Title: Development of an economic irrigation threshold for diseased wheat

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Summary
Each year, approximately 1.1M acres of irrigated wheat are grown in the Texas panhandle, and at 241,874 ac-ft water per year, wheat is the second largest user of irrigation water from the Ogallala Aquifer. In this same region, and across the entire southwestern Great Plains, mite-vectored virus diseases (MVVD), such as Wheat Streak and Triticum Mosaic, are the predominant pathogenic constraints to economically sustainable wheat production. MVVD not only impact forage and grain yields, but also reduce root development, water uptake and crop water use efficiency (WUE). However, because these diseases typically develop as gradients across fields over time, producers don't know whether the cost of irrigation, or other inputs, will result in a profitable economic return. A variety of remote sensing technologies, including an unmanned aerial vehicle (UAV) will be used by a transdisciplinary, multi-institutional team to quantify disease distribution and severity over time, and to evaluate how time of infection impacts water use and subsequent yield parameters. A model will be developed that will relate disease severity at various developmental stages of the wheat crop to final grain yield. Then a disease distribution map will be created that can be used in conjunction with a variable rate irrigation system to reduce or eliminate unproductive irrigation applications to severely diseased areas of the field. Results of these studies will provide producers with information that will allow them to make better management decisions and improve economic returns, and ultimately conserve irrigation water from the Ogallala.

Project Narrative
Objectives. This study will address *OAP sub-objective 1 – Develop and evaluate water management strategies and technologies that could reduce water withdrawals for irrigation by 20% in 2020 compared to 2012, while maintaining and enhancing the economic viability of the agriculture industry.* Our primary research objective is to develop an economic irrigation threshold for diseased wheat that will provide producers with the information needed to make management decisions regarding irrigation of diseased wheat. Although it has long been recognized that irrigation amount and scheduling can impact disease incidence, very little work has been done on the impact of plant disease on WUE (Harveson and Rush, 2002; Balota et al., 2005). A model will be developed that relates disease severity at particular crop developmental stages to final yield, and with that information it will be possible to eliminate irrigation applications that have little chance of providing a profitable economic return. For instance, detection of severe disease, at or before boot stage, would typically warrant elimination of at least two irrigation applications on all or part of the field, depending on disease distribution, and this would easily relate to at least a 20% decrease in seasonal irrigation application, compared to a disease-free field.

Rationale. Of the 6M acres planted to hard red winter wheat in Texas each year, over 60% of the grain is produced in Northwest Texas, Extension Districts 1, 2 and 3. This is because of the high yields produced on the 1.1M acres that are irrigated with water from the Ogallala Aquifer. In District 1 alone, the value of the wheat crop exceeds $322M, but at 241,874 ac-ft water per year, wheat is also the second largest user of water from the Ogallala Aquifer (USDA, 2011; Colaizzi, et al., 2009).

Although significant progress has been made in conserving ground water with the implementation of low-pressure sprinkler irrigation systems and use of drought tolerant wheat cultivars, the presence of plant disease in a field can overshadow all other efforts to establish an economically sustainable water management system. Across Northwest Texas and much of the Western Great Plains, mite-vectored virus diseases (MVVD) are the predominant pathogenic constraint to sustainable wheat production each year (Price and Rush, 2014; Valendia-Parra, et al., 2010). The viruses that cause these diseases are transmitted by the wheat curl mite (WCM), which is wind disseminated. Wheat plants infected with MVVD not only have reduced grain and forage yields, but also *greatly reduced root weight and water-use efficiency (WUE)*(Price, et al, 2010; Workneh, et al., 2010). Plants infected by MVVD are unable to efficiently use available soil water and *therefore addition of fertilizer or irrigation water to severely diseased wheat constitutes a waste of labor, energy, and natural resources.*

During the growing season, MVVD typically develop disease severity gradients across fields, but under optimum conditions for disease, almost every plant in the field eventually becomes infected (Mirik, et al., 2013; Workneh, et al., 2009). However, plants infected later in the season are still capable of producing profitable grain and forage yields. The progressive nature of MVVD makes it difficult for producers to know whether additional crop inputs, such as fertilizer and multiple spring irrigations, are economically feasible. However, disease severity gradients in fields also create opportunities for water and fertilizer conservation through site-specific management.

In preliminary studies, members of our team used a hand-held hyperspectral radiometer to quantify *MVVD* severity gradients in the field (Jones, 2004; Workneh, et al., 2009). *By recording hyperspectral readings of MVVD severity (reflectance at 555nm) over time, and associating each reading with GPS coordinates, it was possible to demonstrate that the reflectance reading at early boot stage related to disease severity and seasonal grain and forage yields* (**Fig. 1**). *Knowing when specific crop inputs are applied, in relation to disease severity at a specific crop developmental stage, will allow economic cost/benefit analysis and development of an economic threshold for irrigation of diseased wheat. This, in combination with site-specific, variable rate irrigation, could result in reduced water applications,* increased *WUE, and an overall increase in farm sustainability.* For instance, in years when MVVD are epidemic, 100% of the crop usually becomes infected, and in these years a large percentage of fields show symptoms in early spring (Price, et al., 2014). As our ability to detect disease early in the growing season improves, using remote sensing technologies, farmers could eliminate unproductive irrigations of severely diseased wheat, for an estimated savings of 4" to 6" per acre (up to 412,500 ac-ft of water region-wide). By eliminating just one unnecessary 2" irrigation on a half-mile center pivot, a farmer could save approximately $9,000 and 28.6M gallons of groundwater (Tom Marek, personal communication).

Approach. This research will be conducted at the USDA CPRL/AgriLife Research facility in Bushland, TX. The study will be planted under the Plant Pathology's six span center pivot that will be equipped with a variable rate irrigation package. In July 2014, a strip of Karl 92 will be planted along the south edge of the plot area to serve as a natural bait crop that will become naturally infested with viruliferous wheat curl mites. In September 2014, 8 total concentric plots, four of TAM 112 and four of Karl 92, will be planted in 120' wide strips around the pivot. Three forty foot subplots will be established in each strip and irrigated at 100%, 67% or 33% replenishment of soil water depletion to field capacity. Disease presence will be verified throughout the season by destructive sampling of plant in each subplot. Virus species composition (WSMV and/or TriMV) in infected plant tissue will be determined and quantified using ELISA and/or qPCR. Mites from the trap strip will move into the field over time, resulting in a natural disease gradient. During the season, approximately once a week, mite movement from the infested strip into the differentially irrigated strips of Karl 92 and TAM 112 will be quantified, as previously described (Price, et al., 2013), from subplots established at increasing distances from the trap strip. Three neutron

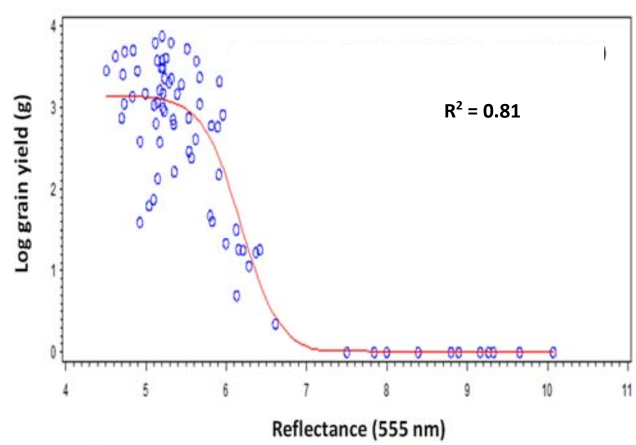

Fig 1. Data from 2013 Bushland wheat study showing potential to predict final yield from mid-season (April 15) reflectance of diseased wheat.

access tubes will be installed in each subplot, at increasing distances from the trap strip, and read approximately every two weeks for irrigation scheduling. Crop water use will be determined using a soil water balance equation and neutron meter readings (Evett, 2008). Disease incidence and severity also will be measured from mid-March to mid-May 2015, using a handheld hyperspectral radiometer (Ocean Optics Inc., Dunedin, FL) by measuring reflectance at 555nm, which is strongly correlated to symptom severity (Jones, 2004).

In addition to collecting data with the handheld hyperspectral radiometer, we will use an UAV drone with remote sensing capabilities (RGB digital geo-referenced imaging) to monitor disease spread across the entire field over time. Vegetative indices generated with high resolution data from our UAV drone http://today.agrilife.org/2013/11/25/agrilife-research-scientist-utilizes-drone-to-detect-wheat-disease-progression/, could possibly provide geospatial crop status in lieu of hand-held or pivot-mounted instruments (**Fig 2&3**). Flights will be made in late fall 2014 and biweekly from mid-March to early May 2015. Wireless infrared thermometers (2 for each concentric plot) will be located on the pivot lateral (O'Shaughnessy, 2011) to monitor crop canopy temperature over daylight hours. At maturity, biomass and grain yields from all subplots will be harvested and the effects of time of infection, and severity of infection on grain yield and crop WUE will be determined. The economic return of the crop for each irrigation treatment level, time of infection, and severity of infection will be analyzed. This study will be repeated for the 2016 harvest season, and the remote sensing equipment will be available throughout the two year project.

Fig. 2. 3D-R UAV drone used to image Bushland research field in fall 2013.

Outcomes. Anticipated IP from this project will include algorithms from aerial and hand-held spectral radiometers to provide decision support for crop inputs and site-specific irrigation management. Irrigation management guidance to producers will be based on disease distribution and severity, growth stage of wheat, and an economic analysis of yields at different levels of irrigation and disease severity (when compared to full irrigation of non-profitable, severely diseased wheat), and this analysis will be conducted by our team economist.

ARS has two utility patents filed, (US 61/513,767) and (US 61/703,846) and a Cooperative Research and Development Agreement with Valmont to increase crop water use efficiency using variable rate irrigation management and automation. IP contained within these patents and CRADA will remain with ARS. However, with this collaboration, we intend to develop algorithms to distinguish between stressed and healthy wheat, and between water-stressed and disease-stressed wheat. This shared IP will be used to provide visual tools or web-based field maps to indicate areas of infection within a field, as well as the severity of infection. Maps will be color-coded with different colors corresponding to different levels of predicted economic return. The maps will serve as dynamic irrigation and fertigation guides for infected areas within the field throughout the irrigation season. In addition, for the yield prediction, a two-variable (time and MVVD severity) quadratic response surface model (Brown and Rothery, 1993) will be used for each water treatment and cultivar. Weather variables will be fitted in the model as covariates if their variations between years and among observation weeks become significant. The output from the model will be summarized and fitted

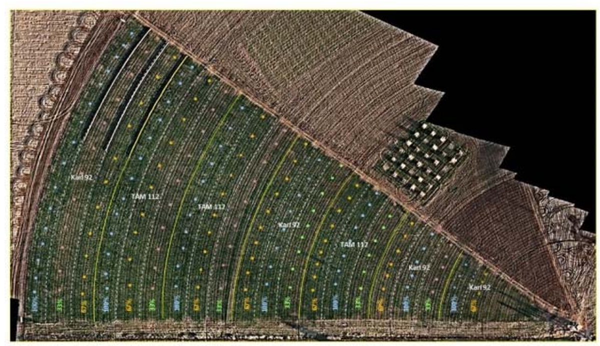

Fig. 3. 3D-R UAV image of Bushland research field with overlay of treatments. Image took 5 minutes to acquire. Dots in each water treatment represent georeferenced locations of repeated reflectance measurements. Brown area at bottom of figure is early planted trap strip, from which mites will move into field. Subsequent images will be digitally processed at the pixel level using methods of co-registration, image segmentation and feature classification to quantify disease severity at the treatment plot level. Results will be compared to those obtained with the handheld hyperspectral radiometer and data used to generate algorithms for site-specific irrigation.

to a 3-dimentional contour plot which will predict grain yield from the MVVD severity value for each observation week.

Results from this study will provide growers with the information needed to determine economic feasibility of irrigating diseased wheat at different stages of crop development. This information will be disseminated to clientele through a variety of outlets including newsletters, field days, training workshops, webcasts, extension bulletins and other web-based media that primarily will be developed in collaboration with Kay Ledbetter, the Ag Communications Specialist on our team. Additionally, results will be presented at national scientific meetings and published in peer reviewed journals.

Relevant Publications

O'Shaughnessy, S.A., Evett, S.R., Colaizzi, P.D. and Howell, T.A. 2011. Using radiation thermography and thermometry to evaluate crop water stress in soybean and cotton. Agric. Water Management 98: 1523-1535.

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