Final Report
to
Texas Corn Producers Board
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Title: Sensitive Detection of Crop Water Status for Irrigation Management

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Long-term goals for project:

- The project will develop a technology to improve the **water-efficiency of irrigated corn production systems in Texas**
- Technology will help optimize timing and amount of irrigation
- Includes principal data needed to prototype handheld meter for sensitive, "as needed" monitoring of crop water status

Rationale

Both excessive water use and irreversible economic losses in yield or quality due to corn crop water stress can be avoided by optimizing timing and amount of irrigation. The challenge is to be able to monitor the corn crop's water status both sensitively and quickly so that irrigation decisions can be made that do not deviate too far either toward incremental losses in yield and quality or to an excessive safety margin in water application. Such optimization requires identification of onset of crop water stress before irreversible economic losses in yield or quality occur. Irreversible losses are initiated before visible symptoms of stress. Current methods suffer from lack of speed in use and/or sensitivity.

Preliminary considerations

- The technology used for the study should provide a "path forward" for inexpensive, simple, sensitive, rapid ("as needed") detection of corn crop water status
- Based on the PI's earlier studies on cotton, we chose to use relative reflectance off leaves at certain bands in the Shortwave Infrared region (SWIR), a part of the spectrum strongly influenced by water absorbance bands, as well as from some major leaf chemical components. We knew what SWIR bands were best for cotton, but not sure about corn
- Our vision is that we can use the results from the study to develop a hand meter that can clip onto the leaf and provide a quick read out of the water status. The meter would be developed around the best combination of SWIR bands for estimating water status. The technology can probably be adopted to 'near-canopy' use also, such as with UAVs (drones) or mounted to center-pivot systems
- None of this is worth the trouble unless we can develop a technology that is better than those used currently

- Of the above characteristics for the technology, an envisioned handheld meter would clearly provide: ‘inexpensive’, ‘simple’, and ‘rapid’, so our initial task was to show ‘sensitivity’
- Sensitivity ought to be defined in terms of saving money, so in this case would be the ability to detect a change in water status that would allow timely crop management to avoid economic yield losses without wasting water
- For corn, we were not sure what this would be in terms of leaf water content, which is what we wanted to use as a measure of crop water status, and compare our reflectance measures to in this study

General Approach

- Conduct two studies under different conditions. Use seed of popular commercial hybrid in Texas
- One is a calibration study designed to: i) identify potential SWIR wavebands for use; ii) identify approximate ‘break point’ of corn leaf moisture content that indicates the level at which stress is beginning to affect physiological performance
- The other study is a validation study, which puts the potential wavebands to the test, so ought to be under different conditions

The plan was to conduct the calibration study in the greenhouse and the validation study in commercial fields, which would provide good diversity in environmental condition

- Using the greenhouse in the first study allowed us: i) control the water stress, ii) conduct physiological monitoring of the plants so that we could find the ‘break point’ in leaf water content
- The commercial field study was needed to ensure we were getting useful results, but also provided the opportunity to ‘compare notes’ with the producer about how the technology might be useful for them

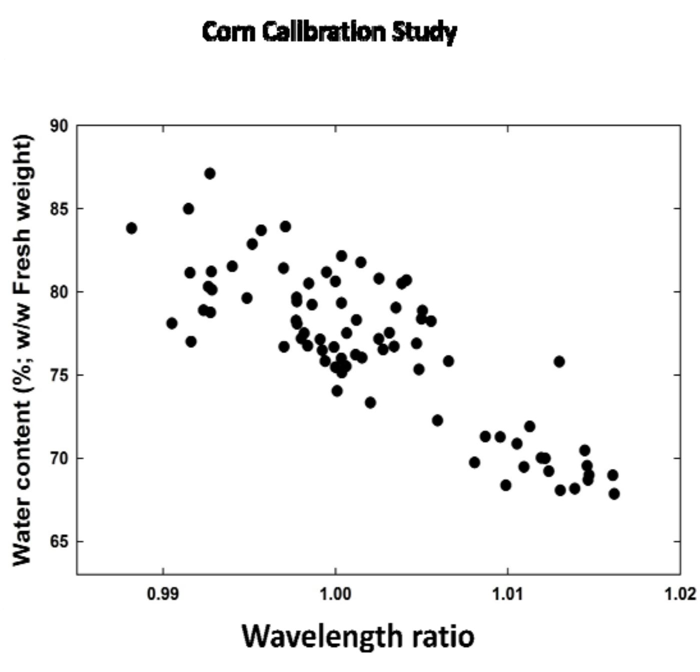
General Results

- The calibration study in the greenhouse went well – we were able to establish SWIR waveband combinations that appear to be a good basis for the technology; we were able to determine a general ‘break point’ in the relationship between leaf water content and maximum photosynthesis. The break point suggests the range of leaf moisture content for which we need a linear relationship between leaf water content and the detection index developed as a combination of wavebands
- The field study went poorly. Planting was greatly delayed due to rains and flooding; the fields were later abandoned. We also abandoned our field sampling from another field due to poor health of the plants

- We conducted a second greenhouse study this fall/early winter and tried to vary conditions by changing the rate by which the water stress was imposed, and by focusing on lower leaves instead of the upper ones of the first study. This study also went well

Specific Results

- The target for the calibration study was 100 plant samples, and 100 were collected
- The target for the 2nd greenhouse study was 120 samples, and 160 were collected
- Rough ‘break point’ in water content with respect to maximum leaf photosynthesis was about 76% WC. At 70% WC, leaf photosynthesis never exceeded 90% of the maxima detected at 76% WC or higher. We will therefore target to have a linear response of the ‘detection index’ from 70 to 82% WC in order to provide a sensitive measure of corn crop water status
- The detection index had a good linear relationship with water content over the range of 70% to 82% WC (see graph below). The best fit line was a straight line not a curve of any sort. This index uses two wavebands
- About 70% of the variation in WC was explained by the detection index. Our target was 80%. We know the inclusion of additional wavebands will increase the amount of variation explained, but we need to balance this against the practicality of a hand meter, which should only use 2-4 wavebands to maintain cost, and probably robustness, in use



- The results of the 2nd greenhouse study were similar in that about the same amount of variability was explained with a 2-waveband detection index, with a 3-waveband index providing only marginal improvement

- The detection indices were developed systematically by examining all possible two-band indices. This allows us to see which combinations of wavebands from various regions of the spectrum work well together (and which don't). In both of our corn studies, as well as in the cotton study that the PI conducted previously, the wavebands that worked well were always associated with the large water absorbance features, always along the edge of the feature, which would be expected to be sensitive to change in water content and highly encouraging to see
- The biggest concern is the lack of precision (the tightness of fit to the best-fit line)

Where we stand

- Simple detection indices were established that can serve as the basis of a hand meter for inexpensive, simple, sensitive, rapid ("as needed") detection of corn crop water status
- In particular, linear response (sensitivity) was established for the critical range of crop water status for which management could be used to prevent economic losses from occurring, which avoids an issue with current technologies
- The primary limitation with this promising technology is the lack of precision
- The field study is needed for two reasons: i) real validation of the technology under the conditions in which it would be used, ii) as an initial outreach step to work beside the producer and understand how this technology could best benefit their crop management

Where should we go from here

- Explore the use of leaf water potential instead of leaf water content as a measure of crop water status. We think the water content measurements might actually be a source of the unexplained variation – variation that could not be explained by the detection indices
- Try again in the field: the instrument for leaf water potential can be taken to the field and used on the pickup bed, for example; also we should compare the detection indices with what the producers use for monitoring crop water status

What is the benefit of this research to Texas corn producers?

- The project will develop a technology to improve the **water-efficiency of irrigated corn production systems in Texas**
- Technology will help optimize timing and amount of irrigation
- Includes principal data needed to prototype handheld meter for sensitive, "as needed" monitoring of crop water status in various parts of the field, with potential for incorporation on UAVs or on center pivot systems, thus providing the basis for precision irrigation