Effect of Phymatotrichum Root Rot on Yield and Seed and Lint Quality in *Gossypium hirsutum* and *G. barbadense*

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ABSTRACT

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Yields of field-grown, *Phymatotrichum*-infected, upland cotton (*Gossypium hirsutum*) and Pima cotton (*G. barbadense*) were reduced 10 and 13%, respectively, compared with healthy plants. Losses were greatest (0.46 bales per infested hectare) in upland cotton grown in monoculture and less (0.26 bales per infested hectare) when grown in rotation with barley, wheat, sorghum, and sudangrass. Yield reduction in infected upland cotton had two components: fewer bolls set and less lint per mature boll. Yield losses in Pima cotton were associated with lower total boll set. Fibers from infected upland cotton plants were significantly shorter, less uniform, and finer than fibers from healthy plants. Fiber quality in Pima cotton was adequate in spite of root rot. Seed quality and germinability were reduced in seeds collected from infected plants of both varieties.

Additional key words: cotton root rot, crop loss assessment

Phymatotrichum root rot, caused by the soilborne fungus *Phymatotrichum omnivorum* (Shear) Dug., is a common disease of both upland cotton (*Gossypium hirsutum* L.) and Pima cotton (*G. barbadense* L.). The first symptom is plant wilting, which occurs just before or during early flowering. Rapid collapse and plant death normally follows within 72 hr. Effects of infection on fiber quality have been studied by Stroman et al (7) and Taubenhaus and Ezekiel (8). Stroman et al (7) primarily measured fiber width and concluded that fiber from infected cotton plants was thicker than that from healthy plants. Taubenhaus and Ezekiel (8) found no significant difference in fiber length but reported an average seed weight reduction of 28% associated with infected plants.

Modern fiber quality analysis has become more elaborate and sophisticated. The price and marketability of cotton is based on fiber length and strength, thickness, and uniformity of fiber lengths in the bale. These tests establish the dollar value of the fiber and the applicability of the fiber for certain types of textile processing.

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During harvest, cotton from healthy and *Phymatotrichum*-infected plants are mixed. These fibers are further homogenized during ginning and baling. To assess crop losses attributable to root rot in cotton accurately, lint yield and fiber and seed quality must be considered. Thus, studies were initiated during 1980 and large-scale surveys made during the summer of 1981 near Marana, AZ. In this area, upland and Pima cotton varieties are normally planted in April and harvested in the fall. Root rot symptoms appear in July and August.

The objectives of these studies were 1) to collect field data to determine lint yield and fiber quality loss per hectare, 2) to use data from aerial infrared (IR) photography to establish the total number of hectares affected by root rot, and 3) to combine these two data sets to make loss estimates that take into account loss per hectare, hectares affected, and fiber quality and marketability. A preliminary report has been published (3).

MATERIALS AND METHODS

Field surveys. Thirty-seven fields of upland cotton (7,597.8 ha) and nine fields of Pima cotton (1,626.9 ha) were surveyed from the ground. Plant density per hectare and boll density per plant were determined along a randomly selected 1.98-m length of rows (0.02 ha). Four locations for both healthy and diseased cotton were assessed in each field. Thirty open, fully fluffed cotton bolls were collected from healthy and diseased cotton plants in each field and returned to the laboratory for fiber quality and yield assessment.

Cropping histories compiled through grower interviews and previous research records were used to evaluate the effect of crop rotation on yield loss. Of the upland fields, 27 were in cotton monocultures, 5 in cotton/small-grain rotations, and 1 in lettuce/small-grain/cotton rotation. Small-grain rotations consisted of wheat or barley grown as winter crops or sorghum or sudangrass grown during the summer. No cropping records could be found for four of the fields. Rotation histories were compiled for seven of the nine Pima cotton fields studied.

Aerial photography and image analysis. On 6 October 1981, the Marana agricultural area in Pima County, AZ, was photographed by personnel from the USDA Fruit Protection and Production Laboratory, Weslaco, TX. One series of 81 frames (23 × 23 cm) was taken from 3,050 m above ground level, covering 275 km^2. A second series of 93 frames was taken from 2,035 m above ground level, covering 85 km^2.

Each field studied was outlined on base maps. For each field, the total number of hectares was recorded and an identification number was assigned. A transparent acetate overlay was prepared using the 1981 aerial photographs for each of the fields surveyed. Darkened areas on the overlays represented areas where plants were infected with *P. omnivorum*. Overlays were analyzed with a scanning densitometer (Model 704 Density Profile Display, Spatial Data Systems, Inc., Goleta, CA 93017) to determine the proportion of each field infested with *P. omnivorum*. This percentage infestation value was then combined with the hectares reported on the base maps to express the area of infestation in hectares.

Estimated actual yields, expressed as bales per hectare, were calculated using the following equation: [(plants/ha healthy) (bolls/healthy plant) (g lint/boll) (total ha healthy) (454 g/lb)] ÷ 480 lb lint/bale + [(plants/ha infested) (bolls/infected plant) (g lint/boll) (total ha infested) (454 g/lb)] ÷ 480 lb lint/bale = actual yield (bales/ha). Estimated optimal yields were calculated using the formula: [(plants/ha healthy) (bolls/healthy plant) (g lint/boll) (total ha in field) (454 g/lb)] ÷ 480 lb lint/bale = optimal yield (bales/ha).

Fiber quality testing. Standard procedures for fiber quality analysis were followed. Each lint sample contained 30 mature, fully fluffed cotton bolls. Two samples were tested per field, one collected from healthy cotton and the other from *Phymatotrichum*-infected plants. Fiber analysis included 1) weight of seed cotton, the total weight of nonginned lint that still contained seeds; 2) percent lint turnout, the weight of cotton fiber divided by the weight of seed expressed as a percentage; 3) seed index, the weight of 100 acid-delinted seeds; 4) 2.5% span length (M), the length that will be spanned by the longest 2.5% of the fibers when they are parallel and distributed randomly; 5) 50% span length (UHM), the fiber length spanned by the longest 50% of the fibers when they are parallel and distributed randomly (both the 2.5 and the 50% span length were measured using a Digital Fibrograph); 6) fiber uniformity, calculated by dividing the 50% span length by the 2.5% span length; 7) fiber strength, measured using a ⅛-in.-gauge Pressley flat-bundle tester and expressed as grams per tex; and 8) fiber fineness as measured by and expressed as micronnaire readings.

Seed viability and vigor. Seed from healthy and diseased plants were acid-delinted and planted in the greenhouse to evaluate seed viability and seedling vigor. Three replicates of 10 seeds each were planted in a mixture of 50% nonsterile clay loam soil and 50% sand. Fresh weights and percentage of germination were measured 21 days after planting.

Table 1. Fiber quality analysis from diseased and healthy upland cotton in Marana, AZ, in 1981[y]

Quality assessments	Healthy	Diseased
Seed cotton weight (g)	138.10 a[z]	114.20 b
Lint turnout (%)	39.70 a	38.90 a
Seed index (g/100 seeds)	9.10 a	7.60 b
Length		
2.5% span	60.50 a	57.70 b
50.0% span	1.19 a	1.17 b
Uniformity	50.40 a	48.30 b
Strength	3.30 a	3.30 a
Fineness	4.90 a	3.90 b

[y] Quality data represent the average from 37 fields.

[z] Numbers in each row followed by the same letter were not statistically different at $P = 0.05$.

RESULTS AND DISCUSSION

Yields of both cotton varieties were significantly lowered by *Phymatotrichum* infection. Upland cotton grown in monoculture was most severely affected. Within a given field of either variety, no significant differences were observed in plant stand density between healthy and root-rotted areas.

Twenty-one percent of the hectares in upland cotton surveyed were infested with *P. omnivorum*. In infested fields, upland cotton yielded an average of 10% less seed cotton than healthy cotton. Total yield loss was estimated at 310.5 bales. Yield loss had two major components: lower total boll set and less fiber per boll. Upland cotton boll density was significantly lower in root rot areas, averaging 3.95 mature bolls per infected plant compared with 6.54 bolls per healthy plant. This decrease in total bolls on diseased plants may reflect the lack of late-season boll set due to plant stress and wilting. Bolls that matured on diseased plants contained significantly less lint than bolls from healthy plants and averaged 1.44 and 1.77 g lint per boll, respectively.

Yields of Pima cotton averaged 13% lower in fields with root rot compared with fields of healthy cotton. Loss was estimated at 88.5 bales, with a total of 311.6 ha infested. Infected plants set only about half as many bolls (4.29 bolls per plant) as healthy cotton (8.12 bolls per plant) but there were no significant differences in the amount of lint per boll (avg. 1.17 g/boll).

When yield estimates (based on field survey data) were compared with growers' gin records, estimated yields proved extremely accurate. Estimated upland cotton yields averaged 0.04 bales/ha lower than actual yields, and estimated yields for Pima cotton were 0.07 bales/ha lower than actual. The basic survey procedures and yield-estimating formulas were reliable. Assuming a 1981 upland seed cotton price of $0.65 per pound, loss per infested hectare averaged $58.05.

Yield reduction associated with plant disease could be calculated by dividing the total loss by the total number of hectares and expressed as loss per hectare. Such calculations would be made based on the assumption that the disease (and subsequent loss) was uniformly distributed throughout the fields. For several reasons unique to Phymatotrichum root rot, this method of loss evaluation is not applicable. In the field, root rot consistently occurs within well-defined areas that are surrounded by healthy plants. Consequently, yield losses attributable to root rot were calculated and expressed as loss per infested hectare, because losses occurred only in infested areas.

Table 2. Fiber quality analysis from healthy and diseased pima cotton in Marana, AZ, in 1981[y]

Quality assessments	Healthy	Diseased
Seed cotton weight (g)	97.6 a[z]	84.8 a
Lint turnout (%)	38.4 a	39.4 a
Seed index (g/100 seeds)	11.9 a	10.7 b
Length		
2.5% span	72.7 a	71.3 a
50.0% span	1.4 a	1.4 a
Uniformity	51.9 a	52.6 a
Strength	4.6 a	4.9 a
Fineness	4.5 a	4.1 b

[y] Quality data represent the average of nine fields.

[z] Numbers in each row followed by the same letter were not statistically different at $P = 0.05$.

Statistical analysis of the influence of rotation practices on yield loss in upland cotton were restricted to cotton monoculture versus cotton in rotations with small grains because there were too few fields in other rotation practices for meaningful comparisons. Significantly greater losses were attributed to cotton monoculture, with average losses of 0.46 bales per infested hectare. Fields in small-grain rotations suffered losses of only 0.26 bales per infested hectare. The effect of rotation on seed cotton loss in Pima cotton could not be assessed because six of the seven fields were in cotton monoculture.

Ratliffe (5), reported that 2-yr rotations of cotton with small grains or other nonsusceptible crops had little effect on the incidence of root rot; however, only infected plants were counted and yields were not measured. Scofield (6) was unable to correlate yield increases in cotton following various rotations with any decrease in the incidence of root rot. The definition of disease severity sensu James (1) is difficult to apply to Phymatotrichum root rot in cotton when loss is measured as yield reduction. *Phymatotrichum*-infected cotton plants ultimately wilt and die, so severity expressed as percentage of plant tissue affected would be considered 100%. Delaying the onset of wilting in root-rotted plants should have a positive effect on yield without measurably changing the incidence of root rot, particularly if incidence is measured (as it usually is) at the end of the season. Small-grain rotation reduced yield loss without affecting root rot incidence.

Upland fiber and seed quality were lowered significantly by root rot infection (Table 1). Seed index (weight [g] of 100 seeds) was lower in infected cotton, whereas lint turnout was unaffected. The ratio of seed weight to fiber weight in infected cotton was comparable to that in healthy cotton, but both seed and fiber weights were lower in infected cotton. Statistically significant differences were observed in all fiber length parameters (2.5 and 50% span length and uniformity). However, all fiber lengths fell within the range considered acceptable for general textile uses. Fiber fineness, as measured by micronnaire readings, were lower, with diseased plants producing slightly finer fiber than healthy plants.

Pima cotton generally maintained better fiber quality than upland cotton, with significant losses observed only in seed index and fiber fineness (Table 2). Although infected Pima plants produced inferior cotton, the quality generally fell well within the acceptable range. Unless quality parameters become more stringent, growers in root rot areas need not be concerned about the effects of *Phymatotrichum* infection on fiber quality, regardless of the variety grown. In years with severe root rot, it may be prudent to blend cotton from the root-rotted portions of fields with healthy cotton before ginning.

Cotton fiber length, strength, and fineness are under strict genetic regulations. However, Longenecker and Erie (2) showed that inadequate moisture during the 50- to 60-day period of fiber maturation could adversely affect lint length and thickness. Taproot degradation by *Phymatotrichum* infection results in plant water stress that ultimately progresses to permanent wilting (4). The fiber quality reductions observed on infected plants would be consistent with those attributed to water stress by Longenecker and Erie (2).

P. omnivorum infection also decreased the germination percentage and seedling vigor of seeds collected from diseased upland cotton plants. About 79% of seed from infected plants germinated, with an average seedling weight of 0.85 g after 21 days. About 90% of the healthy seed germinated, with an average seedling weight of 1.03 g. Pima seed germination was comparable for seed collected from both healthy and diseased plants and averaged 85%. Seedling vigor, however, was significantly lowered for seeds from infected plants, with average fresh weights of 1.08 g/seedling compared with 1.2 g/seedling from healthy seed.

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