Evaluation: 'SynErgy: Montitoring and control system for conditioning of plants and greenhouse' (WP-066)

November 2010

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Duration: January 2007 – December 2010

Introduction

Currently, the greenhouse industry contributes to about 10% of the total natural gas consumption in the Netherlands. However, the horticultural sector has set the ambitious goal to reduce the CO_2 emission by about 50% in 2020 compared to the reference year 1990. To achieve this goal, energy consumption in existing greenhouses will have to be reduced considerably. Additionally, new greenhouse concepts are being developed, such that greenhouses will need only a small fraction of the energy they need today or that the greenhouses will even be net producers of energy. In closed greenhouses, the excess of solar energy in summer is collected and stored in aquifers to be reused in winter to heat the greenhouse. In The Netherlands, since 2002, a number of (semi-) closed greenhouses were constructed. However, in these greenhouses climate conditions differ considerably from those in conventional greenhouses. In the research project "Crop management in conditioned greenhouses", funded by the Dutch Commodity Board and the Ministry of Agriculture, Nature and Food Safety, the effects of the new climate conditions on the crop are investigated. In the accompanying twin project "SynErgy: monitoring and control system, for conditioning of plants and greenhouses", funded by TransForum, this knowledge is used to develop new concepts of climate control for optimal crop growth.

Research

In this project, the PhD student Tian Qian set up the research according to the following steps:

1. Confirmation of production increase in conditioned greenhouses compared to that in open greenhouses.
2. Quantification of climate effects, such as temperature, air humidity and CO_2 concentration, on crop physiological processes and morphological characteristics.
3. Explanation of climate effects on crop growth and development by the quantified relations and by using crop growth model.
4. Adaptation of existing model by integration of the quantified relations, to make the model suitable to conditioned greenhouses.
5. Application of the adapted model to determine an optimal climate for crop growth and production in conditioned greenhouses.

At Wageningen UR Greenhouse Horticulture in Bleiswijk, in 2008, 2009 and 2010, in 5 greenhouse compartments, tomato crops were grown under different climates in closed, semi-closed or open greenhouses. In these experiments, the PhD student determined climate characteristics, plant growth and development, photosynthesis in relation to light, temperature, CO_2 and humidity, adaptation to long term high CO_2 concentration and assimilate distribution. The information obtained was used to calibrate the model. With this model, scenario studies will be performed to determine the optimal climate for crop growth and production in conditioned greenhouses.

Main results

Climate characteristics of conditioned greenhouses

With increasing cooling capacities of (semi)closed greenhouses, window opening for temperature control is less. Consequence is that higher CO_2 concentrations can be maintained in the greenhouse, which is the primary reason for the production increase. When cooling is applied in the lower part of the greenhouse, vertical temperature gradients occur, which affect plant development and morphology

Plant growth and development
In (semi)closed greenhouses, tomato fruit production is higher than in open greenhouses. This production increase is due to the higher assimilate (dry matter) production, i.e. higher total crop photosynthesis. Dry matter partitioning to the fruits did not differ between treatments. Analysis of climate data and data of plant growth by a crop growth model suggested that the differences in dry matter production and assimilate distribution can be fully explained by the realized differences in CO_2 concentration in the greenhouses.

Photosynthesis responses to light, CO_2, temperature and humidity
The basis for plant growth is photosynthesis, which is influenced by climate factors such as light, CO_2, temperature and humidity. In conditioned greenhouses, climate can be controlled more accurately, and combinations of climate conditions are possible, which do not occur in open greenhouses (i.e. combination of high light and high CO_2 concentration). To determine the optimal climate in semi-closed greenhouses, effects of climate factors on photosynthesis were quantified.

Light response curves measured at four different CO_2 concentrations show clear interaction between light and CO_2. CO_2 response curves also show an optimal pattern. At low CO_2 concentration, increasing light intensity hardly affects photosynthesis. With increasing CO_2 concentrations, the effect of light on photosynthesis increases as well.

The optimal temperature for leaf photosynthesis was found to be about 34°C, when light and CO_2 concentration are not limiting photosynthesis. However, under sub-optimal conditions (photosynthesis limited by light or CO_2), temperature hardly affects photosynthesis rate.

VPD response of photosynthesis was measured at a rang of VPD about 0.2 – 2.5 kPa at two light intensities and two CO_2 concentrations. Photosynthesis was not affected by VPD, despite the fact that the stomatal conductance was significantly affected by VPD. Apparently, stomatal conductance in this range of humidities does not limit CO_2 uptake.

The quantified climate response curves of leaf photosynthesis were up scaled to crop photosynthesis based on light extinction through canopy and Gaussian integration. Crop photosynthesis shows the same responses to climate, but has different optima. This information will be input into the crop growth model, to determine the optimal climate for growth and production in conditioned greenhouses.

Photosynthesis acclimation to continuous high CO_2 concentration
In conditioned greenhouses, CO_2 levels are higher than in open greenhouses. This raises the question whether plants under these conditions adapt to the prolonged high CO_2 concentrations. If photosynthesis would be down-regulated after prolonged high CO_2 concentrations, this implies that the optimal CO_2 strategy needs to be adapted. Results of photosynthesis measurements show that there is no acclimation in the upper leaf layer but do show acclimation at middle leaf layers. This process will be added to the crop growth model to improve simulations for crop growth in conditioned greenhouses.

Meaning for TransForum
Currently, greenhouses industry contributes to about 10% of the total gas consumption in The Netherlands. Recently, new greenhouse concepts are being developed, which reduce the amount of energy per m^2 considerably, or which even transform greenhouses into net energy producers. It turns out that climate in these new types of greenhouses is completely different from the climate in conventional greenhouses. A major bottleneck in introducing the new concepts into practice, is the lack of knowledge on the crop response to these new climate conditions. This twin project aims at obtaining knowledge on crop growth and development and underlying physiological processes, such that this bottleneck can be solved. This will

facilitate the introduction of energy friendly or energy producing greenhouses. Next step will be to integrate such new growth models with production and delivery of energy at peak time demand moments in order to optimize income. At a peak time demand moment energy is most expensive.

Implications for Metropolitan Agriculture

To make the energy producing greenhouse sustainable, the surplus of energy it collects, has to be used for multiple purposes. Heating houses could be one of the applications for the surplus of heat. Therefore the energy producing greenhouses are most suited to be part of a Metropolitan Agricultural community. Furthermore, the fresh produce of the greenhouses can be directly distributed to the inhabitants of the city, thereby reducing energy costs of transport and the time between harvest and consumption or other use.

Implications for Connecting Values and Agro-Innovations System

The combination of plant production and production of energy instead of using energy is new. This scientific project contributes to enable the development of an energy producing greenhouse in combination with a high and controllable vegetable production. This ensures the competitiveness of the greenhouse horticultural sector for the future. In this project, new plant physiological knowledge is developed, which can be used for this and future new greenhouse concepts to reduce energy consumption and further increase of production and quality, thereby improving the profit of the horticultural sector. It is clear that the design of energy producing greenhouses is asking for redesigning the whole greenhouse production system involved combined with its surrounding.