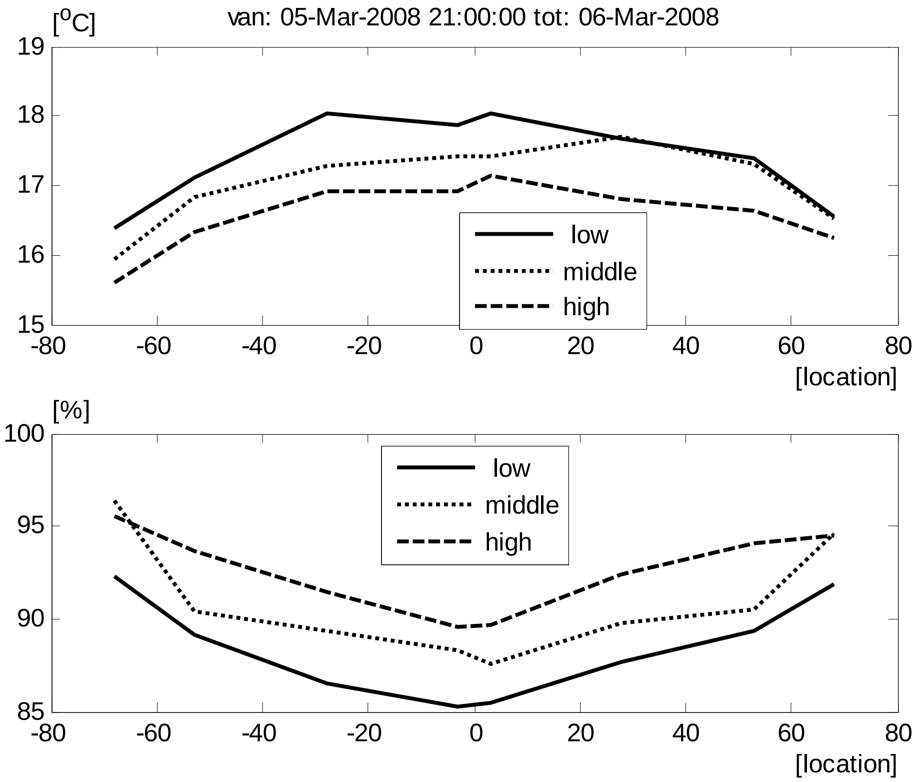

Fig. 4. Temperature and relative humidity profile along the air duct from side to side in the greenhouse during a heating period.

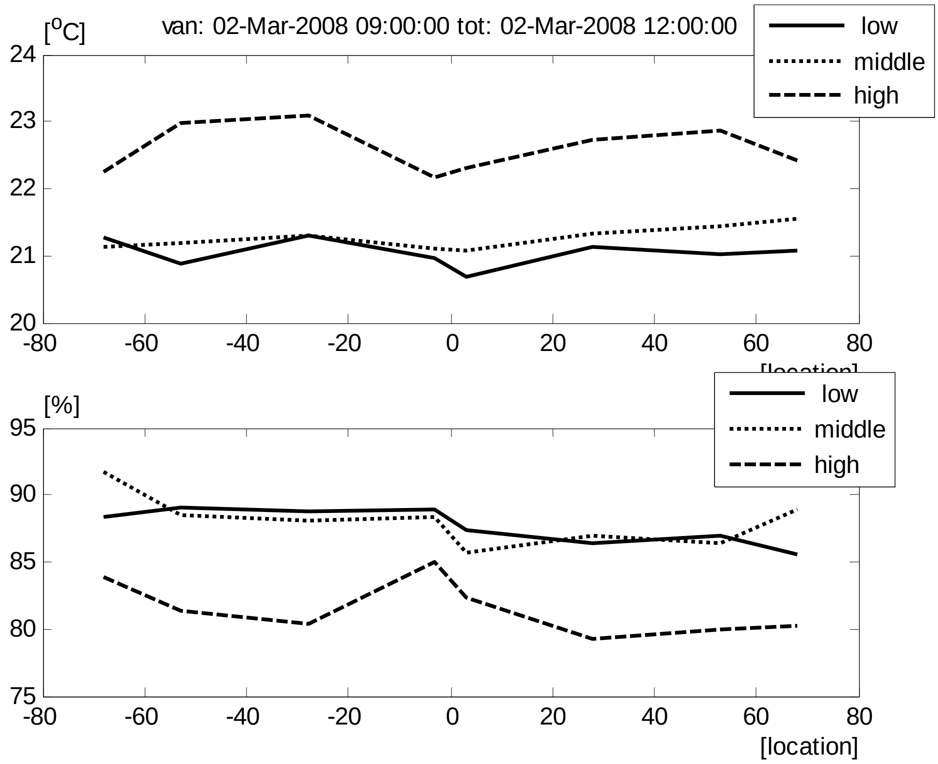

Fig. 5. Temperature and relative humidity profile along the air duct from side to side in the greenhouse during a cooling period.

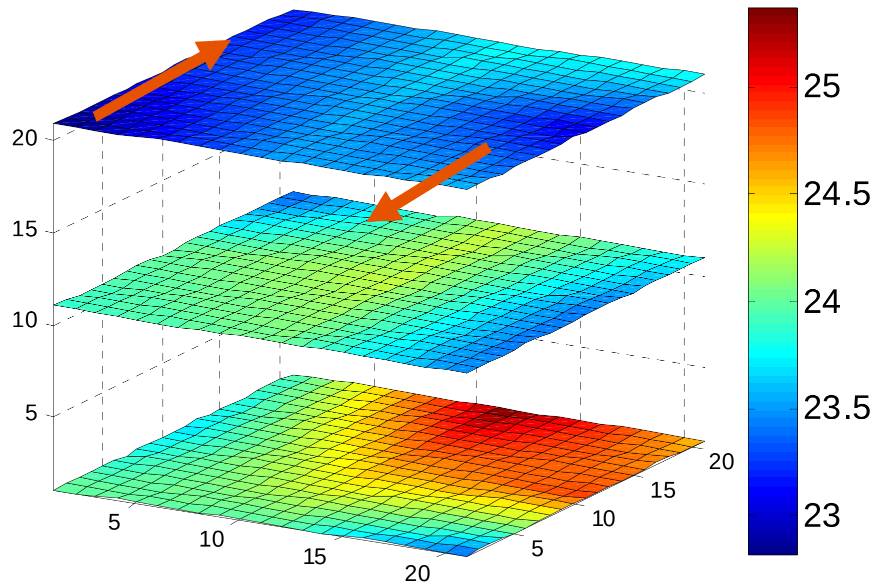

Fig. 6. Temperature profile during cooling periods (between 25 July and 1 August 2008) for a repeatable section of a greenhouse at three heights where top coolers are used to condition the air.