Progressive plant health monitoring: NDVI

Kyle Schneider[1,3], Richard Barker[1], Amit Nimunkar[2], Simon Gilroy[1]

1) Gilroy Astro-Botany Lab, University of Wisconsin—Madison

2) Engineering department, University of Wisconsin—Madison

3) Industrial engineering, University of Wisconsin—Madison

Introduction

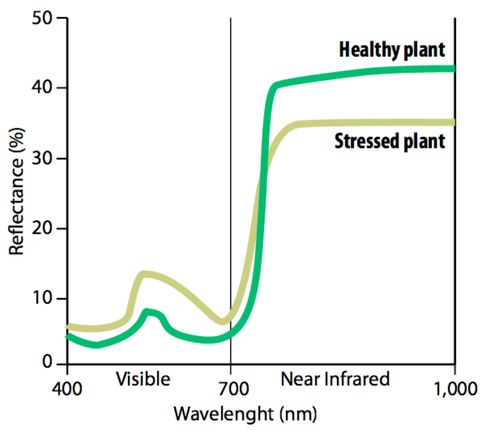
Normalized Difference Vegetative Index (NDVI) imaging allows one to see plant photosynthesis activity. Stress induces changes in photosynthesis and so it is possible deduce if a plant is stressed in real time using this approach. This type of imaging is possible because photo-synthetically active plants absorb blue wavelengths but reflect near infra-red (NIR) light.

This equation is applied in every pixel of an image to make a grey scale normalized image which is then rendered into a false color scale so it is easier to see the relative levels of photosynthesis.

$$NDVI = \frac{(NIR - Blue)}{(NIR + Blue)}$$

To get the values needed in the NDVI equation we need to use an RGB sensor camera with a blue filter which lets us obtain both the blue and NIR areas in the spectrum in the blue and red channels. There are many different products currently on the market, but unfortunately these products are very expensive and have to be manually operated.

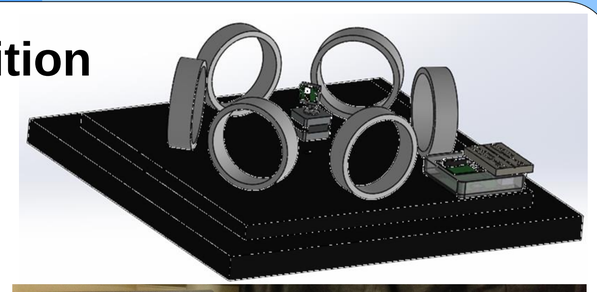
Our goal is to make an automated system that takes NDVI pictures of plants creating time-lapse video of plant stress response. Additionally we are using a design built around an inexpensive IR camera. The product we have made can hold six petri dishes of plant seedlings. Being able to compare these six different time lapse videos would allow us to non-invasively detect what part of the plant shuts down photosynthesis in response to a range of stresses.



Methods

1 Image acquisition

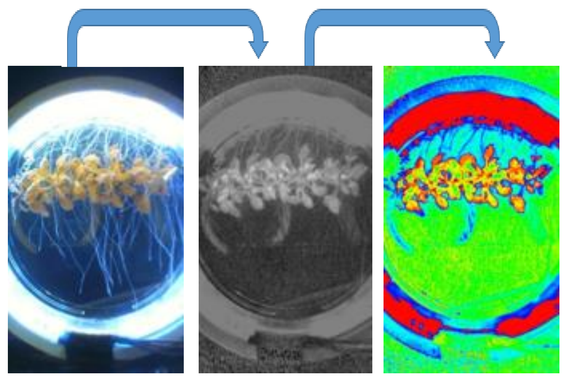
A webcam had the infra-red (IR) exclusion filter replaced with a blue/NIR filter. This was then mounted on a stepper motor. The camera was then surrounded by 6 PVC ‘halos’ containing strips of variable RGB and warm white LED’s. The whole system is then controlled by Python codes run on a raspberry pi microcomputer.



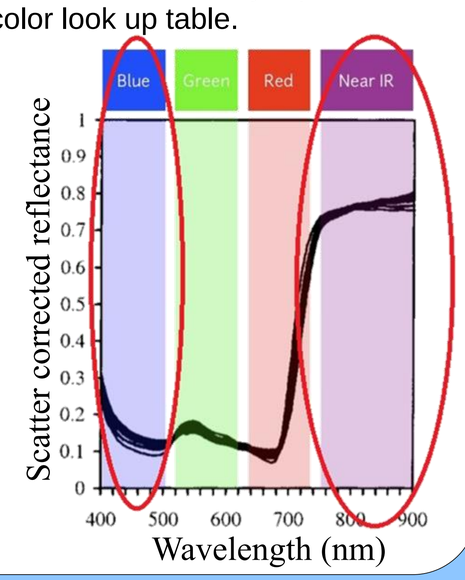
2 Image processing

Original image is run through code which subtracts the blue channel, which due to the filter only allows blue visible light to be recorded. NIR is simultaneously captured in the red channel.

To get from NDVI to false color one looks at the range of grey scale values and then converts the different tones of gray into certain colors determined by a pseudo-color look up table.



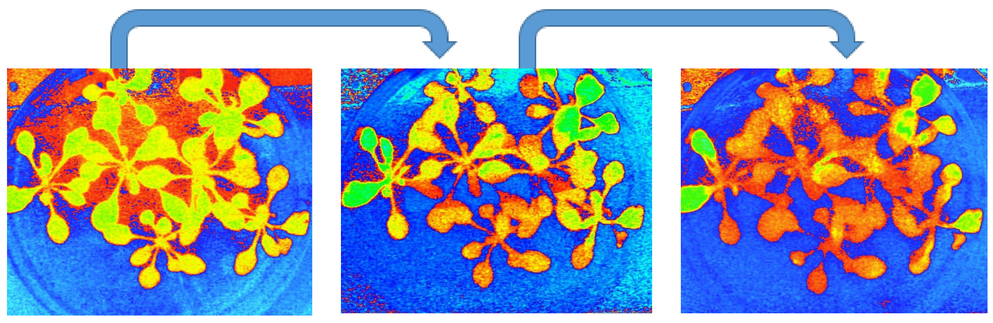
Original IR picture | Greyscale NDVI | False color



Results

3 Time Lapse of Images

From making a time lapse of the false color images its easy to see how plant health changes over time. Another advantage of using time-lapse of the images in conjunction with the six petri dish holding capacity is that it is easy to compare a healthy plant with a plant that is, for example infected with pathogen. This gives us insight into how long it takes the plant to stop photosynthesis, and also where in the plant it stops photosynthesis first.



1st day post infection | 2nd day of infection | 3rd day of infection

4 Preliminary Conclusion

This series of images demonstrates that this cost effect method of observing photosynthetic capacity is capable of detecting signs of pathogen-induced stress before any physiological signs of harm can be observed using normal imaging.

3rd day of infection

Discussion

5 Application in precision agriculture

This technology can easily be implemented into drones which could be used to regularly assess plant health in fields. The drone could then automatically relay the data it acquires regarding plant health to the farmers. If the computer measures any decline in photosynthesis in a certain region it would alert a human who can see what the problem is and address it. The key thing about this approach to NDVI technology using a relatively cheap camera (<$50) is that it accessible to everyone, from gardeners to commercial agriculture.

Future work

- We aim to test the changes in plant photosynthetic responses to flooding, drought, salt, heat, cold, mechanical stimulation, cosmic radiation, increased G-forces and micro-gravity.
- We then hypothesize that certain genes may reduce the negative impact of these environmental factors and will investigate this hypothesis by testing mutant plants or transgenic over expression lines.

References

Public Lab provided python codes: https://publiclab.org/wiki/infragram

International Maize and wheat center: http://www.plantstress.com/methods/Greenseeker.PDF

Acknowledgement

I’d like to thank NASA and NSF for funding.

Drs Barker, Nimunkar and Gilroy for guidance

Adam Steinberg for poster advice and template