MONITORING COTTON ROOT ROT PROGRESSION WITHIN AND ACROSS GROWING SEASONS USING REMOTE SENSING

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Abstract

Cotton root rot, caused by the soilborne fungus *Phymatotrichopsis omnivore* Shear (Duggar), is one of the most destructive plant diseases occurring throughout the southwestern U.S. More recently, a fungicide, flutriafol, has been evaluated in Texas and was found to have the potential for controlling this disease. It is necessary to identify infected areas within the field so that variable rate technology can be used to apply the fungicide only to infected areas for more effective and economical control. The objectives of this study were to use airborne multispectral imagery for detecting and monitoring the expansion of root rot infection in cotton fields within and across growing seasons. Two dozen cotton fields near Edroy and San Angelo, Texas were selected for this study. Airborne multispectral digital imagery with blue, green, red and near-infrared bands was taken from these fields multiple times during the growing seasons in 2009, 2010, and 2011. In this paper, four images taken from a field near San Angelo in 2011 was used to illustrate the progression of cotton root rot within the growing season, and two images taken from a field near Edroy in 2001 and 2011, respectively, were used to demonstrate the consistency and change of this fungus over a 10-year interval. The results from this study will be useful for the understanding of the progression of the disease and for the development of site-specific treatment plans for the disease.

Introduction

Cotton is an economically important crop that is highly susceptible to cotton root rot, a destructive plant disease that occurs throughout the southwestern U.S. The fungus is prevalent in calcareous, alkaline clay loam soils with a pH range of 7.0 to 8.5 and in areas with high summer temperatures (Walla and Janne, 1982; Goldberg, 1999). Infected plants wilt and quickly die in several days with the leaves attached to the plants (Smith et al., 1962). The symptoms usually begin during the period of rapid vegetative growth, are more visible during flowering and fruit development, and continue to increase through the growing season. Plants infected earlier in the growing season will die before bearing fruit, whereas infection occurring at later plant 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. Despite decades of research efforts, effective practices to control this disease are still lacking. More recently, new fungicides have been evaluated and a commercial formulation of flutriafol (TOPGUARD® - Cheminova, Inc., Wayne, NJ) was found to effectively control cotton root rot (Isakeit et al., 2007, 2009, 2010). Because of cost and environmental considerations, defining infected areas and understanding seasonal spread of the disease within fields will allow variable rate technology to be used to apply fungicide only to infected areas for more effective and economical control.

Remote sensing is perhaps the only practical means for effectively mapping this disease because of large numbers of infected areas and their irregular shapes within cotton fields. This technology has been successfully used to map cotton root rot infections in cotton fields (Nixon et al., 1987; Yang et al. 2005, 2010). However, only limited work has been done to monitor the progression of the disease over a growing season or across different growing seasons (Yang et al., 2011). This information is important for the understanding of the initiation and subsequent development and expansion of the disease. It can also be used to formulate the site-specific strategies for within-season and pre-season control of the disease. Therefore, the objectives of this study were to use airborne multispectral imagery for detecting and monitoring the progression of cotton root rot infections in cotton fields within and across growing seasons.

Materials and Methods

Study Sites

A semicircular cotton field near San Angelo (31°26′42″ N, 100°16′49″ W) was used to illustrate the progression of cotton root rot within the growing season in 2011 and a circular field near Edroy (27°58′19″ N, 97°42′29″ W) was used to demonstrate the consistency and change of this fungus between 2001 and 2011. These two fields were both center-pivot irrigated and had a history of cotton root rot.

Airborne Multispectral Image Acquisition

A three-camera imaging system described by Escobar et al. (1997) was used to acquire images in 2001 from the Edroy field. The system captured 8-bit images with 1024 × 1024 pixels in three spectral bands: green (555-565 nm), red (625-635 nm), and NIR (845-857 nm). A four-camera imaging system described by Yang (2010) was used to take images in 2011 from both fields. The system captured 12-bit images with 2048 × 2048 pixels in four spectral bands: blue (430-470 nm), green (530-570 nm), red (630-670 nm), and near-infrared (NIR) (810-850 nm).

A Cessna 206 single-engine aircraft was used to acquire imagery from the Edroy field on 9 July 2001 and 7 July 2011 and from the San Angelo field on four dates (18 August, 1 and 13 September, and 4 October 2011). All images were acquired at altitudes of 3048 (10000 ft) between 1130h and 1430h local time under sunny conditions. The ground pixel size achieved was 1.3 m in 2001 and 0.85 in 2011.

Image Alignment and Rectification

An image-to-image registration procedure based on the first-order polynomial transformation model was used to align the individual band images in each composite image. The registered images were then georeferenced or rectified to the Universal Transverse Mercator (UTM), World Geodetic Survey 1984 (WGS-84), Zone 14, coordinate system based on a set of ground control points around the field located with a Trimble GPS Pathfinder ProXRS receiver (Trimble Navigation Limited, Sunnyvale, California). The RMS errors for rectifying the images using first-order transformation were approximately 2 m. All images were resampled to 1 m resolution using the nearest neighborhood technique. All procedures for image registration and rectification were performed using ERDAS Imagine (ERDAS Inc., Norcross, Georgia).

Image Classification

The rectified three-band and four-band images were classified into 2-12 spectral classes using ISODATA (Iterative Self-Organizing Data Analysis) unsupervised classification (ERDAS, 2010). The unsupervised method uses minimum spectral distance to group each pixel to a class. The process began with arbitrary class means from the image statistics based on the number of classes specified. It repeatedly performed a classification and recalculated new class statistics, which were used for the next iteration. The process continued until the number of iterations reached 100 or the convergence threshold reached 1.00. The spectral classes in each classification map were then grouped into root rot-infected and non-infected zones by comparing with the original image and based on ground observations. The root rot-infected areas and non-infected areas were estimated from the best two-zone classification maps.

Results and Discussion

Figure 1 shows color-infrared (CIR) images acquired on the four dates for the San Angelo field in 2011. On the CIR images, healthy plants showed a reddish-magenta tone, while infected plants had a dark grayish or cyanish color. Root rot-infected areas could be easily separated from the non-infected areas on the CIR images. Cotton root rot started to appear in early August and continued to expand throughout the rest of the growing season.

Figure 2 shows the best two-zone classification maps for the four dates for the field. A visual comparison of the classification maps and their respective CIR images indicated that the classification maps effectively identify apparent root rot areas within the field. The estimated percent root rot areas increased from 6.5% on 18 August to

17.0% on 1 September, and then continued to expand to 22.8% on 13 September. By the end of the growing season on 4 October, 35.8% of the field was infected.

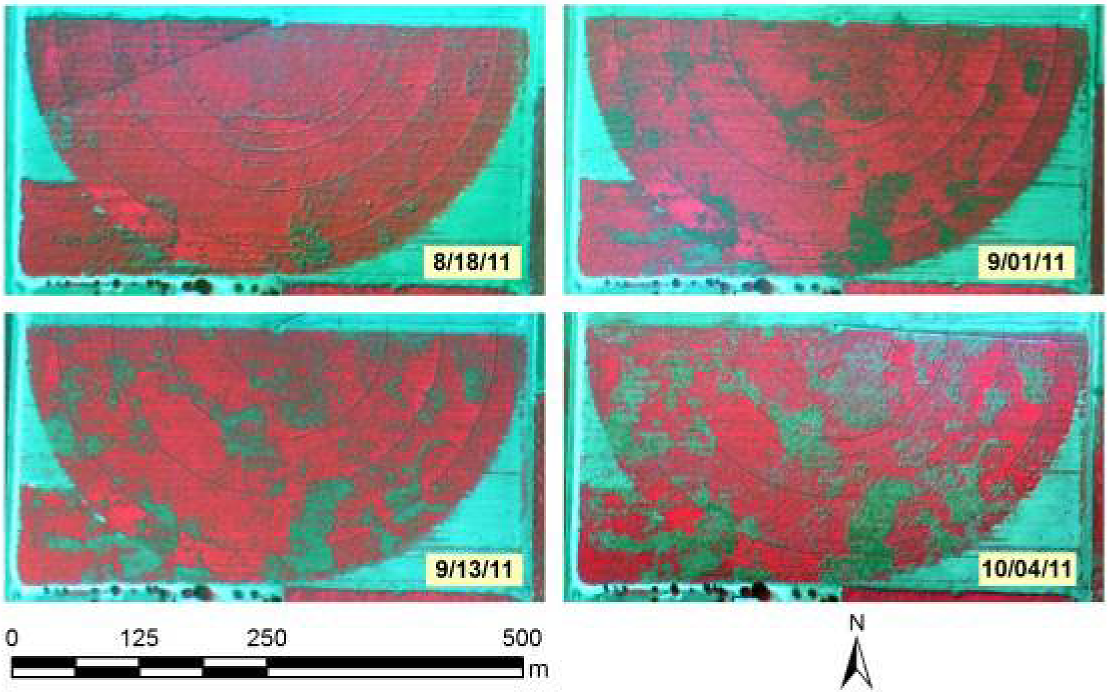

Figure 1. Airborne CIR images acquired on four dates during the 2011 growing season from a 10.5-ha cotton field infected with cotton root rot near San Angelo, TX.

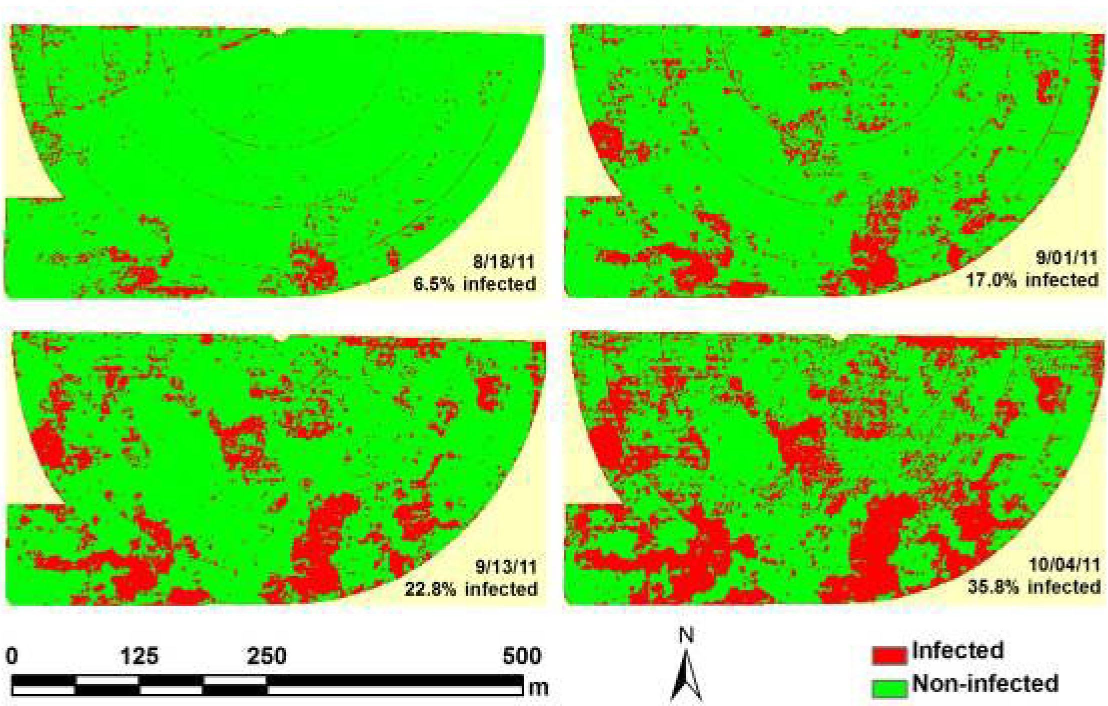

Figure 2. Two-zone classification maps for four different dates for a 10.5-ha cotton field infected with cotton root rot near San Angelo, TX.

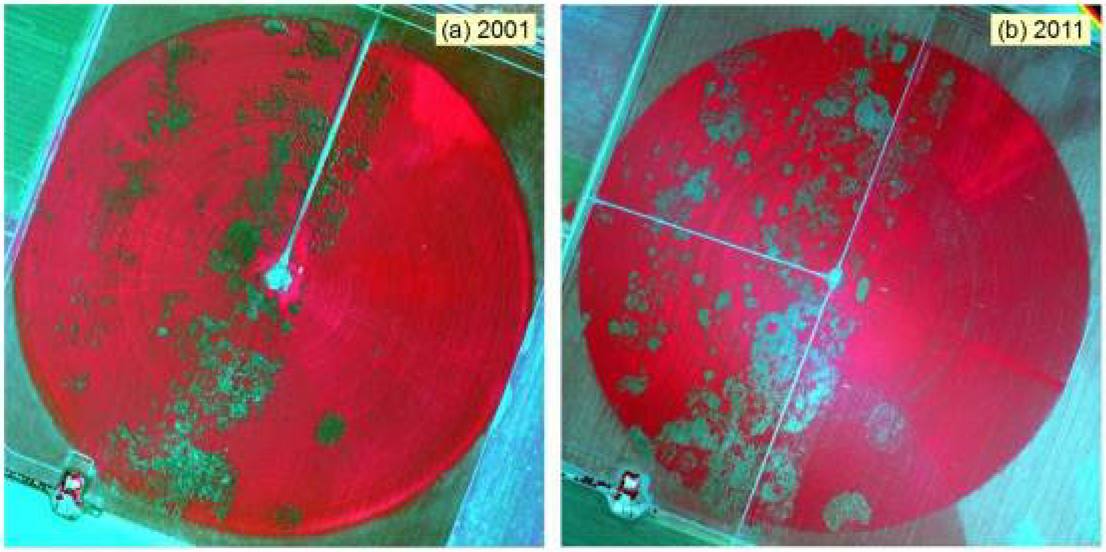

Figure 3. Airborne CIR images acquired in 2001 and 2011 from a 102-ha cotton field infected with cotton root rot near Edroy, TX.

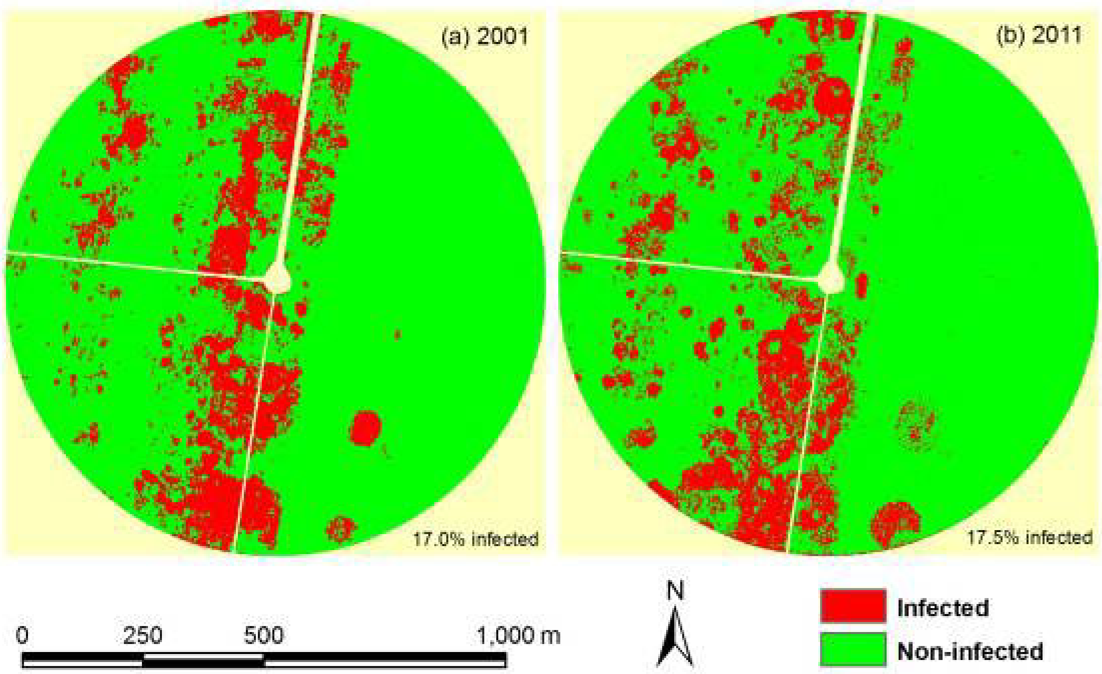

Figure 4. Two-zone classification map for 2001 and merged two-zone classification map for 2011 for a 102-ha root rot-infected cotton field near Edroy, TX.

Figure 3 shows the CIR images acquired in 2001 and 2011 for the field near Edroy, TX and Figure 4 shows the two-zone classification maps for both years for the field. The estimated percent root rot areas for the field were 17.0% in 2001 and 17.5% in 2011. The overall spatial patterns of infections between the two years are similar, but there are changes in the locations of infected areas. A change detection analysis showed that 9.0% of the field was infected in both years, while 8.0% of the field was infected only in 2001 and 8.5% only in 2011 in addition to the common infection areas. Thus, a total of 25.5% of the field was infected in either 2001 or 2011. This combined infection map can then be used for site-specific fungicide treatment.

Conclusions

Results from this study demonstrate that airborne multispectral imagery in conjunction with unsupervised classification can be a useful tool for detecting and mapping cotton root rot infections within and across growing seasons. Once the infection is initiated, the fungus will continue to expand throughout the growing season, though other factors such as weather and cultural practices may affect its expansion rates and magnitude. The disease tends to occur in similar areas in recurring years, but there are variations in infection patterns. The infection maps can be used for site-specific fungicide treatment. For long-term effective and economical management of this disease, it is necessary to not only understand the within-season expansion patterns, but also to monitor the consistency and variation of the spatial patterns from year to year.

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