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Change detection of cotton root rot infection over 10-year intervals using airborne multispectral imagery

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ABSTRACT

Cotton root rot is a very serious and destructive disease of cotton grown in the southwestern United States. Accurate information regarding its spatial and temporal distribution within fields is important for effective management of the disease. The objectives of this study were to examine the consistency and variation of cotton root rot infections within cotton fields over 10-year intervals using airborne multispectral imagery and to assess the feasibility to use historical imagery to create prescription maps for site-specific management of the disease. Airborne multispectral images collected from a 102-ha cotton field in 2001 and 2011 and from a 97-ha field in 2002 and 2012 in south Texas were used in this study. The images were rectified and resampled to the same pixel size between the two years for each field. The normalized difference vegetation index (NDVI) images were generated and unsupervised classification was then used to classify the NDVI images into root rot-infected and non-infected zones. Change detection analysis was performed to detect the consistency and change in root rot infection between the two growing seasons for each field. Results indicate that the spatial patterns of the disease were similar between the two seasons, though variations existed for each field. To account for the potential expansion and temporal variation of the disease, buffer zones around the infected areas were created. The buffered maps between the two years agreed well. The results from this study demonstrate that classification maps derived from historical images in conjunction with appropriate buffer zones can be used as prescription maps for site-specific fungicide application to control cotton root rot.

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1. Introduction

Cotton root rot, caused by the fungus *Phymatotrichopsis omnivora*, is a destructive cotton disease occurring throughout the southwestern United States and northern Mexico (Percy, 1983). Cotton (*Gossypium hirsutum* L.) is an economically important crop that is highly susceptible to this disease. The symptoms usually begin during extensive vegetative growth, are more visible during flowering and fruit development, and continue through the growing season (Smith et al., 1962). Infected plants wilt and quickly die with the leaves attached to the plants. The fungus usually spreads more during rainy years as moisture favors all aspects of the disease cycle. Plants infected earlier in the growing season will die before bearing fruit, whereas infection occurring at later growth stages will reduce cotton yield and lower lint quality (Ezekiel and Taubenhaus, 1934; Yang et al., 2005).

Cotton root rot has plagued the cotton industry for more than 100 years (Pammel, 1888; Uppalapati et al., 2010). Cultural practices such as deep plowing, organic amendments, late planting, and rotation with monocotyledonous crops have been used to reduce the occurrence and severity of the disease (Smith et al., 1962; Rush and Lyda, 1984). Some fumigants and fungicides applied to root rot-infected areas reduced the incidence of the disease, but they were not consistently effective and economical for long-term control (Lyda and Burnett, 1970; Whitson and Hine, 1986). Despite decades of research efforts, effective practices for control of this disease were lacking until TOPGUARD® Fungicide, a commercial formulation of flutriafol from Cheminova, Inc. (Wayne, NJ), showed considerable promise for suppressing this disease in field studies (Isakeit et al., 2009, 2012).

TOPGUARD (flutriafol) was used effectively in Texas from 2012 to 2014 to control cotton root rot under Section 18 emergency

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exemptions granted by the U.S. Environmental Protection Agency (EPA). As a result, growers achieved lower cotton root rot incidence, higher yields, and better fiber quality (Drake et al., 2013). In early 2015, TOPGUARD® TERRA Fungicide, a new and more concentrated formulation of flutriafol developed specifically for this market, was registered by the EPA. It provides the same level of cotton root rot control as TOPGUARD. Growers generally treat their fields uniformly even though they are aware that only portions of their fields are infected. There are probably two main reasons for the uniform treatment. One is that growers want to make sure all existing and potential new infections are treated since they are not sure if the infection patterns will expand from year to year. The other reason is that site-specific application equipment and the capacity to create prescription maps are not readily available for their use. Since only portions of the field are infected, it may not be appropriate to treat the whole field. Therefore, it is necessary to define the infected areas within the field so that variable rate technology can be used to apply the fungicide only to the infected areas for more effective and economical control.

Remote sensing has long been used as a useful tool for mapping cotton root rot in cotton fields (Taubenhaus et al., 1929; Nixon et al., 1975, 1987). Remote sensing is perhaps the only practical means for accurately and effectively mapping this disease because of large numbers of infected areas and their irregular shapes within cotton fields. In our previous studies, airborne imagery has been successfully used to map the extent of cotton root rot infections near the end of the growing season when cotton root rot is fully pronounced for the season (Yang et al., 2005) and to monitor the progression of the infections within cotton fields during a growing season (Yang et al., 2014a). In these studies, ISODATA (Iterative Self-Organizing Data Analysis) unsupervised classification applied to multispectral imagery has been used to identify root rot-infected areas. With this method, the optimal number of spectral classes is determined based on the average transformed divergence for each classification map. The spectral classes are then grouped into root rot-infected and non-infected zones.

More recently, Yang et al. (2015) evaluated and compared two unsupervised classification techniques (ISODATA applied to multispectral imagery and to NDVI) and six supervised classification techniques (minimum distance, Mahalanobis distance, maximum likelihood, spectral angle mapper (SAM), neural net, and support vector machine (SVM)) for mapping and detecting cotton root rot from airborne multispectral imagery. Although all eight methods appear to be equally effective and accurate for detection of cotton root rot, the NDVI-based classification can be easily implemented without the need for complex image processing capability. Therefore, it has been recommended as one of the simple and accurate classification methods to map cotton root rot and develop prescription maps for effective and economical control of this disease.

The objectives of this study were to: (1) examine the consistency and variation of cotton root rot infection within two cotton fields based on airborne multispectral imagery taken over 10-year intervals; and (2) assess the feasibility to use historical imagery to create prescription maps for site-specific management of the disease. This information is important not only for a better understanding of the progression of the disease over a relatively long period of time, but also for the formulation of site-specific strategies for effective control of the disease.

2. Materials and methods

2.1. Study area

This study was conducted in two center-pivot irrigated fields near Edroy, Texas over 10-year intervals. Field 1 was a 102-ha circular field with center coordinates of (27°58′19″N, 97°42′"N, 97°42′49.22"W). Both fields had a history of cotton root rot. Cotton and grain sorghum had been cropped alternately in the fields. Cotton was planted to Field 1 in 2001 and 2011 and to Field 2 in 2002 and 2012.

2.2. Image acquisition

Three different imaging systems were used to acquire images from the two fields in four different years shortly before harvest when root rot was fully expressed for the respective season. A three-camera imaging system described by Escobar et al. (1997) was used to acquire images from Field 1 on 9 July 2001 and from Field 2 on 19 July 2002. The imaging system consisted of three digital charge coupled device (CCD) cameras and a computer equipped with three image digitizing boards that had the capability of obtaining 8-bit images with 1024×1024 pixels. The three cameras were filtered for spectral observations in the green (555–565 nm), red (625–635 nm), and near-infrared (NIR, 845–857 nm) wavelength intervals, respectively.

A four-camera imaging system described by Yang (2012) was used to acquire images from Field 1 on 7 July 2011. The system consisted of four high-resolution CCD digital cameras and a ruggedized PC equipped with frame grabbers and image acquisition software. The four cameras were filtered to capture 12-bit images with 2048×2048 pixels in four spectral bands: blue (430–470 nm), green (530–570 nm), red (630–670 nm), and NIR (810–850 nm), respectively. A two-camera imaging system described by Yang et al. (2014b) was used to take images from Field 2 on 25 July 2012. The system consisted of two consumer-grade digital cameras with a 5616×3744 pixel array. One camera captured normal RGB color images, while the other camera was equipped with a 720-nm long-pass filter to obtain NIR images.

A Cessna 206 single-engine aircraft was used to acquire imagery from the two fields in each of the four years at an altitude of 3050 m (10,000 ft) above ground level between 1130 h and 1530 h local time under sunny conditions. Images from the three-camera and four-camera systems were saved to the respective on-board computers as three-band and four-band Tiff files, respectively, while images from the two-camera system were stored in two separate CompactFlash (CF) cards in both 14-bit RAW and 8-bit JPEG files. The ground pixel size achieved was 1.3 m in 2001 and 2002 and 1.0 m in 2011 and 2012.

2.3. Image processing and classification

An image-to-image registration procedure based on the first-order polynomial transformation model was used to align the individual band images in the three-band and four-band composite images as well as the RGB and NIR images from the two-camera system. The aligned images were then georeferenced or rectified to the Universal Transverse Mercator (UTM), World Geodetic System 1984 (WGS-84), Zone 14, coordinate system based on a set of ground control points around each field located with a Trimble GPS Pathfinder ProXRS receiver (Trimble Navigation Limited, Sunnyvale, California). The root mean square errors for rectifying the images using first-order transformation were within 2 m. All images were resampled to 1 m resolution using the nearest neighborhood technique. All procedures for image alignment and rectification were performed using ERDAS Imagine (Intergraph Corporation, Madison, Alabama).

The rectified images for the two dates were stacked as one image for each field. A field boundary or an area of interest (AOI) was defined for each field. Normalized difference vegetation index (NDVI) images were created for each field and year combination using the following formula: