

# EFFECT OF COTTON PATHOGENS ON DISEASE SYMPTOMS AND YIELD OF COTTON VARIETIES IN LARGE PLOT FIELD TRIALS

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## Abstract

Large plot variety tests were conducted at seven sites with histories of soil-borne diseases in the High Plains of Texas. In a site which was infested with *Phymatotrichum omnivorum* (cotton root rot), no varietal differences occurred for the incidence of dead plants, and the highest yielding varieties were Tamcot 'Sphinx' and All-Tex 'Atlas'. In a site with Fusarium wilt and *Meloidogyne incognita* (root-knot nematode), yield was correlated with an interaction between root-knot nematode density and incidence of wilt. The highest yielding variety was Paymaster 'HS26'. In a site with Fusarium wilt, root-knot nematode, and seedling disease (*Rhizoctonia solani* and *Pythium*), yield was correlated with all three factors, including an interaction between seedling disease and root-knot nematode. The highest yielding varieties were Stoneville 887 and Paymaster '330'. Verticillium wilt was not a serious problem in 1997, and in one of three fields selected for this disease, wilt was correlated with yield. All-Tex Atlas was either the first or second ranked variety in all three of these wilt sites. In a site where no disease occurred, no yield differences in the varieties were seen. Varietal tolerance or resistance to root-knot nematode, Fusarium and Verticillium wilts, and seedling diseases was observed.

## Introduction

Important soil-borne diseases of cotton in the U.S. which have no pesticides currently labeled for control include wilt diseases (*Verticillium dahliae* and *Fusarium oxysporum* pv. *vasinfectum*) and cotton root rot (*Phymatotrichum omnivorum*). Other soil-borne diseases which can be only partially controlled by pesticides includes nematodes (root-knot [*Meloidogyne incognita*], reniform [*Rotylenchulus reniformis*] and Columbia lance [*Hoplolaimus columbus*]), and seedling disease fungi (*Rhizoctonia solani*, *Pythium* spp., *Fusarium solani* and *Thielaviopsis basicola*). These soil-borne pathogens are difficult to manage to the degree where yields are not negatively impacted.

Cotton cultivars can vary in their tolerance or resistance to these pathogens. Resistance refers to the ability of the plant to limit reproduction of the pathogen, for example with *V. dahliae*, the amount of fungal propagules in resistant varieties was less than the amount in susceptible varieties

(Davis et al., 1983; Garas et al., 1986). Tolerance refers to the ability of the plant to yield in the presence of a pathogen, even though that pathogen is capable of reproducing and spreading on the plant. Varieties with resistance or tolerance to Verticillium wilt, Fusarium wilt, and root-knot nematode can positively impact yields (Bell, 1992; Johnson & Parmer, 1985; Kappelman, 1980). The objectives of this study were to determine if varieties commonly grown in the High Plains of Texas would be affected to a different degree by soil-borne plant pathogens; if disease symptoms could be correlated to yield; and if yield differences would be found among different varieties in disease situations.

## Materials and Methods

Cotton growing areas in the High Plains of Texas were divided into three regions, labeled northern, middle and southern. Two sites were chosen in the northern region, three sites in the middle region and two sites in the southern region for large plot variety tests. Three varieties were tested at all sites (All-Tex 'Atlas', Paymaster 'HS26' and 'Tejas'). In addition, in the northern sites varieties tested were: Associated Farmers Delinting (AFD) '2525', All-Tex 'Excess', Holland '186', Paymaster '145' and '183'. In the middle sites, varieties tested were: AFD 'Explorer', Holland 186, Paymaster '280' and '300', SeedCo 9023, and in one location (Hockley co.), Stoneville '887'. In the southern regions, varieties tested were Holland '338', Paymaster 'HS200', Ranger 'Whitegold', SeedCo 9023, and Tamcot 'Sphinx'. Untreated seed was obtained for all varieties except Stoneville 887. The seed was treated at a delinting plant with Baytan 30 + Apron Fl + Captan 4000 + Thiram 42S at 0.5 + 0.75 + 1 + 1 oz/100 lb seed, respectively.

A northern site in Swisher co., had six row plots with 30" centers, row length of 1358 ft, and three replications. This site was selected for seedling disease potential and was planted on 5/28/97. The field was row watered and harvested on 12/16/97. A northern site in Parmer co., had three row plots with 40" centers, row length of 1552 ft, and four replications. This site was selected for Verticillium wilt potential and was row watered. The test was planted on 5/13/97 and harvested on 11/31/97. A middle region site in Hockley co. had four row plots with 40" centers, row length of 1320 ft. and four replications. This field was selected for Fusarium wilt, root-knot nematode (*Meloidogyne incognita*) and seedling disease (*Rhizoctonia solani* and *Pythium*). The test was planted on 5/7/97. There was severe seedling disease, so that the farmer eventually replanted the bottom half of the entire test area. The top 600 ft of the rows also had seedling disease though not as severe, and this was the area harvested on 11/18/97. This field was irrigated with a center pivot. A middle region site in Floyd co. was selected for Verticillium wilt, and had four row plots with 40" centers, 1320 ft. in length, and four replications. The field was row watered, and was planted on 5/26/97 and harvested on 11/22/97. The third middle region site was in Crosby co.

and was selected for Verticillium wilt. Plots were eight rows wide with 40" centers, 1320 ft long, with four replications. Planting was on 5/23/97 and harvest was on 11/3/97. A southern region site was in Gaines co. which was chosen for Fusarium wilt and root-knot nematode. Plots were four rows wide with 40" centers, and variable row length ranging from 1296 to 1905 ft, and with four replications. Irrigation was with a center pivot, however, during August and September water became limiting due to mechanical problems with the pump. Planting was on 5/6/97 and harvest on 10/6/97. The last site was in the southern region in Mitchell co. and was selected due to its history of cotton root rot (*Phymatotrichum omnivorum*). Plots were on 40" centers with a skip row between every two rows, and length varied from 2814 to 3217 ft. There were three replications. This was a dryland field and planting was on 6/30/97 and harvest on 11/25/97.

All sites were rated for stand at 21 days after planting by measuring out three 20 ft areas in each plot and counting the stand. Then six plants were dug from the area (18 plants/plot) and rated for severity of *Rhizoctonia* type lesions and percent root necrosis. Sites were visited on approximately two week intervals until October to rate for disease symptoms. Wilts and cotton root rot were rated by counting the number of plants with wilt symptoms until 50 were seen, and then measuring the distance in each plot to obtain that number. To measure root-knot nematode density, composite soil samples were taken in early September from each plot, consisting of 20 cores taken over 400 ft at a depth of 4-8" near the tap root. These samples were assayed for root-knot nematode eggs by chlorox extraction (Hussey & Barker, 1973) and second-stage juveniles by a modified baermann funnel method (Thistlethwayte, 1960). All fields were also sampled (one composite soil sample/replication) and assayed for *Verticillium dahliae* (Wheeler & Rowe, 1995).

Variety tests were all conducted in randomized complete block designs, and yields were compared with analysis of variance. In addition, disease data across all varieties was regressed against yield. If there was more than one type of disease in a site, then all disease types and their interactions were tested in regression analysis using the stepwise procedure of SAS. Within a region (northern, middle, southern), varieties were tested between sites as well as among a site. If there was an interaction between sites, then only the within site analysis was conducted. In the case of the middle region, there was no interaction between sites, so an additional analysis of the three sites combined is presented.

## Results

Swisher co. was the site farthest north in these tests. Challenges to production in this area are limited heat units and seedling disease. No seedling disease was observed at this site (probably due to the late planting date), but limited

heat units probably impacted yields. Plant stand at 21 days after planting ranged from 2.5 to 3.2 plants/ft and root necrosis averaged < 10% across all varieties. Soil samples assayed for *V. dahliae* averaged 1 cfu/cm<sup>3</sup> soil. There were no differences between varieties, with respect to yield (average yield was 725 lbs of lint/acre).

The second site in the northern area was in Parmer co. This site was selected for wilt, however, plant senescence was not observed until mid September. There was no correlation between the number of senescent plants/ft of row and yield. There were varietal differences between the number of senescent plants/ft row (Table 1). In general, the shorter season varieties (All-Tex Excess, Paymaster 183, Holland 186, and Paymaster 145) had more senescence in mid September than the longer season varieties (All-Tex Atlas, Paymaster Tejas, and Paymaster HS26). The exception was AFD 2525 which is considered a shorter season variety, but had a senescence reading similar to the longer season varieties (Table 1). *Verticillium dahliae* was not found in any of the soil samples taken from this site, so the actual type of wilt at this site is not known. Seedling disease was present at low levels, with some root necrosis (caused by *Thielaviopsis basicola*) and stand differences between varieties (Table 1). Paymaster HS26 had higher root necrosis (17 %) and a worse stand (2.8 plants/ft) than most other varieties (Table 1). All-Tex Excess and Atlas had significantly ( $P=0.05$ ) higher yields than other varieties at this site, while Paymaster HS26 and Paymaster 145 had the lowest yields (Table 1).

Soil samples from the site in Floyd co. averaged 25 cfu of *Verticillium dahliae*/cm<sup>3</sup> soil. Plants did not show signs of senescence until mid September. Yield was correlated with the number of senescent plants/ft row: Yield (lbs of lint/acre) = 642 - 35.1(W), SE=12.9, R<sup>2</sup>=0.20, where W is the number of senescent plants/ft row. Holland 186 had significantly more plants with wilt symptoms than AFD Explorer, Paymaster HS26, and Paymaster Tejas (Table 2). Plant stand at 21 days after planting ranged from 4.4 to 5.6 plants/ft and root necrosis (caused by *Thielaviopsis basicola*) averaged 15-22 % across the different varieties (Table 2). Yield was significantly higher for All-Tex Atlas than any other variety (Table 2). Paymaster HS26 yielded less than any variety except Holland 186 (Table 2).

Soil samples from the site in Crosby co. averaged 20 cfu of *V. dahliae*/cm<sup>3</sup> soil. Wilt symptoms were abundant by the middle of August. This site was also under considerable water stress, and there was variation in the amount of water being applied to different parts of the field. Wilt was not correlated to yield, nor were there differences between varieties in the incidence of wilt. The incidence of wilt did not increase between August and September. Stands were all uniform at 5 plants/ft and root necrosis was < 10% for all varieties. Yield was significantly higher for All-Tex Atlas than all other varieties except AFD Explorer (Table 3).

The Hockley co. site had high levels of seedling disease caused by *Rhizoctonia solani* and *Pythium*, high levels of *Meloidogyne incognita*, and some Fusarium wilt. Plant stand, root-knot nematode density and incidence of plants with wilt all impacted yield:

Yield (lbs of lint/acre) = 374 - 231(W) + 111(S) - 0.0035(S)(RK), where W is the number of plants with wilt symptoms/ft row, S is the stand at 21 days after planting/ft row, and RK is the density of root-knot nematode/500 cm<sup>3</sup> soil taken in September. This model had an R<sup>2</sup> = 0.37. No *V. dahliae* propagules were recovered in soil samples, indicating that Fusarium wilt was the cause of wilt symptoms. Incidence of Fusarium wilt was highest in Paymaster 280 (0.7 plants/ft) and Holland 186 (0.5 plants/ft) and lowest in Stoneville 887 (0.08 plants/ft), All-Tex Atlas (0.28 plants/ft) and AFD Explorer (0.32 plants/ft) (Table 4). Root-knot nematode population density in September was highest in Holland 186 (12,200 RK/500 cm<sup>3</sup> soil) and All-Tex Atlas (10,015 RK/500 cm<sup>3</sup> soil) and lowest in Stoneville 887 (880 RK/500 cm<sup>3</sup> soil) (Table 4). Stoneville 887 was included in this site because of the known severity of the root-knot nematode problem. There was approximately 3.5 inches of rain right after planting, which most likely washed out the Temik 15G which was applied at planting. The varieties had no protection against root-knot nematode other than resistance or tolerance. Stands were highest for Holland 186 (3.3 plants/ft) and Paymaster 330 (2.6 plants/ft) and lowest for Paymaster HS26 (1.5 plants/ft), SeedCo 9023 (1.6 plants/ft), and All-Tex Atlas (1.5 plants/ft) (Table 4). Root necrosis was higher for Stoneville 887 (29%) than all other varieties except Paymaster HS26 (20 %) and All-Tex Atlas (19 %) (Table 4). Yields were higher for Stoneville 887 (573 lbs/acre) and Paymaster 330 (534 lbs/acre) than for Seedco 9023 (391 lbs/acre), Paymaster 280 (378 lbs/acre) and Paymaster HS26 (356 lbs/acre) (Table 4).

The Gaines co. site was selected for Fusarium wilt and root-knot nematode. Propagules of *V. dahliae* averaged 1 cfu/cm<sup>3</sup> soil, indicating that Fusarium wilt was the primary type of wilt. Incidence of wilt and the interaction between wilt and root-knot nematode were significantly correlated with yields, as described by the equation:

$$\text{Yield (lbs of lint/acre)} = 615 + 371(W) - 2(W)(RK), R^2 = 0.21.$$

Incidence of wilt was significantly higher for Tamcot Sphinx and Paymaster Tejas than for all other varieties. Severity of wilt, though not measured, was clearly higher for Sphinx than all other varieties. Root-knot nematode density in September was highest for Paymaster HS200 (44,650 RK/500 cm<sup>3</sup> soil) and Tamcot Sphinx (18,100 RK/500 cm<sup>3</sup> soil) and lowest for Paymaster HS26 (6,855 RK/500 cm<sup>3</sup> soil) and Paymaster Tejas (9,670 RK/500 cm<sup>3</sup> soil) (Table 5). Stands at 21 days after planting ranged from 2.9 to 3.7 plants/ft and root necrosis was < 10 % for all

varieties. Yields were highest for Paymaster HS26 and lowest for Tamcot Sphinx and Paymaster HS200 (Table 5).

Cotton root rot was the disease encountered at the Mitchell co. site. All varieties tested were susceptible to this disease, and dead areas of the rows ranged from 33 to 68 %. The rows which were terraced appeared to show a reduction in root rot compared to those which were not terraced, though, there was not sufficient replication of this phenomena within a variety to test the hypothesis. Plant stand at 21 days after planting ranged from 2.5 to 3.0 plants/ft and root necrosis averaged < 10% across all varieties. Yield was not correlated with the percent of a plot affected by cotton root rot. Tamcot Sphinx had a significantly higher yield (420 lbs/acre) than Paymaster HS26 (302 lbs/acre) and Paymaster HS200 (299 lbs/acre) (Table 6).

In the northern and southern regions, there was a significant interaction between variety and site. In the middle region, there was no interaction between variety and site, indicating that varietal differences overall for these three sites can be determined. The top yielding variety in the middle part of the High Plains was All-Tex Atlas (619 lbs of lint/acre) and the lowest yielding variety was SeedCo 9023 (452 lbs of lint/acre) (Table 7).

### Discussion

Seedling disease in Hockley co., cotton root rot in Mitchell co., and root-knot nematode and Fusarium wilt in Gaines co. were all substantial in 1997. Varietal yield differences seen in these sites are all at least partially attributed to the impact of the diseases. Unfortunately, Verticillium wilt was not severe in any of the sites. Even though there was a correlations between Verticillium wilt and yield (Floyd co.), it is important not to draw conclusions from such a light case of wilt. Varieties may perform differently under more severe Verticillium wilt. In conclusion, varieties can be chosen which minimize the impact of certain soil-borne diseases. However, no highly resistant varieties were tested with the exception of Stoneville 887 to root-knot nematode, and losses due to soilborne diseases will still be costly, regardless of varietal choice.

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Table 1. Affect of varieties on yield, wilt, root necrosis, and plant stand in Parmer Co., TX.

Variety	Yield <sup>1</sup>	Wilt <sup>2</sup>	% Root necrosis	Stand <sup>3</sup>
All-Tex Excess	1022 a <sup>4</sup>	2.7 a	8 b	4.9 bc
All-Tex Atlas	958 b	1.6 c	11 ab	4.9 bc
Paymaster 183	893 c	2.8 a	8 b	5.6 a
Paymaster Tejas	865 c	1.6 c	8b	5.8 a
Holland 186	846 c	2.6 a	10 ab	4.6 c
AFD 2525	843 c	1.5 c	10 ab	5.1 b
Paymaster HS26	751 d	1.1 d	17 a	2.8 d
Paymaster 145	724 d	2.2 b	4 b	5.5 a

<sup>1</sup>lbs of lint/acre

<sup>2</sup>Number of plants per foot exhibiting senescence

<sup>3</sup>Number of plants per foot at 21 days after planting

<sup>4</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .

Table 2. Affect of varieties on yield and Verticillium wilt in Floyd Co., TX.

Variety	Yield <sup>1</sup>	Wilt <sup>2</sup>
All-Tex Atlas	725 a <sup>3</sup>	1.9 ab
Paymaster Tejas	631 b	1.2 b
Paymaster 280	610 b	1.6 ab
Paymaster HS26	596 b	1.1 b
AFD Explorer	581 b	1.2 b
Paymaster 330	561 b	1.4 ab
Holland 186	542 bc	2.3 a
SeedCo 9023	459 c	2.1 ab

<sup>1</sup>lbs of lint/acre

<sup>2</sup>Number of plants per foot exhibiting senescence

<sup>3</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .

Table 3. Affect of varieties on yield and Verticillium wilt in Crosby Co., TX.

Variety	Yield <sup>1</sup>	Wilt in <sup>2</sup> August	Wilt in September
All-Tex Atlas	636 a <sup>3</sup>	0.38	0.35
AFD Explorer	581 ab	0.43	0.40
Paymaster HS26	512 bc	0.39	0.44
SeedCo 9023	505 bc	0.38	0.40
Paymaster 330	490 bc	0.33	0.37
Holland 186	460 c	0.32	0.48
Paymaster Tejas	457 c	0.38	0.35
Paymaster 280	412 c	0.41	0.42

<sup>1</sup>lbs of lint/acre

<sup>2</sup>Number of plants per foot exhibiting senescence

<sup>3</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .

Table 4. Affect of varieties on yield, root-knot nematode (RK) density, Fusarium wilt incidence, and stand due to seedling disease in Hockley Co.

Variety	Yield <sup>1</sup>	RK/500 cm <sup>3</sup>	Wilt <sup>2</sup>	Stand <sup>3</sup>	Root Nec. <sup>4</sup>
Stoneville 887	573 a <sup>5</sup>	880 c	0.08 e	1.7 b-d	29 a
Paymaster 330	534 ab	5,575 a-c	0.47 bc	2.6 ab	17 b
Paymaster	512 a-c	5,955 a-c	0.49 bc	2.4 a-c	18 b
All-Tex Atlas	497 a-d	10,015 ab	0.28 d	1.5 cd	19 ab
Holland 186	454 a-e	12,200 a	0.50 ab	3.3 a	17 b
AFD Explorer	440 b-e	3,210 bc	0.32 d	2.0 b-d	18 b
SeedCo 9023	391 c-e	5,740 a-c	0.42 b-d	1.6 cd	16 b
Paymaster 280	378 de	8,295 a-c	0.70 a	1.8 b-d	14 b
Paymaster HS26	356 e	5,195 a-c	0.39 cd	1.5 d	20 ab

<sup>1</sup>lbs of lint/acre

<sup>2</sup>Number of plants per foot exhibiting senescence

<sup>3</sup>Number of plants per foot at 21 days after planting

<sup>4</sup>Percent of the root with necrosis at 21 days after planting

<sup>5</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .

Table 5. Affect of varieties on yield, Fusarium wilt and root-knot nematode (RK) density in Gaines Co.

Variety	Yield <sup>1</sup>	RK/500 cc soil	Wilt <sup>2</sup>
Paymaster HS26	693 a <sup>3</sup>	6,855 d	0.25 bc
Paymaster Tejas	674 ab	9,670 cd	0.50 a
Ranger Whitegold	670 ab	13,925 bc	0.30 b
SeedCo 9023	665 a-c	17,095 b	0.25 bc
Holland 338	650 a-c	11,815 b-d	0.25 bc
All-Tex Atlas	631 b-d	11,961 b-d	0.20 c
Tamcot Sphinx	616 cd	18,100 b	0.50 a
Paymaster HS200	595 d	44,650 a	0.20 c

<sup>1</sup>lbs of lint/acre

<sup>2</sup>Number of plants per foot exhibiting senescence

<sup>3</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .

Table 6. Affect of varieties on yield and cotton root rot (*Phymatotrichum omnivorum*) in Mitchell Co.

Variety	Yield <sup>1</sup>	Average % of Plot with <i>P.</i> <i>omnivorum</i>	% of plots not terraced with <i>P.</i> <i>omnivorum</i>
Tamcot Sphinx	420 a <sup>2</sup>	36	45
All-Tex Atlas	380 a	44	no terraces
SeedCo 9023	359 ab	30	33
Holland 338	356 ab	40	no terraces
Paymaster Tejas	354 ab	50	no terraces
Ranger	351 ab	56	no terraces
Whitegold			
Paymaster HS26	302 b	54	no terraces
Paymaster HS200	299 b	40	68

<sup>1</sup>lbs of lint/acre

<sup>2</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .

Table 7. Affect of varieties on yield across three sites with different stresses in 1997.

Variety	Yield (lbs of lint/acre)
All-Tex Atlas	619 a <sup>1</sup>
AFD Explorer	534 b
Paymaster Tejas	533 b
Paymaster 330	528 bc
Paymaster HS26	488 bc
Holland 186	486 bc
Paymaster 280	467 bc
SeedCo 9023	452 c

<sup>1</sup>Different letters indicate a significant difference between varieties using a Waller Duncan k-ratio t-test with  $P=0.05$ .