Photosynthetic activity imaging of plants

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Introduction

The CropReporter uses LED (light emitting diode) induced direct fluorescence imaging technology to image the plant health/stress status by calculation of F_v/F_m (variable fluorescence over saturation level of fluorescence). Within a short time interval (≈800 ms) multiple images are captured. For each pixel of the fluorescence image F_v/F_m is calculated and presented as an image that correlate with the quantum yield of PSII photochemistry. The advantage of the technology lies in the imaging of photosynthetic parameters of whole plants within a short time interval and detectable before it can be seen by eye.

Inside the CropReporter there is place for 6 different optical filters. With these filters the following images can be made:

- Separate red, green and blue images
- Chlorophyll absorption images
- Anthocyanin absorption images
- Near Infra Red (NIR) images.

The CropReporter captures spectral images by using a 6 position optical filter wheel. For colour it uses red, green and blue information. The software reconstructs these images into a 3x14 bit colour image with a spatial resolution of 1.4MP (Fig. 2A). Plant parts contain chlorophyll and show fluorescence. Using a measuring protocol the minimal fluorescence, F_0, and the maximum fluorescence, F_m, are captured by the camera. From these two images the maximum efficiency of photosynthesis of Photosystem II is calculated (Fig. 2B). At locations where the photosynthesis functions optimal the colour is green. Plant parts that show a stress response are coloured yellow for moderate stress and red for severe stress. The average Fv/Fm value for this stressed plant was 60.6%. Using the analysis software plant parts showing an F_v/F_m value between 0 and 50% can be coloured light blue (Fig. 3A). This can also be done with the false colour table of Fig. 2B for F_v/F_m values between 0 and 50% and presented as an overlay onto the colour image (Fig. 3B).

Figure 1. CropReporter for side view imaging of monocotyledons. Using high intensity red light emitting diodes fluorescence images are being captured, white light emitting diodes together NIR lighting are being used for spectral imaging at six different filter bands. Images are captured at a resolution of 1.4 Mp and 14 bit digital grey values.

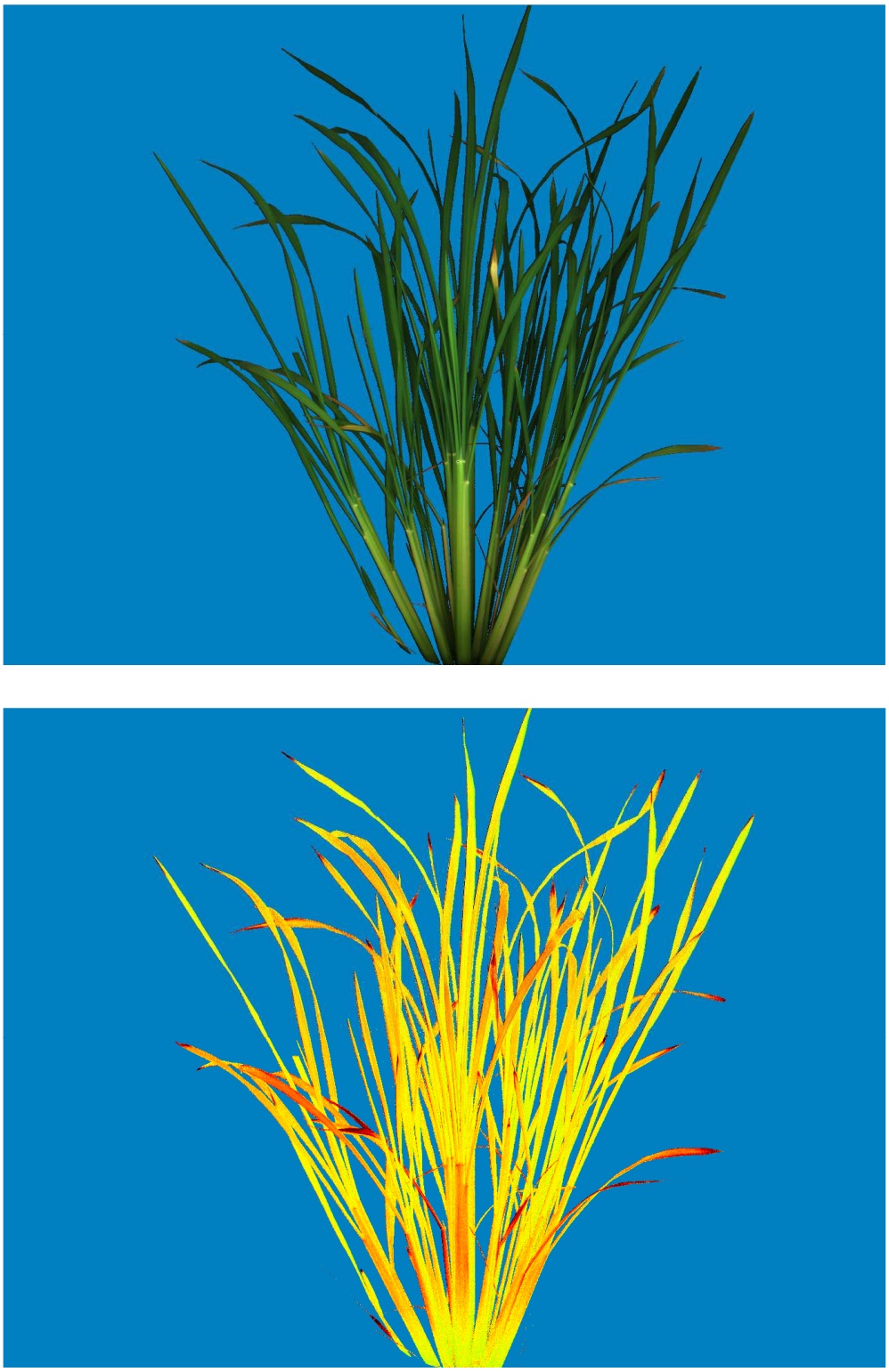

Figure 2. A) Colour image constructed from separate red, green and blue images of a rice plant (Oryza) subjected to a drought stress. B) Image showing the maximum efficiency of photosynthesis of Photosystem II, F_v/F_m. At locations where the photosynthesis functions optimal the colour is green. Plant parts that show a stress response are coloured yellow for moderate stress and red for severe stress. The average F_v/F_m value for this stressed plant was 60.6%.

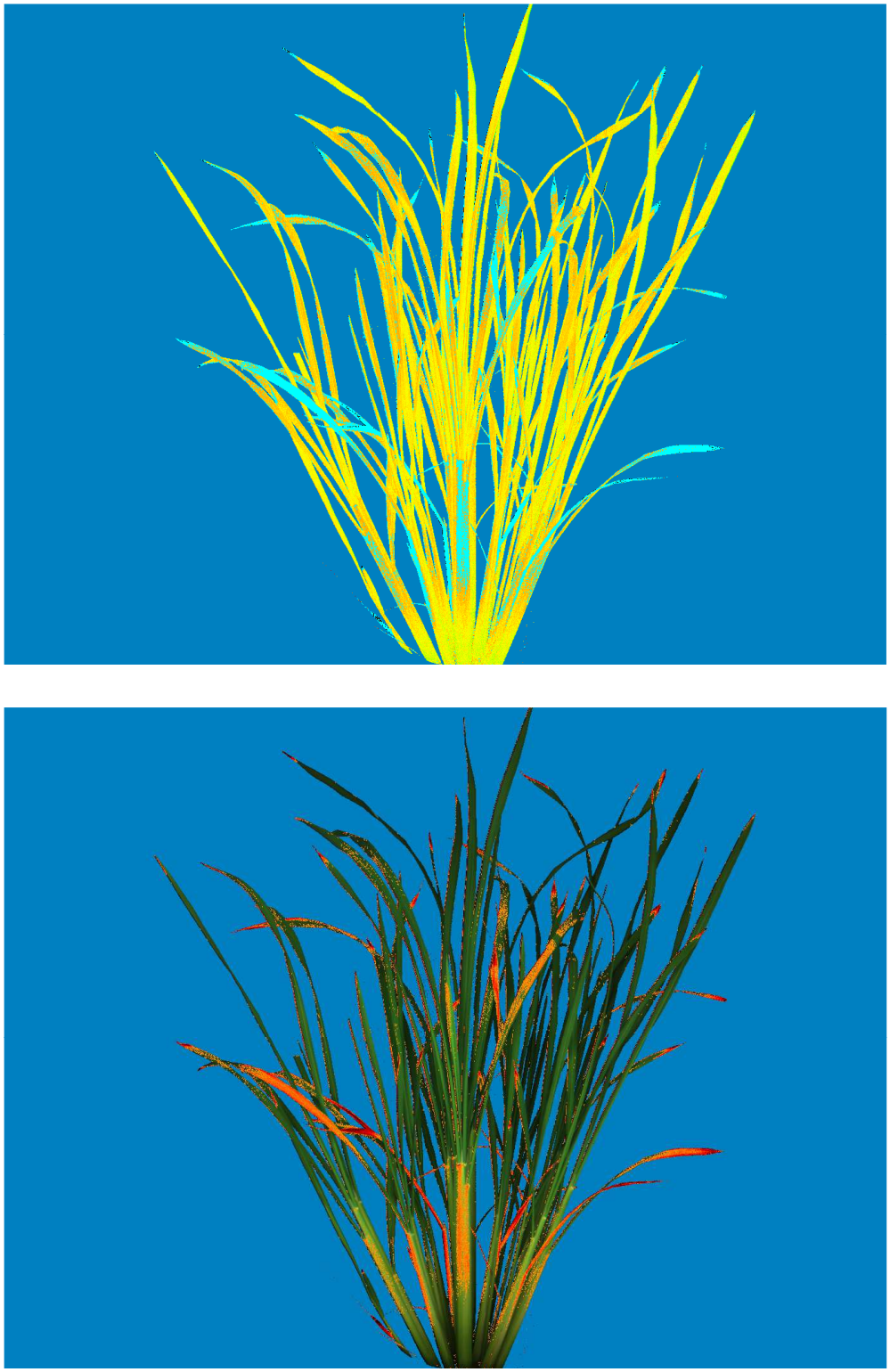

Figure 3. A) Using the analysis software plant parts showing an F_v/F_m value between 0 and 50% can be coloured light blue. For this plant 8.2% of the projected plant area showed an F_v/F_m value lower than 50%. B) Colour image with an overlay for F_v/F_m values between 0 and 50% in the false colour table of Fig. 2B.

Advantages

This camera uses different excitation sources for capturing chlorophyll fluorescence images and spectral images in combination with an 6 position optical filter wheel. The same lens and ccd-camera is used for all the captured images. This gives the advantage that all the images can be analysed on a pixel to pixel basis. Overlay of images can be made without resizing or recalculation of the different images. Chlorophyll fluorescence images can be captured of whole plants and the functioning of the photosynthesis can be displayed as an image in false colours showing the F_v/F_m values per pixel. Using software Part of plants can be located that show certain range of F_v/F_m values and this information can be displayed as an overlay onto the colour image.

Conclusion

The CropReporter was able to calculate the maximum efficiency of photosynthesis of Photosystem II, F_v/F_m and present this as an image in false colours showing inhomogeneity due to drought stress of the rice plant. Parts of the plant that show a certain range in F_v/F_m values can be highlighted using false colours in either the F_v/F_m image or the colour image as an overlay. This functionality gives a good overview by visualizing where specific stress or healthy parts of the plant are located.

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