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Cultivar, irrigation, and soil contribution to the enhancement of Verticillium wilt disease in cotton

C.J. Land [a], K.S. Lawrence [a,*], C.H. Burmester [b], B. Meyer [c]

[a] Department of Entomology and Plant Pathology, Auburn University, Auburn, AL 36849, United States
[b] Crops, Soils, and Environmental Sciences, Auburn University, Auburn, AL 36849, United States
[c] AGRI-AFC, Decatur, AL 35601, United States

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ABSTRACT

Verticillium wilt of cotton is incited by *Verticillium dahliae* Kleb., which colonizes the vascular cylinder of the plant resulting in defoliation, stunting, and yield loss. This project investigated cultivar selection and soil type predisposition for management of this disease to preserve cotton yields. All cotton cultivars planted in this study were susceptible to Verticillium wilt infection and all had some amount of vascular discoloration observed. However, there were varying ranges of tolerance found among different cultivars. ST 4747 GLB2 appeared to the consistently the most tolerant of the cultivars planted and exhibited the highest yields consistently over different seasons. Verticillium wilt disease incidence and severity were increased with irrigation in the controlled microplot test over six soil types. Verticillium wilt symptom severity was greater in the Decatur silt loam and Houston clay soils which have the highest clay and silt content.

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1. Introduction

Losses from Verticillium wilt for the U.S., according to disease loss estimates, between the years of 1990–2014 are approximately 480 million bales (Disease database; Lawrence et al., 2016). Verticillium wilt most often occurs in the northern regions of Alabama and causes a decline in plant health and yield. Two *Verticillium* species have been found in cotton in Alabama, *V. albo-atrum* Reinke and Berthold (Palmateer et al., 2004) and *V. dahliae* Kleb., (Land et al., 2016). The primary causal agent of Verticillium wilt in cotton is *V. dahliae;* which is the only *Verticillium* sp. shown to cause wilt in cotton under field conditions (Bell, 1992). *Verticillium dahliae* first colonizes the root and then moves upward through the vascular system of the plant (El-Zik, 1985). Wilt symptoms may appear in young plants to disappear in mid-summer as temperatures increase then reappear when plants are fruiting (Bell, 1992). Typically, symptoms include stunting, lack of lateral growth, and decreases in yield, fiber quality and seed quality (Bugbee and Sappenfield, 1970; Wheeler et al., 2012; Xiao and Subbarao, 2000). Defoliation is thought to lead to yield reductions resulting from the lack of photosynthetic activity.

This disease was first observed on Upland cotton in Virginia in 1918 by Carpenter (1914). Of the approximately ten million acres of cotton grown in the U.S. today, 97% is planted to Upland cotton (National Agricultural Statistics Service, 1995) and Verticillium wilt is present in most of the cotton belt region of the U.S. This project focuses on the serious problem of Verticillium wilt on cotton (*Gossypium hirsutum* L.). Temperature and moisture are the two most important environmental factors that contribute to the spread and proliferation of *Verticillium dahliae* (Arbogast et al., 1999). Moist soils from irrigation enhance the incidence of Verticillium wilt in cotton. As the timing intervals of watering regiments increase so do the disease incidences of cotton plants (Schneider, 1948). Irrigation cools the soil thereby enhancing pathogen survival and increasing infection rates (Karaca et al., 1971). Microsclerotia germination increases with periodical wetting and drying of the soil (Farley et al., 1971). Moisture is also an important component for conidia dispersal, along with root infection and colonization. Infected plants are more susceptible to water stress due to the presence of *V. dahliae* hyphae in the xylem inhibiting water flow (Xiao and

* Corresponding author.
E-mail address: lawrekk@auburn.edu (K.S. Lawrence).

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Subbarao, 2000). Plants also experience stomatal closure causing the plant to become deficient in the accumulation of carbon dioxide, an important component for photosynthesis (Bowden et al., 1990). Drought-stressed cotton typically suffers less infection by *V. dahliae* compared with irrigated cotton (Kadolph and Langfold, 1998). It is unknown if this relationship is due to the moisture contributing to the level of humidity or if it is related to irrigated-related cooling of the soil. The critical point of disease development late in the production season occurs when soil temperatures decline and plants begin to mature (Bell, 1992).

Verticillium dahliae over winters in the soil thus the soil moisture and temperatures have a large impact on how pathogen virulence. *V. dahliae* and *V. albo-atrum* are both not very dynamic inhabitants and cannot grow more than a few millimeters through the soil before encountering and infecting a host (DeVay and Pullman, 1984). Disease incidence is higher on heavier soils with higher clay and silt content and may be linked to the lower temperatures and higher moisture levels. However, elevated levels of Verticillium wilt have also been noted on intensively irrigated cotton on sandy soils (Rudolph, 1931).

The overall goal of this study is to identify cultivars for best management and assess risk potentials for certain environmental and cultural practices on Verticillium wilt on cotton. Specifically, our objectives were: 1) to evaluate cotton cultivars for resistance or tolerance to Verticillium wilt in the field and 2) to determine if soil types and irrigation were conducive to Verticillium wilt disease incidence and severity.

2. Material and methods

2.1. Field trial design and data collection

In 2013, 2014, and 2015 cotton cultivars were planted in commercial cotton fields naturally infested with *V. dahliae* to determine cultivar disease response to Verticillium wilt under field conditions. Field locations were selected based on severity of Verticillium wilt and the wiliness of growers to participate in this research. In the 2013 field trial, 13 cultivars were planted in Colbert County Alabama (34°49′16.8″N 87°59′37.1″W) in a Decatur silt loam (Fine, kaolinitic, thermic Rhodic Paleudults). Seed of adapted cultivars and experimental lines expected to be released in the next season were provided by AGRI AFC, LLC of Land O'Lakes (Decatur, AL). Cotton cultivars and lines were planted in a strip plot design with four replications with plots being 6 rows with a 1.02 m row spacing by 152 m plots evenly spaced throughout the field. The irrigation scheduling in this field was determined using a balance method (Perry and Barnes, 2012) that was derived from the estimated water use, rainfall, and water holding capacity of the soil. During the 2013 growing season, timely rainfall was received with 283 mm in the critical growth stages requiring five irrigation events. These irrigation events were during mid-bloom stage through late bloom stage and boll maturity to aid with boll fill. A center pivot was used to apply 26 mm/ha of water in each of the irrigation event for a total of 130 mm. In 2014 and 2015, the trials were located in Madison County (34°51′10.5″N 86°31′28.9″W) in a field with Decatur silt loam and Dewey silt loam (Fine, kaolinitic, thermic Typic Paleudults) soils. Eighteen cultivars and lines were again planted in a strip plot design with plots being 6 rows wide, 152 m in length on a 1.02 m row spacing and replicated four times. The entire fields were drip irrigated as needed in both years scheduling irrigation again using the balance method (Perry and Barnes, 2012). In 2014 and 2015 growing seasons the timely rainfall was received (156 and 117 mm) requiring six and eight irrigation events, respectively. Drip irrigation applied 10 mm/ha of water in each application during mid-bloom stage through late bloom stage and boll maturity for a total of 60 and 80 mm of irrigation in 2014 and 2015. Parameters measured included disease incidence, severity, and yield were evaluated from a randomly selected 3 m section of the third row in each plot. Verticillium wilt disease severity ratings were conducted near cotton plant maturity. Foliar symptoms of Verticillium wilt were evaluated on a scale from 1 to 5 with 1 = no foliar wilting, 2 = interveinal chlorosis and necrosis of the leaves, 3 = interveinal chlorosis and necrosis of the leaves with 10–30% of the plant defoliated, 4 = interveinal chlorosis and necrosis of the leaves with 40–60% of the plant defoliated, and 5 = 70–100% defoliation. Plants were individually rated and averaged for a total plot disease severity rating. Vascular discoloration was determined by cutting the plant stem longitudinally exposing the vascular cylinder and the number of plants with a discolored vascular cylinder indicated the percent incidence (Fig. 1). Stem section with discoloration were collected for fungal isolation to confirm Verticillium spp. present. Yields were handpicked at the end of the season from a 3 m section equaling 18 to 25 plants, adjacent to the area evaluated for disease incidence and severity in each plot. A one-liter volume subsample of the seed cotton from each plot was weighed and ginned to determine lint percentages.

2.2. Soil and irrigation microplot trial

2.2.1. Soil and irrigation trial design

The microplot trial was conducted to determine what level of

Fig. 1. Vascular discoloration of the cotton (top) observed with Verticillium wilt foliar symptoms (bottom).

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