Multi-sensoral detection of physiological changes in cucumber leaves during pathogenesis of CMV, CGMMV, and powdery mildew

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Introduction

- Disease progress in plants is associated with biophysical and biochemical changes
- Viruses and fungal pathogens often differ in their interactions with host plants
- The effects of cucumber mosaic virus (CMV), cucumber green mottle mosaic virus (CGMMV) and the fungus *Sphaerotheca fuliginea* (causing powdery mildew) on cucumber leaves have been studied using non-invasive methods
- Non-imaging – chlorophyll fluorescence - and imaging sensors – hyperspectral imaging, IR thermography - were used repeatedly during disease etiology to detect the effect of pathogens on host plants
- Changes in photosynthetic activity, spectral reflectance and transpiration were assessed by the use of non-invasive devices, and were compared to data on chlorophyll (CHL) content from leaf extracts

Materials and Methods

- Inoculation of cucumber leaves with CMV, CGMMV and *S. fuliginea* under controlled conditions
- Non-invasive sensor measurements and destructive analysis of CHL content were conducted during disease etiology 4, 8, 12 and 16 days after inoculation (dai)
- Assessment of photosynthetic activity (electron transport rate) by chlorophyll fluorescence (PAM-2000, Heinz Walz GmbH, D) and comparison to actual chlorophyll content
- Measurement of leaf reflectance with hyperspectral camera (ImSpector V10, SPECIM, FIN; range 400 – 1000 nm)
- Calculation of the pigment specific simple ratio b (PSSRb)

  $PSSRb = (R800 / R635)$
- Leaf temperature, a parameter for transpiration rate, was measured with a digital infrared scanning camera (Varioscan 3201 ST, Jenoptic, D; 8 – 14 µm); the maximum temperature difference (MTD) within individual leaves was calculated

Results

- First symptoms of powdery mildew became visible 4 dai, symptoms of CMV and CGMMV 12 dai

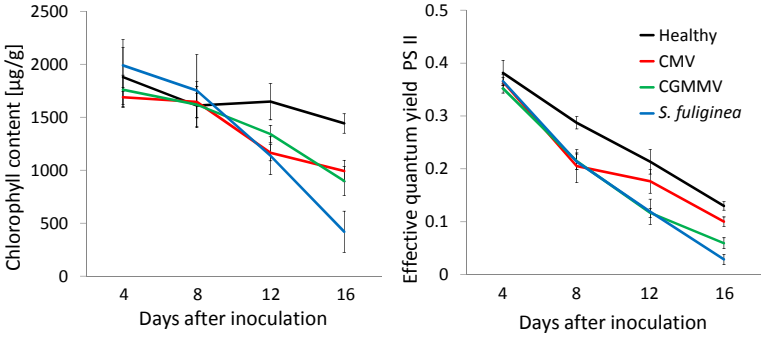

Figure 1 Total chlorophyll content (left) and effective quantum yield of PS II (right) of healthy cucumber leaves and leaves inoculated with CMV, CGMMV and *S. fuliginea* 4, 8, 12 and 16 days after inoculation. Bars denote standard error of the mean (n = 5)

- Differences in chlorophyll content between healthy and inoculated leaves were evident 12 dai, powdery mildew diseased leaves showed the lowest chlorophyll content 16 dai (Fig. 1)
- Similar results were obtained by chlorophyll fluorescence measurements characterizing photosynthetic activity (Fig. 1)
- Maximum temperature difference of leaves with powdery mildew was significantly higher than that of the other leaves (Fig. 2)
- Changes in leaf temperature to healthy leaves were detectable 12 dai for powdery mildew, and 16 dai for leaves diseased by CMV and CGMMV
- PSSRb values, calculated from hyperspectral data of leaves covered by powdery mildew decreased significantly 8 dai, values for leaves with CMV and CGMMV infections decreased 12 dai

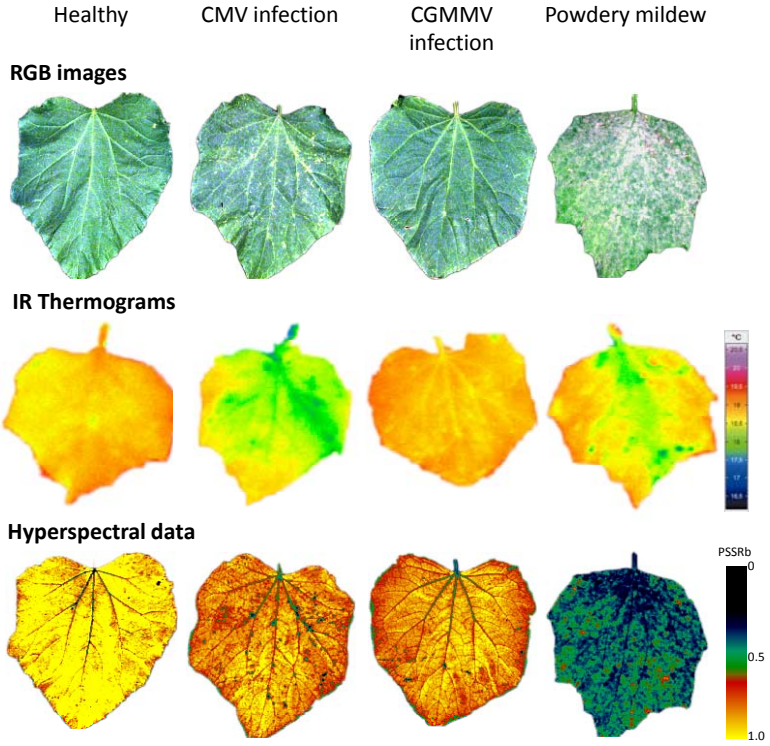

Figure 2 RGB-images (top), and false-colour images for leaf temperature and values of the spectral vegetation index PSSRb of healthy cucumber leaves and leaves with CMV, CGMMV, and powdery mildew, 12 days after inoculation

Conclusions and Perspectives

- Effects of viruses and fungal plant pathogens on cucumber leaves could be detected by using different sensor techniques
- Impact of powdery mildew on physiology and vitality of cucumber plants was more pronounced than that caused by CMV and CGMMV
- Non-destructive imaging sensors may be fast and reproducible alternatives to destructive methods for chlorophyll measurement
- Imaging sensors increases spatial information on various levels and allow repeated measurements on the same plant
- Sensor fusion may be useful for the identification of diseases
- Thermography and hyperspectral imaging have potential for monitoring the health status of plants and for disease detection, also in the field