THE RELATIONSHIP BETWEEN INCIDENCE OF VERTICILLIUM WILT AND REFLECTANCE IN A WILT NURSERY

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Abstract

A Verticillium wilt nursery was rated twice for incidence of wilt in 1040 plots. Aerial, color, infrared photographs of the nursery were used to determine the reflectance of near-infrared, red, and green color bands, and various combinations of these bands. Twenty-five cotton lines were replicated in $\geq$ 8 plots, including the susceptible variety ‘Lankart 57' and the Verticillium-tolerant variety ‘Paymaster (PM) 147'. Incidence of wilt from the entire nursery was most highly correlated with reflectance of the green band. Incidence of wilt averaged 6 plants/plot for Lankart 57 and 2 plants/plot for PM 147 on 19 July, and 12 and 6 plants/plot on 18 August. However, reflectance of the green band averaged 146 for Lankart 57 and 150 for Paymaster 147 (not significantly different). Within a cotton line, reflectance of various color bands or band combinations was associated with incidence of wilt, but only for 8 of 25 cotton lines with the July rating, and 4 of 25 cotton lines with the August rating. Remote sensing with aerial color infrared photography can not replace visual rating for cotton lines in a Verticillium wilt nursery.

Introduction

Verticillium wilt is caused by the fungus *Verticillium dahliae*. This fungus can infect roots several weeks after cotton is planted, but does not usually spread systemically through the vascular system until flowering is initiated. Generally, cool conditions (< 95 F) during the flowering period result in more severe wilt symptoms (Garber & Presley, 1971; Pullman & DeVay, 1982a). Abundance of water has also been associated with more severe wilt symptoms (Cappaert et al., 1994). The initial infection propagule is often a microsclerotia (Fitzell et al., 1980), which is capable of surviving in the absence of a host for many years(Huisman & Ashworth, 1976). Crop rotation is not effective in controlling Verticillium wilt. Verticillium wilt can reduce plant size and cause shedding of fruiting structures, which leads to substantial yield reductions (Pullman & DeVay, 1982b). *Verticillium dahliae* is distributed in an aggregated pattern in the soil (Wheeler et al., 1994), which results in nonuniform wilt severity across cotton fields. The primary method of controlling Verticillium wilt is with resistant or tolerant varieties. Cotton breeders may screen cotton lines in breeding nurseries that are infested with *V. dahliae*. Since wilt disease typically progresses up a plant slowly (3-5 weeks after initiation of symptoms), wilt intensity should be rated several times once symptoms have initiated (Adair, 1996). This rating time coincides with flowering, which is also the time that breeding programs are very busy with selfing and crossing cotton plants. As a result, plants may not be rated for wilt symptoms and selected only for yield and/or vascular browning at the end of the growing season.

Remote sensing may offer a way of rating plots for Verticillium wilt during flowering without taking personnel from other tasks. Images can be broken down into individual color bands. Images from color infrared film can be divided into a near-infrared (NIR) band, red band, and green band. A value from 0 to 255 is obtained for each band, depending on the intensity of the reflectance of light at each of these bands. Reflectance of individual bands or band combinations have been associated with plant stress (Jackson, 1986). Since Verticillium wilt causes significant plant stress, it may be associated with reflectance from certain bands or band combinations. Aerial photographs can be taken with color infrared film of an entire nursery with minimal time expenditure during the growing season. However, it is necessary to show that reflectance from a single band or band combinations is an accurate and consistent indicator of wilt, with a number of different cotton lines.

Materials and Methods

A Verticillium nursery consisting of 1040 plots, 1-row wide, 30' long with 40" centers was planted with a number of different cotton lines. Plants were thinned to 1 plant every 8" in each plot. The nursery was 52 rows wide and 20 plots long. Twenty five cotton lines were replicated with at least 8 plots/line in the nursery, however the arrangement of these cotton lines was not randomized. Two of these cotton lines were the Verticillium-susceptible cultivar ‘Lankart 57' (planted in 189 plots) and the Verticillium-tolerant cultivar ‘Paymaster (PM) 47' (planted in 85 plots) (Adair, 1996). The field was furrow irrigated, with water accumulating on one end of the field. The number of plants demonstrating wilt symptoms were counted in each plot on 19-20 July and 18-19 August.

Aerial infrared color photographs were taken of the field on 22 July and 11 August. The film was Kodak Ektachrome Infrared EIR 135-36 , and the camera (35-mm) used a yellow # 12 Tiffen 62M filter. The photograph on 22 July was taken at 2000' above ground level, and the photograph on 11 August was taken at < 1000' above ground level. The images were scanned as JPEG files and processed in ARCVIEW (Environmental Systems Research Institute, Vancouver, B.C.) with the Image Analysis Procedure. In each plot, 3 points were taken (one in each 1/3 of the plot), and the reflectance

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value (ranging from 0 to 255) of the NIR, red, and green bands were obtained. An average of each of these values were obtained for each plot, as well as the ratio of NIR/red, NIR/green, red/green, and NVDI ((NIR-red)/(NIR+red)). The photograph taken in July could not be resolved clearly down to single, one-row plots, so only the August image data was applied in the analyses.

A correlation analysis (PROC CORR in SAS, SAS Institute, Cary, NC) was performed on the number of plants with wilt/plot (at two dates) and reflectance from each of the band and band combinations described previously. Wilt ratings and reflectance values from the 25 cotton lines which were replicated at least 8 times in the nursery were averaged, and analyzed with correlation analysis. Reflectance values of all band combinations were related to wilt ratings for each of the 25 cotton lines with stepwise regression analysis (PROC STEPWISE, SAS).

Results and Discussion

Air temperatures during the entire flowering period of the cotton nursery were above that considered acceptable for wilt development (Garber & Presley, 1971). Water stress was also a factor during 1999, despite furrow irrigation. Water stress can make visual rating for wilt symptoms more difficult (Harrison, 1970). As a result, this heavily infested nursery did not demonstrate severe levels of wilt in 1999. Wilt development was patchy and heavier on the end of the field where water had accumulated from irrigations. Wilt ratings taken on 19-20 July and 18-19 August in the entire nursery were significantly (P=0.05) correlated with reflectance of NVDI, NIR, red, green, NIR/red, and NIR/green, with the highest correlation (r=0.24 and 0.18 for July and August, respectively) associated with reflectance from the green band. This provided preliminary evidence that reflectance in the green band may be useful in rating the nursery for wilt. The rest of the analysis was conducted only on 25 cotton lines which were planted in multiple locations in the nursery.

The nonrandom planting pattern for the 25 cotton lines resulted in all lines being exposed to low and moderate levels of wilt. The incidence of plants with wilt symptoms/plot was ranked consistently for most cotton lines at both rating periods (Table 1). However, the average reflectance value in the green band associated with each cotton line was ranked inconsistent with wilt symptoms, and reflectance rankings between Lankart 57 and PM 147 were only separated by 4.5 ranks (Table 1).

Wilt ratings in July for 8 of the 25 cotton lines were significantly (P=0.05) correlated with reflectance from a band or band combination (Table 2), though no single band or band combination was consistently associated with wilt for all eight cotton lines. In August, wilt within 4 of the 25 cotton lines were associated with reflectance (Table 2). Two examples of the poor relationship between actual wilt ratings and predicted wilt ratings are presented in Figure 1. These results indicate that reflectance can be used to indicate wilt intensity within a single variety, however, it would be difficult to predict which band should be used before extensive testing of each variety. This tool may eventually be useful in mapping fields for wilt, but currently needs more testing. Reflectance may be a better indicator of Verticillium wilt in a year with less water stress and lower temperatures.

Summary

Verticillium wilt incidence was associated with reflectance, particularly in the green band. However, this tool cannot currently replace the need to visually rate wilt symptoms in cotton nurseries during the flowering period.

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Table 1. The effect of cotton lines on verticillium wilt incidence and reflectance in the green band.

		# of plants/plot with Verticillium wilt		
Cotton line	**# of plots**	**19 July**	**18 August(rank)**	**Reflectance in the green band and rank ()**
GM-20	12	9.9	18.6 (1)	134 (18.5)
GM-34	12	8.3	14.5 (5)	143 (10.5)
GM-22	12	6.1	15.7 (2.5)	129 (24)
Lankart	189	5.9	12.3 (8)	146 (7.5)
GM-31	12	5.8	15.7 (2.5)	149 (4)
GM-29	12	5.7	12.5 (6.5)	142 (12.5)
GM-33	12	4.8	12.3 (9)	132 (20)
GM-40	12	4.8	12.5 (6.5)	152 (2)
GM-35	12	4.6	7.7 (14)	134 (18.5)
GM-19	12	4.4	14.7 (4)	129 (24)
GM-24	12	4.3	11.8 (10)	146 (7.5)
GM-28	12	4.1	6.0 (16.5)	130 (21.5)
GM-27	12	3.7	11 (11)	142 (12.5)
GM-38	12	3.3	7.8 (13)	155 (1)
GM-42	12	2.9	10.3 (12)	147 (6)
GM-39	12	2.4	6.2 (15)	148 (5)
GM-26	12	2.4	5.0 (18.5)	137 (15.5)
GM-21	12	2.3	5.0 (18.5)	130 (21.5)
GM-25	12	2.2	3.4 (23)	135 (17)
PM147	85	2.2	6.0 (16.5)	150 (3)
GM-23	12	1.8	4.2 (21)	129 (24)
GM-41	11	1.6	4.9 (20)	144 (9)
GM-32	11	1.4	3.7 (22)	143 (10.5)
GM-30	8	1.1	3.3 (24)	141 (14)
GM-37	11	0.6	1.9 (25)	137 (15.5)

Lankart is Lankart 57 and PM147 is Paymaster 147

Table 2. Cotton lines which demonstrated a significant (P=0.05) relationship between wilt ratings and reflectance for one or more bands or band combinations.

Cotton line	**Band or band combinations that were fitted to the regression model**	**R^2**	**Prob. > F**
July wilt data			
GM-22	Green	0.41	0.02
GM-25	NIR/Red	0.62	0.002
GM-28	Red/Green	0.43	0.02
GM-29	NIR/Green	0.37	0.03
GM-33	NIR/Green; NIR/Red	0.66	0.02; 0.04
GM-34	NIR; Green	0.51	0.01; 0.04
GM-37	Red	0.58	0.01
Lankart	Green; NIR/Red	0.10	0.001; 0.02
August wilt data			
GM-22	Green	0.41	0.02
GM-29	NIR/Green; NIR/Red	0.61	0.04; 0.04
GM-39	Red/Green	0.61	0.002
Lankart	NIR/Green	0.05	0.001

Lankart is Lankart 57
NIR= near-infrared.

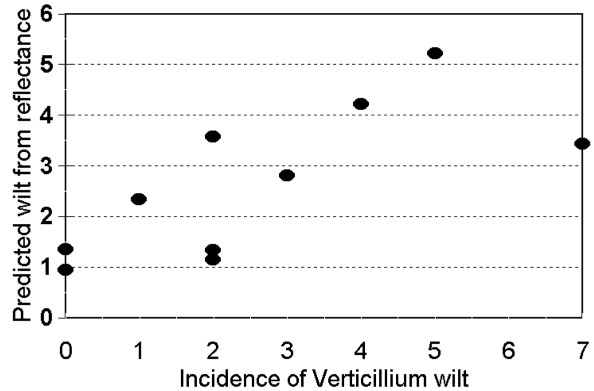

Figure 1. The relationship between actual wilt incidence in a plot and predicted wilt incidence as a function of reflectance from an infrared color photograph for cotton line, GM-25.

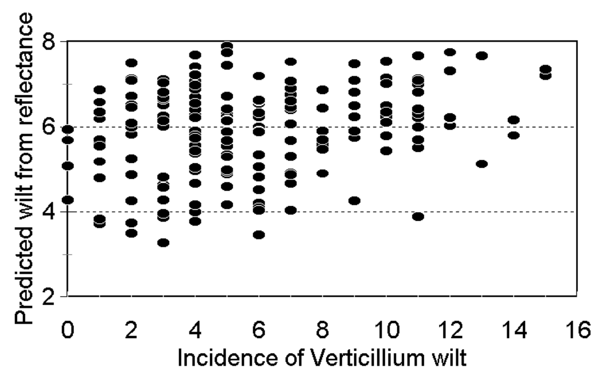

Figure 2. The relationship between actual wilt incidence in a plot and predicted wilt incidence as a function of reflectance from an infrared color photograph for cotton cultivar, Lankard.