Tomato Yield in a Closed Greenhouse and Comparison with Simulated Yields in Closed and Conventional Greenhouses

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Abstract

In 2002 tomato was cultivated in a closed venlo-type greenhouse to investigate the influence of cooling with forced air movement along heat-exchangers combined with high CO_2 level under summer light conditions on production and quality. Transpiration in the closed greenhouse with forced air movement was, compared to a conventional greenhouse, higher at low light levels (2 instead of 1 kg/m^2) and lower at high light levels kg/m^2 (4 instead of 5 kg.m^2).

Comparison of the observed yield with crop yields predicted with TOMSIM showed that yield was increased by 22% from 46.2 to 56.2 kg/m^2 compared to a conventional greenhouse with CO_2 concentration always above 500 ppm. The higher CO_2 concentration in the closed greenhouse (always 1000 ppm) could explain only a 9% yield increase.

INTRODUCTION

The development of a closed greenhouse is one of the major innovations in dutch horticulture in the last years. The system is described in Opdam et al. (2005).

Besides the important step forward, the realization of the technical equipment, the most important need for success is a good growth result. Growth in a closed greenhouse is new. There is no experience with growing tomato or other crops in such a greenhouse system. The only experience in closed systems is in climate chambers. For the return on investment a higher production is needed. Calculations with ECP, a growth model of PPO, (Houter, 1991) - predicted level 14 % higher production for tomato if the CO_2 concentration was kept at 1000 ppm. The ECP model and other crop growth models are not validated for conditions with high light level and high CO_2 concentration. Consequently, a practical experiment with a 1400 m^2 tomato crop was set up to test the concept of the closed greenhouse and measure the production.

MATERIAL AND METHODS

Tomato plants cv Aromata were planted on rockwool slabs in gutters on January 24th in a greenhouse of 1400 m^2. Fresh weight production of fruits was monitored in 10 plots of 4.8 m^2 untill 15 November. During crop handling the fresh weight of removed old leaves of the plots was recorded. At the end of the experiment fresh weight of remaining fruit, leaves and stems was measured.

The CO_2 level at daytime was 1000 ppm. Maximum temperature in summer was 26 ^{o}C. The relative humidity was kept below 90 %.

Dry and fresh weight, leaf area, number of fruits and trusses of 10 plants a time was measured with a four-week interval. Transpiration was measured on-line with weighing equipment (de Graaf et al., 2004). Dry and wet bulb temperature and CO_2 level were every minute registrated on a computer. Climate set points were depending on crop development and determined together with a commercial grower. The experiment was continued until November 28th. As a comparison with a normal crop was not possible the results were compared with the predicted yield of a crop grown under conventional conditions simulated by TOMSIM, a photosynthesis-driven crop growth model

(Heuvelink,1996). The models TOMSIM and ECP are based on the same physiological approach for plantgrowth and are well validated for prediction of tomato crop production in conventional greenhouses (Heuvelink, 1996).

RESULTS AND DISCUSSION

An example of the climate on two, hot summer days is given in Fig. 1. The system with cooling, dehumidification and forced air movement realized the desired climate for tomato growing.

The realized production (56.2 kg/m^2) and predicted production for a conventional (46.2 kg/m^2) and a closed greenhouse (51.2 kg/m^2) of TOMSIM is showed in Fig. 2. The prediction was made using measured leaf area index of the crop and climate data from the greenhouse. The results of the prediction were compared with measured dry and fresh weight data. To calculate the influence of the higher CO_2 level, data about CO_2 in a normal greenhouse of a grower were used. With the model the production was under estimated. Only 9 % of the higher production in the simulation is due to the higher CO_2 level. It seems likely that the observed much higher yield increase is at least partly the result of a higher air circulation (lower boundary layer resistance). Dry matter of fruits was higher then in a conventionally-grown crop (7-8 % dry matter, desired level is 6%). If this will be realized in practice the production level in fresh weight will increase even more. The model could predict the realized production if the maximum fotosynthesis was set at a higher level.

The air circulation combined with heating and cooling also influenced the crop transpiration Fig. 3. At low radiation levels the transpiration is higher in the closed greenhouse than in a normal heated greenhouse (model data from R. de Graaf, pers comm.). At high radiation levels the transpiration due to the air movement with cooled air. The difference between transpiration during April-May and July-November might be caused by a change in the air distribution system.

Additional advantages of a closed greenhouse, besides the clear possibility of energy saving and increased production (high CO_2) are the very low (if any) need for pesticides, the high water use efficiency (no loss of water vapour) and less peaks in production (better temperature control).

Literature Cited

Graaf, R. de, de Gelder, A. and Blok, C. 2004. Advanced Weighing Equipment for Water, Crop Growth and Climate control management. Acta Hort. 664:163-167.

Houter, G. 1991. ECP - model: simulatiemodel voor energieverbruik, CO_2-verbruik en kg-produktie in de glastuinbouw: eindverslag. Naaldwijk: Proefstation voor Tuinbouw onder Glas. Verslag 4; pp 30.

Heuvelink, E. 1996. Tomato growth and yield: quantitative analysis and synthesis. Wageningen, thesis 326 pp.

Opdam J.J.G., Schoonderbeek, G.G., Heller, E.M.B. and de Gelder, A. 2005. Closed greenhouse: a starting point for sustainable entrepreneurship in horticulture. Acta Hort 691:517-524.

Figures

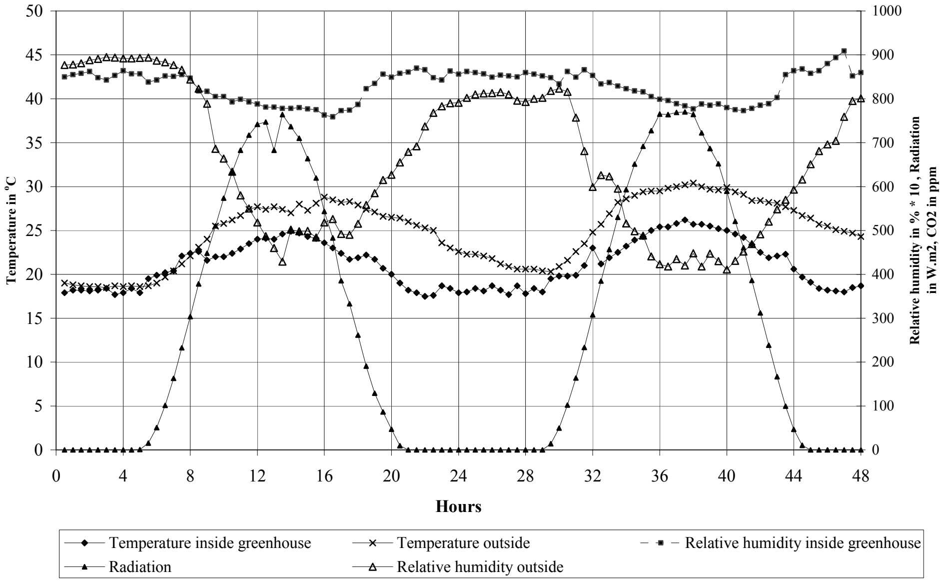

Fig. 1. Detailed climate in a closed greenhouse on 27 and 28 July 2002.

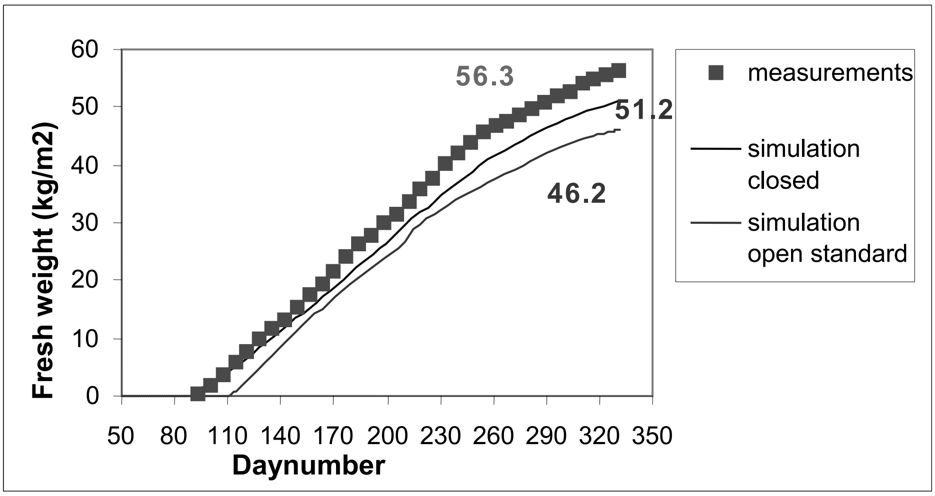

Fig. 2. Comparison between observed and predicted production of tomato grown in a closed greenhouse.

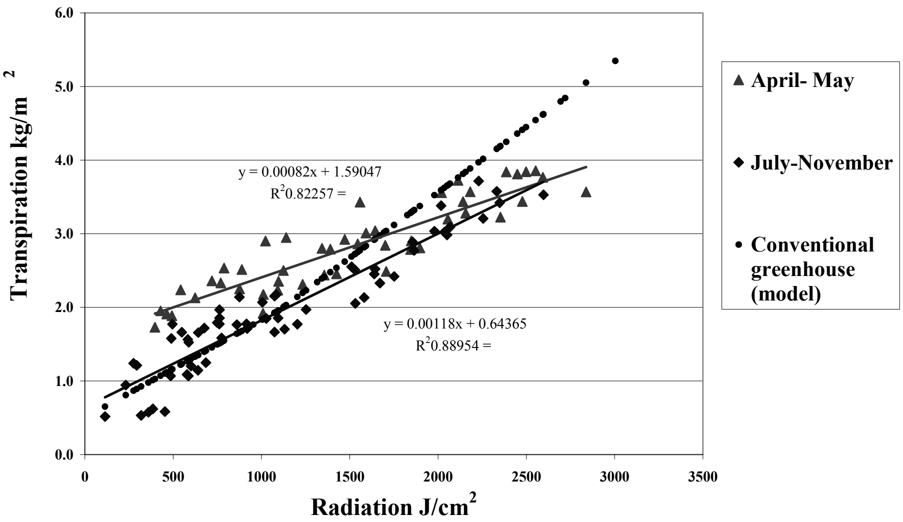

Fig. 3. Daily transpiration of a tomato crop in a closed greenhouse in relation to the daily global radiation.