Fluorescence imaging: a low-cost method for early stress detection

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Industry needs that were addressed: Greenhouse and nursery producers face a wide range of abiotic (fertility, temperature, lack of water, etc.) and biotic stresses (pathogens, insects) that can negatively impact crop production. Early detection of such stresses is important to mitigate the negative impact of such stresses on the crop. Such detection typically depends on visual inspection of crops by an experienced grower. However, stresses can only be detected after symptoms are visible. Earlier detection of potential problems would be beneficial: the sooner a production problem can be addressed, the smaller its impact will be.

Research Progress

OBJECTIVE 1: Detecting nitrogen deficiencies

RESULTS: Figure 1 shows petunia plants fertilized with either 0 or 8 g/pot of CRF. The plant that received more fertilizer was larger (as quantified using the number of pixels in the bottom image) and darker green (compare top images). The differences in greenness between these plants was also clear from the chlorophyll fluorescence intensity, which was much higher for the fertilized plant. Note that CFI intensity is based only on the intensity, or brightness, of pixels that represent the plant. The very dark background pixels are ignored.

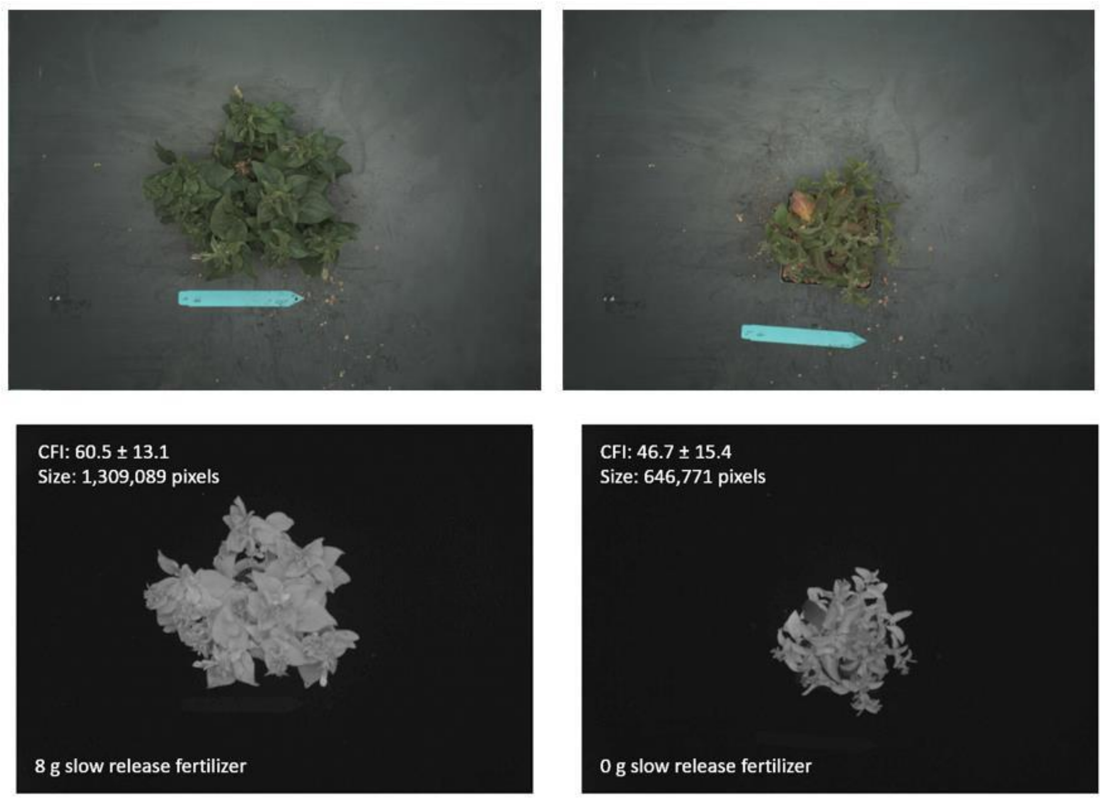

Figure 1. Color (top) and chlorophyll fluorescence images (bottom) of a petunia grown with high (left) and no fertilizer (right). The nutrient-deficient plant has much lower chlorophyll fluorescence intensity (CFI).

Since we use a multispectral imaging system to collect the CFI images, we also have images that are taken under different colors of light. We used those images to calculate the normalized difference vegetation index (NDVI, a common index of plant vigor). These images show clear effects of different fertilizer levels (Fig. 2; same plants as in Fig. 1). Higher fertilizer results in higher NDVI values, as well as more uniform NDVI values throughout the entire canopy. The plant on the right, grown without fertilizer, has a lower average NDVI (as indicated by the red line in the histogram), as well as much more variability in NDVI values throughout the canopy. Based on these preliminary results, both CFI and NDVI look promising to detect plant nutrient status.

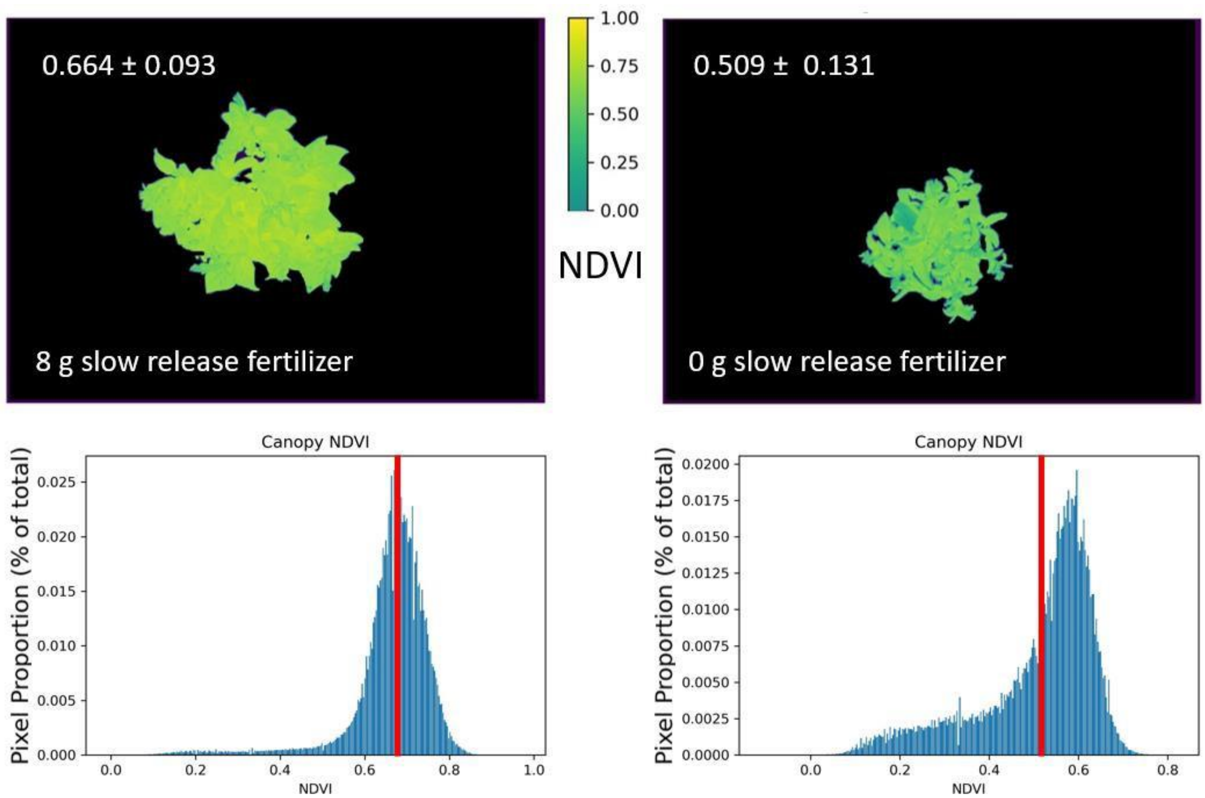

Figure 2. NDVI images of the same two plants as in figure 1 shows that NDVI too is promising to detect nutrient deficiencies. The histograms on the bottom show the distribution of NDVI values of the entire plant. The red line indicates the average NDVI value

OBJECTIVE 2: Substrate pH and micronutrients. Figure 3 shows a chlorophyll fluorescence image of a petunia grown in standard substrate and a substrate with high pH. High pH induced micronutrient deficiency symptoms (most likely Fe). The plant grown in regular substrate had a healthy, dark green color. In the chlorophyll fluorescence image (top right), the healthy plant has a quite uniform pixel intensity (brightness), while in the deficient plants (top left) the younger, center leaves fluoresce less brightly than the older leaves. Whether chlorophyll fluorescence imaging will be useful for detection of micronutrient deficiencies is not yet clear. We will therefore also test multispectral imaging.

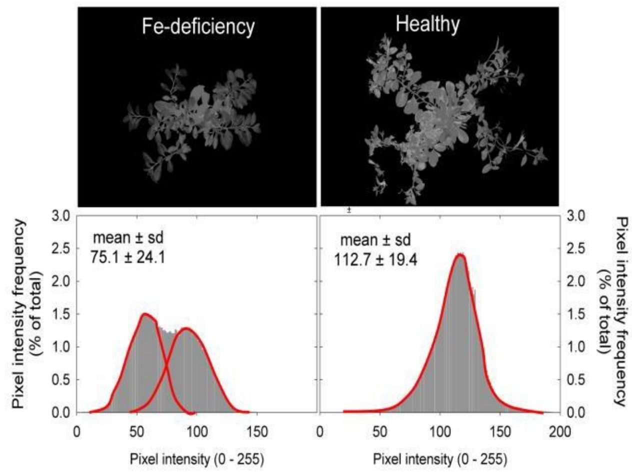

Figure 3. Chlorophyll fluorescence images of a petunia grown at high substrate pH (left) and regular substrate pH (right). The histograms at the bottom show the distribution of pixel intensities, which are clearly different for the two plants.

OBJECTIVE 3. Low and high temperature stress. We just completed our first trial runs after retrofitting a refrigerator/freezer to allow us to control its temperature precisely in the temperature range of interest (20 – 40 °F). Although no formal trials have been done yet, initial images clearly show that cold damage induces extremely bright fluorescence, easily visible in CFI images. We have not yet done trials with heat stress.

Fig. 4. Chlorophyll fluorescence image of two hosta plants after exposure to -5 ºC (23 ºC). The brightly fluorescing leaf, circled in red, was the only leaf to sustain serious damage.

OBJECTIVE 4. Disease detection. We grew and imaged basil in the greenhouse in the summer of 2021, with the hope of getting downy mildew infections. However, no infections occurred, so no useful information was obtained.

Objectives for the coming year. In the coming year, we will do the following:

- Analyze images from nutrient deficiency trial, correlate imaging data with plant nutrient analysis data
- Collect data on hosta responses to heat and cold stress, analyze images,

determine feasibility of CFI to detect these stresses

- Repeat trial with different lime levels, analyze images, and correlate results to nutrient analysis data
- Develop an improved, low-cost version of our imaging system. This will be open-source, with detailed instructions for hardware assembly and freely available software.

Publications and presentations

Plans for publications and presentations in the coming year

In the coming year, we hope to publish four papers (hardware and software of our imaging system, fertilizer levels, lime levels, and a combined manuscript on heat/cold stress) and one MS thesis. Results will be presented at the international horticultural congress in Angers, France and a Controlled Environment Agriculture meeting in Tucson, AZ. We also hope to publish our findings in one or two trade magazine articles.

Reason for continued funding

Results so far are promising and we have expanded on the original topic of only chlorophyll fluorescence imaging by including multispectral imaging. This summer we will work on developing an improved CFI/multi-spectral imaging system that can be assembled by non-specialists for as little as $500 in hardware. Software will be made freely available. This will make this type of low-cost imaging widely available.

RESEARCH WEBSITE/BLOG: https://hortphys.uga.edu/research/imaging-a-powerful-too-for-growth-monitoring-and-stress-detection/