SITE-SPECIFIC MANAGEMENT OF COTTON ROOT ROT USING HISTORICAL REMOTE SENSING IMAGERY

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Abstract

Cotton root rot can now be effectively controlled with Topguard Terra Fungicide, but site-specific application of the fungicide can greatly reduce treatment cost as only portions of the field are infested with the disease. The overall goal of this three-year project was to demonstrate how to use historical remote sensing imagery and variable rate technology for site-specific application of the fungicide. Procedures were developed for creating binary prescription maps from historical airborne and satellite imagery. Two different variable rate liquid control systems were adapted to two existing cotton planters, respectively, for site-specific fungicide application. One system was used for site-specific application on study fields near Edroy, TX and the other on study fields near San Angelo, TX. Airborne multispectral imagery taken during the growing seasons was used to monitor the performance of the site-specific treatments. Three years of field experiments showed that the variable rate systems performed well and site-specific fungicide treatments effectively controlled cotton root rot. Newly infested areas within the fields were identified by the airborne imagery in 2015 and then added to the prescription maps in 2017. On the basis of the results of this multi-year research, a bulletin guide has been developed and published to provide cotton growers, crop consultants, and agricultural dealers with practical guidelines for implementing site-specific Topguard Terra application using historical imagery and variable rate technology for effective management of cotton root rot.

Introduction

Cotton root rot is a destructive cotton disease that has plagued the cotton industry for more than a century. The disease is caused by the soilborne fungus *Phymatotrichopsis omnivora*, which is found in calcareous, alkaline soils with high summer temperatures and moist conditions. 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; Smith et al., 1962; Yang et al., 2005).

Effective practices for the control of this disease were lacking until Topguard® Fungicide showed considerable promise for suppressing this disease in field studies (Isakeit et al., 2012). Topguard was then approved for use in Texas from 2012 to 2015 to control cotton root rot under successively granted annual Section 18 emergency exemptions from 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, Yang et al., 2014). In early 2015, Topguard® Terra Fungicide, a new and more concentrated formulation developed specifically for this market, was registered by the EPA. Topguard Terra provides the same level of cotton root rot control as Topguard.

Remote sensing has long been used to document the distribution of cotton root rot damage within cotton fields. Based on our aerial remote sensing surveys conducted in the coastal Bend and Southern Rolling Plains areas of Texas, cotton root rot-infested areas within fields vary from near 0 to about 75%, but most fields only have about 20-40% of their areas infested. More importantly, cotton root rot tends to occur in the same general areas within the field in recurring years, even though factors such as weather and cultural practices may affect its initiation and severity (Yang et al., 2016). This spatially non-continuous and temporally stable pattern of cotton root rot incidence makes it an excellent candidate for site-specific management. Since Topguard Terra is not effective once the plant is infected, the fungicide is usually applied at planting, though it may be applied shortly before planting or after cotton emergence. Remote sensing imagery and ground measurements taken in the current season cannot be used for the management of this disease within the season. Therefore, historical remote sensing imagery and yield maps provide appropriate data sources for creating prescription maps for the following seasons.

Variable rate technology enables growers to improve crop production efficiency and reduce environmental impacts by adjusting application rates of crop production and protection materials to specific conditions within discrete areas of a field. There have been extensive research and commercial activities on the use of this technology for site-specific ground applications of fertilizers, herbicides, fungicides, water, and seeds. Variable rate control systems are commercially available from many farm machinery manufacturers and can be readily adapted to existing tractors and implements for variable rate applications.

The objectives of this study were to: 1) develop practical procedures to create prescription maps from historical airborne and satellite imagery for site-specific management of cotton root rot; 2) adapt variable rate control systems to existing tractors and planters for implementing site-specific Topguard Terra application; and 3) evaluate the performance and efficacy of site-specific treatments using aerial imagery.

Materials and Methods

Study Sites

This research was conducted in multiple fields with a history of cotton root rot in the Coastal Bend and Southern Rolling Plains areas of Texas in 2015-2017. A 45-ha (112-ac) dryland field with the center coordinates (28°00′5″N, 97°38′33″W) near Edroy, Texas was selected for presentation in this paper. The field was planted to cotton in 2015 and 2017.

Image Acquisition and Processing

Images used in this paper were acquired in 2010, 2015 and 2017 using three different imaging systems, respectively. A four-camera imaging system was used to take images in 2010. 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 two-camera imaging system, consisting of two Canon EOS 5D Mark II digital cameras with a 5616 × 3744 pixel array, was used in 2015. One camera captured red-green-blue (RGB) color images, while the other camera was equipped with a 720-nm long-pass filter to obtain NIR images. In 2017, a different airborne two-camera imaging system, consisted of two Nikon D810 digital cameras with a 7360 × 4912 pixel array, was used. Similarly, one camera captured RGB color images, while the other camera was equipped with an 830-nm long-pass filter to obtain NIR images. All the airborne images were acquired between 1200 and 1500h local time under sunny conditions. The flight altitudes were 2740 m (9000 ft) above ground level (AGL) with a pixel size of 0.9 m in 2010, 1070 m (3500 ft) AGL with a pixel size of 0.35 m in 2015, and 3200 m (10,500 ft) AGL with a pixel size of 0.78 m in 2017.

The four band images from the four-camera system were aligned to each other using an image-to-image registration procedure based on the first-order polynomial transformation model and were then stacked as a four-band composite image. Similarly, the RGB and NIR images from the two-camera systems were aligned and stacked as a six-band image as the NIR image contained three NIR bands. As the three NIR bands were similar, the NIR band image recorded in the red channel was used. The aligned or registered images were then 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. All procedures for image registration and rectification were performed using ERDAS Imagine (Intergraph Corporation, Madison, AL).

Prescription Map Creation

The 2010 image was resampled to 1-m resolution using the nearest neighborhood technique. A field boundary or an area of interest (AOI) was defined and a normalized difference vegetation index (NDVI) image was created within the AOI for the field. The NDVI image was then classified into root rot-infected and non-infected zones using ISODATA (Iterative Self-Organizing Data Analysis) unsupervised classification using ERDAS Imagine. To accommodate the potential expansion and temporal variation of the disease, a 5-m buffer around the infected areas were add to the classification map as part of the treatment areas. The buffered NDVI map was used as the prescription map in 2015.

In 2017, a 16-ha (40-ac) area that was connected to the west border of the field was combined with the original field as the new 62-ha (152-ac) study field. The 2015 image documented root rot-infested areas in the 16-ha (40-ac) area and newly-infested areas in the original 45-ha (112-ac) field. These infested areas were manually digitized from the 2015 image and then combined with the 2015 prescription map as the prescription map for 2017.

Variable Rate Fungicide Application

A John Deere variable rate control system consisting of a controller, a servo valve, a flowmeter, and a shutoff valve was integrated with the John Deere GS 2 Display and the StarFire RTK GPS receiver already mounted on a John Deere 8230 tractor owned by a producer near Edroy, TX. The system was used in 2015-2017. A transparent flow divider was used to distribute the flow evenly to the shanks of a 12-row 0.965-m (38-in) planter. A modified in-furrow method with Y-shaped splitters was used to apply the fungicide on the sides of seed furrow and not in direct contact with the seed. The GS 2 Display was replaced with a John Deere GS 3 2630 Display in 2016. Topguard Terra was applied at 0.292 L/ha (4 fl oz/ac) (half rate) in 2015 and at 0.585 L/ha (8 fl oz/ac) (full rate) in 2017 with 56.1 L/ha (6 gal/ac) of water each year.

Results and Discussion

Figure 1 shows the color-infrared (CIR) composite image taken in 2010, the corresponding two-zone classification map, and the prescription map for the field for 2015. The infected plants had a greenish color, while the non-infected plants had a reddish tone. Approximately 33% of the field was infested in 2010. With a 5-m buffer added to the infested areas, about 57% of the field (green areas) was treated with Topguard Terra in 2015. Figure 2 shows an airborne CIR image taken in 2015 for the expanded field, the corresponding two-zone classification map, and the prescription map for 2017. About 57% of the expanded field was treated with the fungicide in 2017.

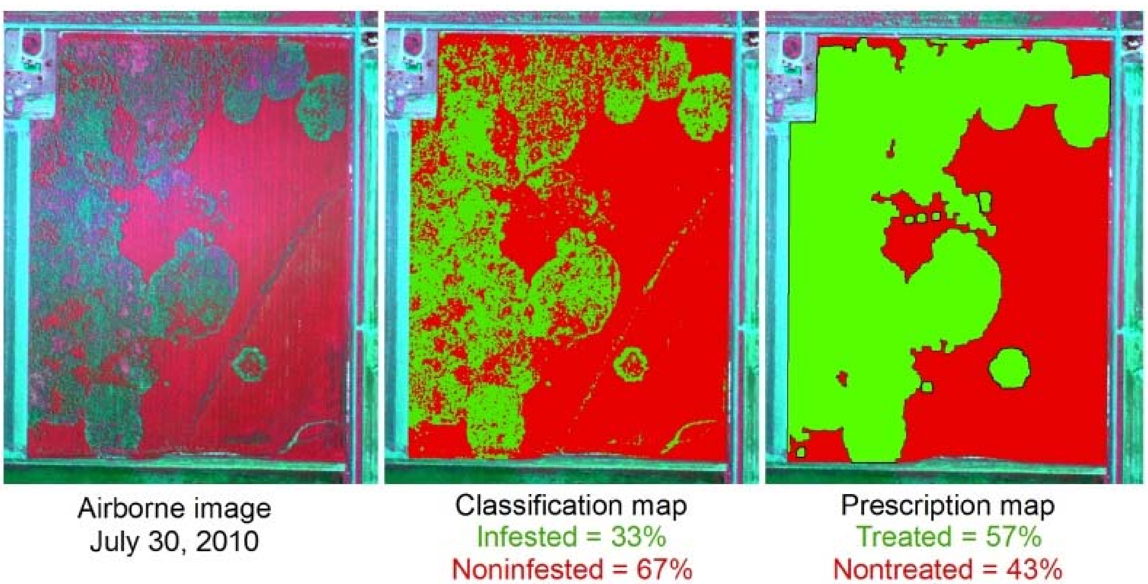


Figure 1. An airborne color-infrared image taken in 2010 (left), a corresponding two-zone classification map (center), and a prescription map (right) for a 45-ha (112-ac) cotton field infested with cotton root rot near Edroy, Texas. The green areas in the prescription map were treated with Topguard Terra Fungicide at 0.292 L/ha (4 fl oz/ac) of product (half rate) with 56.1 L/ha (6 gal/ac) of water in 2015.

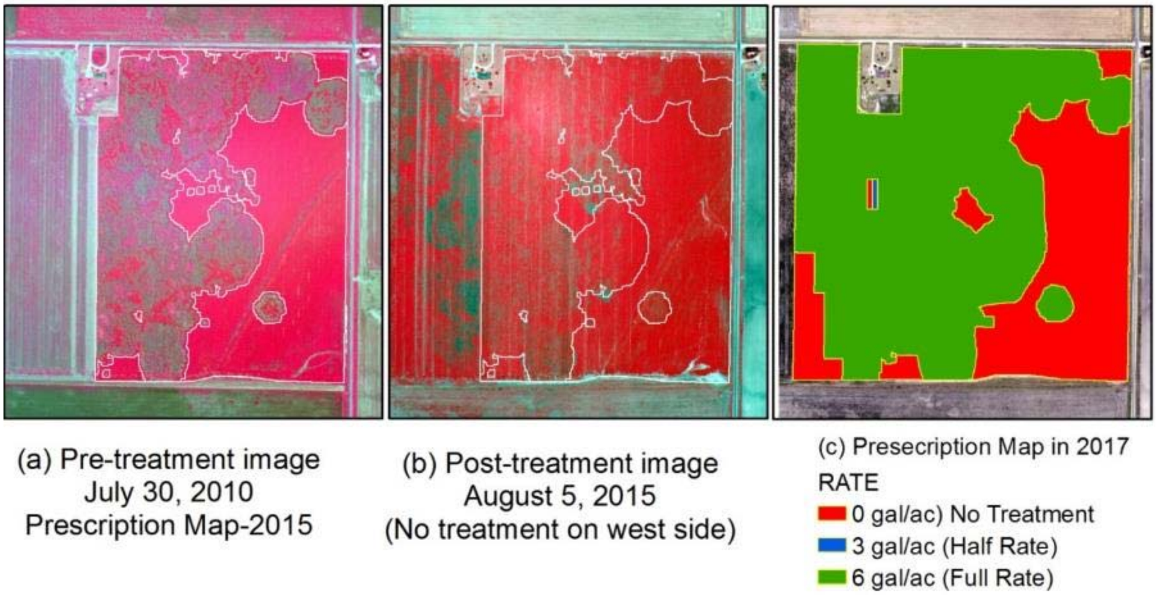


Figure 2. An airborne color-infrared image in 2010 overlaid with the 2015 prescription map (left), an airborne color-infrared image in 2015 (center), and a prescription map (right) for an expanded 62-ha (152-ac) cotton field near Edroy, Texas. The green areas in the prescription map were treated with Topguard Terra Fungicide at 0.585 L/ha (8 fl oz/ac) of product (half rate) with 56.1 L/ha (6 gal/ac) of water in 2017.

Figure 3 compares the airborne CIR images between 2010 (natural infestation) and 2015 (infestation with site-specific treatment) for the field and the as-applied map is also shown with the images. Figure 4 shows the airborne CIR images for the three years (2010, 2015 and 2017). Clearly, the fungicide effectively controlled the disease in the treated areas, though cotton root rot started showing up in some treated areas toward the end of each growing season. The fungicide was only applied at half of the full rate in 2015, whereas the full rate was applied in 2017. Yet late infestations existed in some treated areas in 2017, especially on the new 16-ha (40-ac) portion. In contrast, root rot damage in nontreated areas right across the entire western border of the field can be clearly seen from the dark areas in the 2015 CIR image.

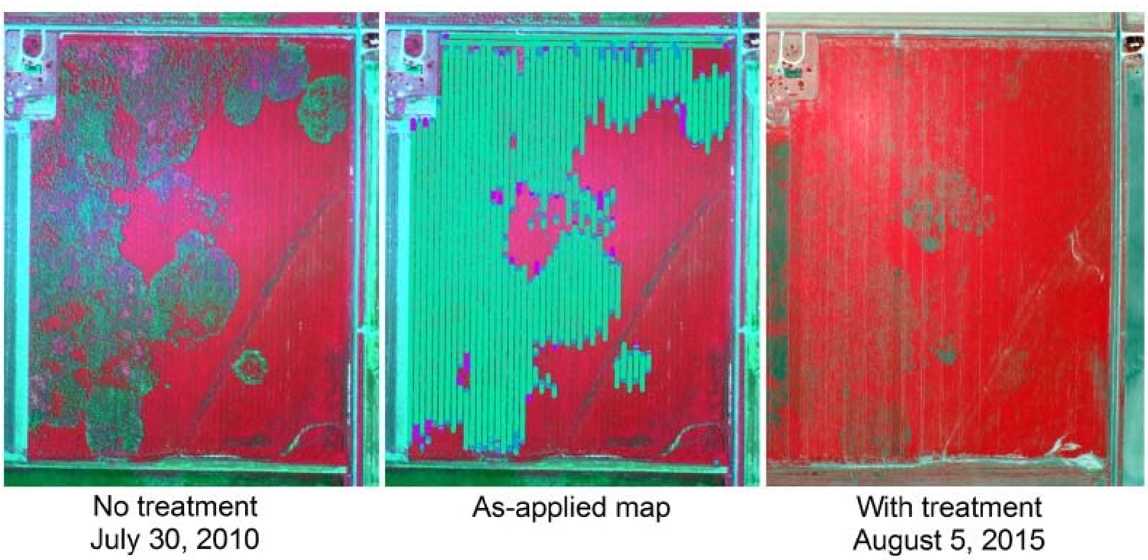
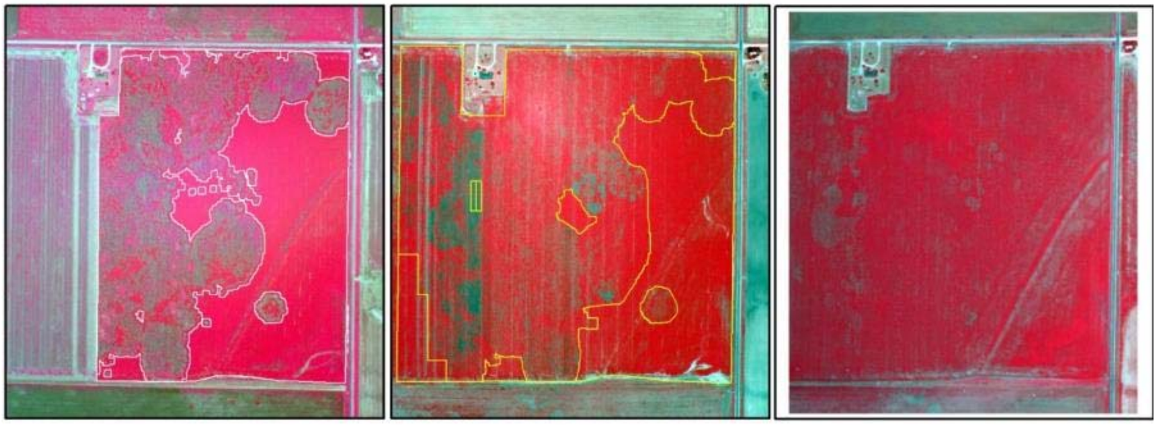


Figure 3. Comparison of airborne color-infrared images acquired in 2010 (natural infestation) and 2015 (infestation with site-specific treatment) for a 45-ha (112-ac) cotton field near Edroy, TX. Also shown is an as-applied map.



(a) Pre-treatment image
July 30, 2010
Prescription map in 2015

(b) Post-treatment image
August 5, 2015
Prescription map in 2017

(c) Post-treatment image
July 10, 2017

Figure 4. Comparison of airborne color-infrared images acquired in 2010 with natural infestation, 2015 with infestation after site-specific treatment only for the original 45-ha (112-ac) field, and 2017 with infestation with site-specific treatment for the expanded 62-ha (152-ac) field near Edroy, TX.

Conclusions

This research has demonstrated how site-specific fungicide application can be implemented based on historical remote sensing imagery and variable rate technology for effective management of cotton root rot. Historical airborne and high resolution satellite imagery provides a useful data source for documenting cotton root rot infestation and can be used to generate prescription maps for precise management of the disease. Variable rate controllers can be easily adapted to existing tractors/planters/applicators for implementing site-specific Topguard Terra applications. As long as only portions of the field are infested with cotton root rot, it is worth the effort to employ site-specific management techniques for controlling it.

Variable rate application is a specialized field and requires more advanced equipment and image processing technology and a better understanding of the techniques involved. If a grower is not comfortable performing any of the tasks, an agricultural dealer and an image processing service can be hired to adapt a variable rate controller to a tractor/planter and to create prescription maps. The savings from reduced fungicide will far exceed the costs associated with the addition of a variable rate controller and the creation of prescription maps. The bulletin guide developed from this project (Yang et al., 2017) and the results presented in this paper and many other our previous papers have provided cotton growers, crop consultants, and agricultural dealers with practical guidelines for implementing site-specific fungicide application using historical imagery and variable rate technology for effective management of cotton root rot.

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