Real-time computer vision-based cultivation control system for ornamental vertical farming

Broes Laekeman[1], Annelies Christiaens[2], Lise De Clerck[2], Bruno Gobin[2], Johan Van Huylenbroeck[1], Emmy Dhooghe[3] and Peter Lootens[1]

[1] Plant Sciences Unit, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), 9090 Melle, Belgium

[2] PCS Ornamental Plant Research, 9070 Destelbergen, Belgium

[3] Department of Plants and Crops, Ghent University (UGent), 9000 Gent, Belgium

E-mail: peter.lootens@ilvo.vlaanderen.be

Abstract

With a total export value of over 700 M euro in 2021, the Belgian ornamental greenhouse sector is a blooming but resource demanding business. To align with the EU Green Deal and EU Blue Deal ambitions, future-proof innovations requiring less (fossil) energy, water and other resources will therefore be needed. Vertical farming (VF) offers a great potential due to its highly controlled environment and circular use of resources. Moreover, the precise adjustment of the indoor climate to the individual plant needs, allows for accurate production planning and year-round quality assurance. Hence this project aims to develop a real-time computer vision (CV) based cultivation control system for ornamental vertical farming.

As use case, the forcing phase of pot azaleas (*Rhododendron simsii*) was chosen because of its high economic value and large energy/water demand. In total 3 batches of pot azaleas ('Sachsenstern') were forced until flowering at different temperatures (18-21-23°C) in the VF system of PCS. All cultivation tables (2 tables/rack - 4 racks in total) obtained the same photoperiod (PP: 16h/day) and light spectrum (UV: 0.1%, B: 14.3%, G: 11.0%, R: 73.4%, FR: 1.2%) using LED lamps (LED Lighting Bar - Urban Crop Solutions, Waregem, Belgium) while the light intensity was adjusted per rack (photosynthetic photon flux density (PPFD): 60-90-120-150 µmol.m^{-2}.s^{-1}). Plants of an entire cultivation table (235cm x 165cm) were phenotyped every 1-2 days in a dedicated phenotyping chamber using a DSLR camera (Canon EOS 90D, EF-S 18-55mm). After image correction (Darktable), the colour stain (CS = area$_{flowers}$/area$_{total\ plant}$ [%]) of each individual plant was extracted for each timepoint using a dedicated image processing script (Python - PlantCV & OpenCV). Subsequently, a forcing model was built based on the drivers thermal time (growing degree days (GDD, °C.day)) and daily light integral (DLI, mol.m^{-2}.day^{-1}) to predict the phenological stage (CS) of the azalea plants. The combination of the visual colour stain assessment and forcing model will finally lead to a real-time CV based cultivation control system which can suggest changes in environmental conditions (temperature, PPFD and PP) based on the real-time flowering stage of the azalea plants in order to meet production quality/delivery dates.

Keywords: vertical farming (VF), controlled environment agriculture (CEA), cultivation control, computer vision (CV), ornamental plant phenotyping