Examining the influences of canopy structure on the light distribution and canopy productivity of cucumber using a 3D structural plant model approach

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Introduction

Greenhouse cucumber production systems are usually intensively managed close to the optimum with light as a major limiting growth factor. To understand the effects of light distribution on productivity in terms of photosynthesis, a spatial examination of this driving force of productivity is required. Cucumber is usually grown in a distinct row structure, resulting in an uneven distribution of leaf area and light. This makes it a well suited crop for examining the effects of heterogeneous canopies on light distribution and productivity.

Material and Methods

To test plant and environment interactions, four canopy architectures with two different plant densities and spatial structures were analyzed (Wiechers et al., 2006). The experimental setup included measurements of plant architecture by 3D-digitizing, leaf level measurements of photosynthetic active radiation (PAR) in the greenhouses and leaf gas exchange measurements of photosynthesis in the growth chamber. Plants were digitized weekly to build a static model of plant architecture accompanied by PAR measurements.

To obtain parameters for the light interception virtual images of the plants (www.povray.org) were rendered in a vertical direction (zenith angle 0°) to the ground plane (Sinoquet et al., 1998). Sunlit and shaded leaf area were distinguished using a projection algorithm to get a measure for the fraction of sunlit leaf area. The intensity of direct light on the sunlit leaf area was calculated by the incoming PAR intensity depending on the angle between irradiance vector and area normal derived from the static model. The radiation transfer on the shaded leaf parts (diffuse light) was calculated based on data measured on single leaves within the canopy. Intensities of the sunlit and shaded leaf areas were used to calculate the corresponding rates of photosynthesis based on a Farquhar-Model (Farquhar et al., 1980; Kim and Lieth, 2003) parameterized for greenhouse cucumber. Calculating these rates from a single leaf over leaf cluster of five leaves up to plants or a whole canopy allows us to identify the effects of canopy architecture on productivity.

Preliminary results and prospect

First results show that for a precise modeling of the assimilation of a heterogonous crop it is necessary to consider the spatial and dynamical differences in light distribution and photosynthesis. For the first productive weeks of the canopy an increase up to 6% in the rate of photosynthetic assimilation per m^2 ground can be simulated for the same plant density only due to a change of the canopy structure from a row crop to an isometric stand.

Future prospects will be to couple a radiation transfer model with modules of photosynthesis and assimilate allocation to one functional-structural model.

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