

# Diseases and Production Problems of Cotton in Arizona



AZ1245  
July 2001

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*This information has been reviewed by university faculty.*

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**MARY OLSEN**  
*Plant Pathology Specialist*

**JEFFREY C. SILVERTOOTH**  
*Agronomist*

*Based on material originally written by RICHARD HINE, Plant Pathologist (retired).  
Photographs by RICHARD HINE AND MARY OLSEN.*

This information has been reviewed by university faculty.

[ag.arizona.edu/pubs/diseases/az1245.pdf](http://ag.arizona.edu/pubs/diseases/az1245.pdf)

AZ1245  
July 2001

Cooperative Extension  
College of Agriculture and Life Sciences  
The University of Arizona  
Tucson, Arizona 85721

## INTRODUCTION

### History

Cotton seed from Egypt was first introduced into Arizona in 1901. Plantings for commercial observations were made in Yuma and at a Territorial experimental farm affiliated with The University of Arizona in the Salt River Valley near Phoenix. In 1902 the Bureau of Plant Industry intensified experimentation with extra-long staple Egyptian cotton in Yuma. A variety called Yuma was released in 1908. The first commercial crop of Yuma, 375 bales, was produced in 1912. In 1907, land for cotton research was acquired on the Gila Indian Reservation in Sacaton. Research there continued until 1957 when the Cotton Research Center in Phoenix was constructed. Cooperative research with federal, state, and U A personnel took place at this facility until 1985 when cotton research was moved to the Maricopa Agricultural Center in Maricopa, Arizona. The last comprehensive discussion of cotton diseases in Arizona appeared in "Diseases of Field Crops in Arizona," a U A publication authored by plant pathologists J.G. Brown and R. B. Streets and published in 1934. The cotton diseases discussed in the publication were: Angular leaf spot, Boll rots, Soreshin, Southwestern Rust, Phymatotrichum root rot, Alternaria leaf spot, Root-knot nematode, and a physiological disease, named Crazy-Top.

### Production Areas

Many different cultivars of cotton are grown in various ecological areas in Arizona. Production areas vary greatly in elevation and annual rainfall. At one extreme is the Yuma Valley in the southwestern corner of Arizona along the lower Colorado River where cotton is planted in the latter part of February. Elevations here are approximately 75-100 feet. In this area, average annual precipitation is less than 4 inches. In the southeastern part of Arizona in Graham, Cochise, and Greenlee counties, cotton is grown at elevations above 3,000 feet and plantings take place during the middle of April. In Cochise County, for example, cotton is grown in Pearce (4,375 feet), Cochise (4,212 feet), Bowie (3,765 feet) and San Simon (3,601 feet). The production areas along the Gila River in Graham and Greenlee counties are approximately 3,000 feet and 3,500 feet, respectively. At elevations of 4,000 feet, temperatures are approximately 12° F lower (maximum and minimum daily temperatures) than temperatures at sea level. Also, there is a correlation in Arizona between elevation and rainfall. Low elevation production sites in the western part of Arizona average less than 4 inches of rain annually, whereas rainfall at Pearce (4,375 feet) is approximately 13-15 inches annually. Cotton is exposed to the so-called "monsoon" season during July, August, and September. This period is characterized by heavy, irregularly distributed rainfall and high humidity. Rainfall during this period at the higher elevations can range as high as 10-12 inches during certain summers. These temperature and rainfall differences play important roles in the distribution and severity of cotton diseases in Arizona.

# PATHOLOGICAL COTTON PROBLEMS

## SEEDLING DISEASES AND STAND PROBLEMS

Although many pathogenic organisms are involved in cotton seedling disease throughout the Cotton Belt, only two pathogenic fungi, *Rhizoctonia solani* and *Thielaviopsis basicola*, cause disease problems in Arizona. These soil-borne fungi are widespread in Arizona soils and cause seedling and root diseases in many plants other than cotton.



A field picture showing serious stand problems in cotton. Picture taken in Coolidge, Arizona.

### **Rhizoctonia solani**

**Symptoms** - The most common symptom caused by *R. solani* is postemergence damping-off. The fungus grows into the lower stem and the upper portion of the root just below the soil line. Lesions on the roots are sunken and reddish-brown in color. The infected seedling dries up and dies. With a hand lens it is possible to see the “fuzzy” brownish mycelium of the fungus in the girdled tissue.

**Epidemiology and control** - *Rhizoctonia solani*, a soil fungus with a highly active saprophyte stage, survives in the soil in the absence of cotton for indefinite periods of time. The isolates that cause disease in cotton are, for all practical purposes, restricted to that host. Pima and upland cottons are equally susceptible to this disease. Typical weather favoring seedling disease occurs when planting and emergence takes place when night temperatures are below 50° F. Any cultural practice

or weather that delays seed germination or seedling growth increases the probability of seedling disease. Such factors include phytotoxicity due to weed control chemicals, irrigation during cool weather, excessive planting depth, excessively cold or compacted soils, poor quality seed, and rainfall prior to cap removal, which may cause crusting problems. Temperature is frequently the most important factor influencing the rate of seed germination. The optimum soil temperature for cotton seed germination and emergence is between 86° and 95° F, with a minimal temperature of about 55° F. Unfortunately, soil temperatures are extremely variable and may be marginal for growth and seedling emergence during the planting period.

Seedling disease caused by *R. solani* can be controlled by:

- 1). Use of high quality seed.
- 2). Fallowing or rotation of fields to crops other than cotton.
- 3). Planting when soil temperature at the 2-inch depth is 65° or above at 8 a.m., preferably for two or three consecutive days.
- 4). Fungicide treatment. A number of highly effective fungicides are registered for seed treatment, incorporation into the planter box, or application into the furrow during planting. These chemicals include PCNB, chloroneb, captan, and carboxin.
- 5). Seedbed preparation. It is important to obtain a weed-free, well-pulverized bed. Any preplant herbicide should be properly applied. Improper incorporation and excessive rates of certain herbicides, such as trifluralin, may increase seedling disease because of reduced plant vigor.



Typical symptoms on cotton seedling caused by the damping-off pathogen, *Rhizoctonia solani*.

## Black root rot of cotton

Black root rot of cotton, caused by the soilborne fungus *Thielaviopsis basicola*, was first reported in North America in Sacaton, Arizona, in 1922. The disease was described as an internal collar rot of mature American-Egyptian cotton, *Gossypium barbadense* L. Later, it was found to cause a seedling root rot of both *G. barbadense* and *G. hirsutum* L. (upland cotton). Historically, this disease has been a problem in Arizona at elevations above 3,500 feet where soil temperatures are cooler at planting than at lower elevations. However, recently the incidence of the disease at lower elevations has increased corresponding with an increase in acreage of Pima cotton. Pima cotton requires a longer growing season than upland cotton and is planted earlier when colder soil temperatures favor disease.

**Symptoms.** - *Thielaviopsis basicola* causes a black cortical decay of the tap root, delays seedling development and may cause seedling death. However, infected plants can recover because of cortical regeneration and secondary root growth. On the contrary, plants infected with *R. solani* usually die. Root symptoms disappear when rapid plant growth occurs during warm weather.



*T* typical root symptoms in cotton caused by the black root rot pathogen, *T. thielaviopsis basicola*.

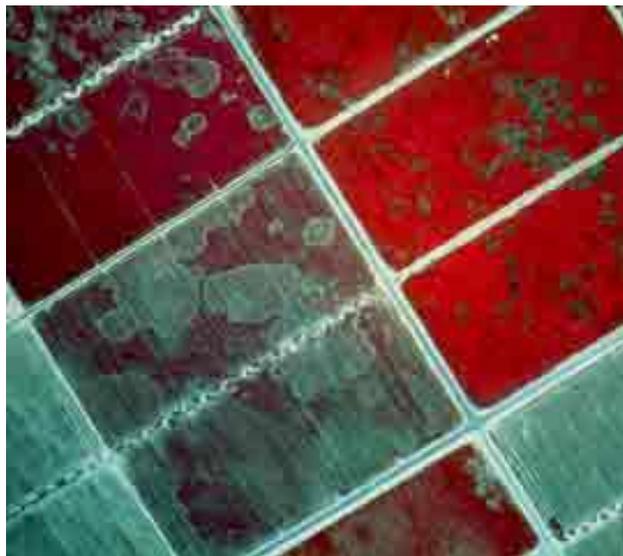
**Epidemiology and control** - All varieties of upland cotton are equally susceptible to black root rot. Pima cotton also is equally susceptible. Infected roots are black in appearance because of the large number of black spores that are produced on infected tissue. These spores survive in the soil and germinate and initiate root infection during early root elongation. Seedling disease is more severe and widespread when fungal inoculum increases because of repeated planting of cotton in the same field. Conversely, fallowing or small grain rotation reduces fungal inoculum and subsequent disease incidence and severity. This disease is similar to Rhizoctonia damping-off in the relationship of soil temperature to disease incidence and severity. Planting into cold soil is the primary cause of disease. There are no commercial seed treatments that are effective for control.

## Seedling Disease Caused by *Pythium* spp.

Several species of *Pythium* have been described as causing seedling disease in cotton. These soilborne organisms cause seed decay, pre-emergence and postemergence damping-off and necrotic lesions on both tap and secondary roots. Damage occurs primarily when soils are cold and saturated with water. In Arizona they do not cause any significant loss in cotton. *Pythium ultimum*, for example, which is commonly cited as an important pathogen throughout the Cotton Belt, has not been identified as a pathogen of cotton seedlings in Arizona. The reasons for absence of this disease are not understood. The most likely explanation is that cotton is planted into preirrigated beds, thus, eliminating saturated soil conditions during early seedling growth. The normal irrigation cycle is a preplant irrigation two to three weeks prior to seeding followed by a second irrigation approximately one month after seeding. To avoid excess moisture, do not irrigate during cool weather, and allow preirrigated beds to drain before planting.

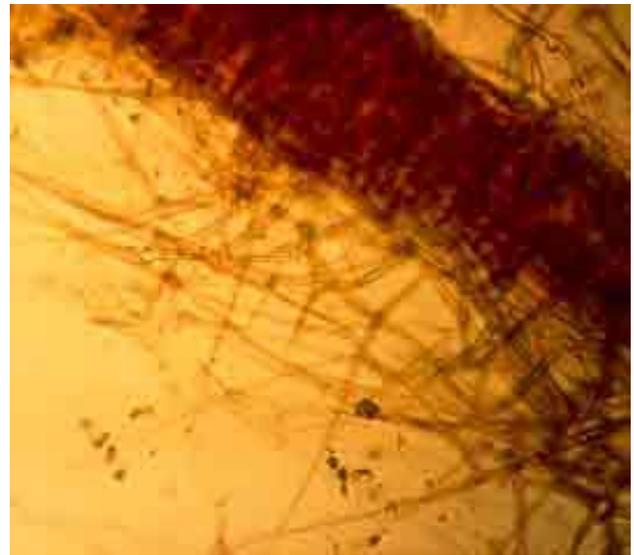
## *Phymatotrichum* Root Rot

*Phymatotrichum* root rot (Texas root rot), occurs only in the low-organic matter soils of the Southwestern United States and Central and Northern Mexico. The fungus that causes the disease, *Phymatotrichum omnivorum*, has the largest host range of any known plant pathogen. It causes a root rot in over 2,300 species of dicotyledonous plants, including not only cotton, but also other important Arizona crops such as alfalfa, stone fruits, grapes, sugar beets, and many ornamental trees and shrubs.

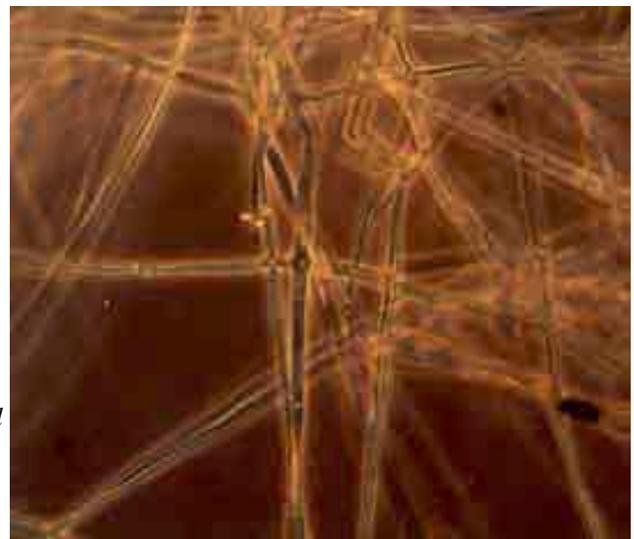


*Typical kill patterns caused by *Phymatotrichum omnivorum* (Texas Root Rot) in fields in Marana, Arizona. These aerial photographs were taken at approximately 3,000 feet elevation during late summer. Note the varying sizes of the patterns.*

**Distribution** - Heavily infested areas of Texas root rot are found in the flood plains and certain tributaries of the Gila River (Safford, Duncan, Solomon, Thatcher, Fort Thomas, Pima, Eden, Florence, Sacaton, Buckeye, Gila Bend, Agua Caliente, Growler, Roll, Mohawk, and Dome Valley); the Santa Cruz River (Sahuarita, Tucson, Cortaro, Avra Valley, Rillito, Marana, Red Rock, and Eloy); the San Pedro River (Hereford, St. David, Benson,



*A photomicrograph showing the typical morphological structure of a strand produced by *Phymatotrichum omnivorum* on the tap root of an infected cotton plants.*



*A microscopic view of the unique mycelial characteristic of *P. omnivorum*.*

Pomerene, Redington, Mammoth, and Winkelman); Colorado River (Parker, Poston, Ehlenberg, Yuma, Somerton, and Gadsden) and certain locations and tributaries of the Salt River and Queen Creek in areas around Scottsdale, Mesa, Higley, Magma, and Queen Creek. Other infested areas include Chandler, Aguila, San Simon, Bowie, McNeal, Douglas, and Duncan.

The “Mesa” (land at elevations above the influence of the Colorado River) in Yuma County seems to be free of the disease, whereas many “valley” production sites are infested. Although *Phymatotrichum* root rot occurs at elevations as high as 4,700 feet in the Elgin and Sonoita areas of Santa Cruz County, the disease has never been detected in the higher elevation farming areas that stretch south from Bonita through Willcox to Kansas Settlement. In the Sulphur Springs Valley, the disease is only found near Elfrida, McNeal, and Douglas areas.

**Symptoms**- All varieties of upland (*Gossypium hirsutum*) and Pima cotton (*Gossypium barbadense*) are susceptible to Texas root rot. However, Pima cotton is usually more severely affected because it has a longer growing season and exposure. Symptoms generally appear first during flowering and boll set. Usually, symptoms consist of rapid wilt and death of infected plants, while dead or dying leaves remain attached to the plant. The tap root is destroyed, and the fungus forms characteristic “strands” on the surface of the rotted, cortical outer tissue. Positive identification of the disease requires microscopic examination of the “strands” that are unique to the pathogen.

**Control** - Texas root rot is restricted to localized areas in individual fields; it is not spread by irrigation or tillage. Apparently this is due to survival of the fungus below plow depth. When fields are continuously cropped with cotton, these infested areas appear in the same location every year. To reduce the disease, spot treatment of infested areas with up to 20 tons/acre of manure has been used successfully in some locations in Arizona. Summer rotations with immune grasses, such as Sudan grass also, have reduced disease incidence. Double cropping systems (barley, wheat followed by late cotton) also have markedly reduced the disease in several locations. Injection of methyl bromide/chloropicrin into preirrigated cotton beds at 18-inch depths has given good control of the

disease in Marana and Safford. The difficulty with this treatment is high cost and erratic carry-over effects in subsequent plantings. There are no chemical treatments that are recommended at this time.

## VERTICILLIUM WILT

Verticillium wilt is caused by the soilborne fungus *Verticillium dahliae*. It is a common and serious disease of upland cotton, *Gossypium hirsutum*, but not Pima cotton. Upland cotton varieties will vary in terms of their susceptibility to Verticillium wilt. Verticillium wilt occurs from South Carolina across the Cotton Belt to California, and throughout most other cotton producing areas of the world.

The fungus that causes Verticillium wilt is one of the most widespread and destructive plant pathogens. In Arizona, *V. dahliae*, causes disease not only in cotton but in many weeds, ornamentals, vegetables, fruit crops and field crops, including olive, pistachio, tomato, and safflower. The fungus is able to survive indefinitely in soil because of the production of small, seedlike structures called microsclerotia. These microsclerotia are produced in large numbers in the roots, stems, and leaves of infected cotton plants during late summer and early fall. They are returned to the soil during harvesting, stalk shredding, and tillage operations.



A field picture of mature cotton plants showing typical leaf symptoms in Upland cotton of Verticillium wilt caused by vascular pathogen, *Verticillium dahliae*.



*T* typical vascular discoloration of stems caused by *V. dahliae*.

**Symptoms** - Symptoms in cotton are dependent on four interrelated factors: the cultivar grown; soil inoculum level; the strain of *V. dahliae* present; and soil and air temperature.

Verticillium wilt does not occur in Pima cotton (*Gossypium barbadense*) because this species is resistant to the strains of *V. dahlia* that occur in Arizona. The cultivars of upland cotton grown in Arizona, however, are susceptible to the disease. Since the fungus is most active at temperatures from 70° to 80° F, symptoms of wilt normally are seen in late summer and early fall as air temperatures decline. Midsummer temperatures at the lower elevations in Arizona are usually too high for the fungus, and symptom expression is masked. The disease is most common and serious at elevations above 3,500 feet in Cochise, Graham, and Greenlee counties where air temperatures are more favorable for symptom expression.

Although seedlings occasionally show effects of the disease during unusually cool spring weather in Arizona, the most common symptoms occur in mature plants in late summer. Irregular, light-green areas appear first on the lower leaves between the veins and along the leaf margins. These areas later become dull-yellow and then brown in color. Defoliation and boll shedding may occur during cool weather. Bolls of infected plants may open prematurely and have reduced fiber quality. The fungus grows internally in the stem and causes streaks of light to dark discoloration of the vascular system. In external appearance, roots remain healthy, in contrast to *Phymatotrichum* root rot where the entire tap root is destroyed.

**Control** - Continuous planting of cotton increases presence of the wilt organism in soil. Fallowing or rotating with non-host summer crops such as sorghum, Sudan grass, or corn or winter rotation with small grains appears to reduce disease incidence in certain locations. Cultural practices that promote early maturity or the use of early maturing or short-season cultivars may reduce disease incidence. Excessive use of nitrogen and irrigation should be avoided. The fungus can be spread in soil, by equipment, and in gin trash. There are no known practical methods of chemical control.

## LEAF DISEASES

Of the several leaf diseases of cotton known throughout the world, only three, Southwestern rust (*Puccinia cacabata*); Alternaria leaf spot (*Alternaria macrospora*) and Bacterial blight (*Xanthomonas malvacearum*) are known to occur in Arizona.

### Southwestern rust

In Arizona, Southwestern rust is the most important of the three foliage diseases. Rust was first described from Baja California, Mexico, in 1893 and from Arizona in 1922. The disease occurs only in certain parts of Southern Arizona, New Mexico, West Texas, and Northern Mexico. The fungus that causes the disease lives on cotton and grama grass (*Bouteloua* spp.). Species of *Bouteloua* occurring in Arizona that are known hosts of rust include two annual species; Needle grama (*B. aristoides*), Six-weeks grama, (*B. barbata*), and perennial



*Ground photograph at the margin of a kill pattern of Phymatotrichum root rot in a Pima cotton field in Marana, Arizona.*



*T*ypical leaf symptoms of cotton rust.



*A* close-up view of the leaf lesions caused by the cotton rust fungus.

Rothrock grama (*B. rothrockii*). The *Bouteloua* spp., which are infected with *P. cacabata*, are the source of infection for cotton.

During summer rains, the spore stage on grama grass germinates to produce airborne spores which are carried up to eight miles and cause initial infections in cotton. There is no repeating spore stage on cotton. All new infections on cotton are dependent upon spore showers from grama grass; the spores produced on cotton can only infect grama grass.

Disease incidence is usually erratic in Southern Arizona and depends on summer rains, high humidity

and an infected source of grama grass for inoculum. The disease is known to occur only in Cochise, Santa Cruz, Graham, Greenlee, and Pima counties.

**Symptoms** - The most common symptom in cotton is the appearance of bright yellow to orange spots on the upper and lower leaf surfaces. The spots become brown with age. Spots may appear on any of the above ground parts including bracts and bolls. Severe infections may cause defoliation and dwarfing of bolls. Spores from these lesions do not infect cotton. If the weather is favorable, several spore showers from grama grass may occur throughout the summer "rainy season." The first symptoms on grama grass are elongate brownish spots on the leaves (uredial lesions). The spores produced in these lesions are spread by air and may reinfest grama grass. A black spore stage on grama grass (telial lesions) appears later. The spores produced from this stage during summer rains infect cotton to complete the cycle.

**Epidemiology and Control** - Typically cotton rust appears in Southeastern and Southern Arizona during the so-called "monsoon season" in July and August. Leaf wetness periods in excess of 16 hours coupled with high humidities and moderate temperatures are factors necessary for epidemics to occur. Rust is a very erratic disease because of the dependence on extended wet and high rainfall periods. Severe outbreaks can cause yield reductions of over 50 percent. The disease is occasionally found as far north as Pima County but essentially it is restricted to the higher elevations,



*T*ypical stem lesions caused by the cotton rust fungus on grama grass.

higher rainfall and cooler producing areas in the southern and southwestern parts of Arizona. Rust may be controlled by three to four aerial applications during July and August of mancozeb (Penncozeb, Dithane M-45 or Manzate 200) plus a sticker in 10 gals/water/acre. Follow label recommendations. Applications should be made prior to the first "spore showers" because these fungicides are only protective.

### Alternaria leaf spot

The first report of Alternaria leaf spot of cotton in Arizona was in 1922. Upland cottons (*Gossypium hirsutum*) in general are considered to be highly resistant to the pathogen (*Alternaria macrospora*) whereas varieties of American Pima cotton (*G. barbadense*) are considered to be susceptible. However, recent studies in Arizona indicate that some cultivars of upland cotton are susceptible to the disease. For example, the increased acreage of Deltapine 90 since its introduction in 1982, the reduced acreage of Deltapine 61, and increased plantings of Pima S-6 explain the increased reports of Alternaria leaf spot in the late 1980's and early 1990's. Deltapine 90 and Pima S-6 are susceptible whereas Deltapine 61 was resistant. The disease occurs in the central and southwestern parts of Arizona but not in the hotter and drier western areas. Often times, as varieties change so do the frequency of occurrences of Alternaria leaf. Often times, as varieties change so do the frequency of occurrences of Alternaria leaf spot.

**Symptoms** - On Pima cotton, Alternaria produces leaf spots that start as tiny, dull-brown, circular lesions,



A photomicrograph of *Alternaria macrospora*, the causal fungus of Alternaria leaf spot.

which may enlarge to spots 1/4 to 1/2 inch in diameter. Because of higher humidity, the lower leaves are more commonly affected. Spots also may occur on bolls. Under favorable wet conditions during July and August, leaf defoliation may occur.

**Epidemiology and control** - The most important factor in the development of this disease is the length of time that leaves remain wet. In most years there is insufficient rainfall to enable leaf infection to occur. The fungus survives in dried infected leaf tissue. Spores are produced during the summer rainy period and are carried to plant tissue by wind.



Typical lesions of *Alternaria* leaf spot on leaf of Pima Cotton.



Symptoms on bolls caused by *Xanthomonas malvacearum* (Angular Leaf Spot). Note the water-soaked, rounded lesions.



Leaf symptoms caused by infection by *Xanthomonas malvacearum*. Both photographs were taken in Bowie, Arizona during an unusually wet monsoon season.

They grow only when a film of water is on the leaf surface. Studies indicate that maximum infection takes place when leaves are wet for more than 12 hours. No chemical control methods are currently recommended.

### Bacterial blight

Bacterial blight of cotton or angular leaf spot, caused by the bacterium *Xanthomonas malvaearum*, was first noted in Arizona in 1922. Prior to the use of acid-delinting, the disease was relatively important because the bacterium survived and was spread on fuzzy seed. With the advent of the acid-delinting process, which eliminates the pathogen from seed, the disease became rare and unimportant in Arizona. However, occasionally, bacterial blight has appeared under unusually wet summer “monsoon” conditions in cotton areas above 3,000 feet in Southeastern Arizona. The disease has not been detected in any other cotton producing areas in Arizona. The bacterium is able to survive in infected, dry plant tissue for many years.

**Symptoms** - In Arizona, symptoms have only been seen on bolls and leaves. Lesions on bolls are circular, dark-green, water-soaked and greasy in appearance. Water-soaked, angular lesions appear on the leaves.

**Control** - Because of the infrequency of the disease, no control measures are recommended for Arizona.

## BOLL ROTS

Boll rots occur primarily during the monsoon season when cotton is exposed to rainfall and high humidity. Most boll decay is found in the lower half of the plant canopy because of high humidity. The three pathogens described under Leaf Diseases, *Alternaria macrospora*, *Puccinia cacabata* and *Xanthomonas malvacearum* also infect and cause specific symptoms on cotton bolls. These symptoms are discussed in the previous section. Of the three, only, *X. vesicatoria*, is able to invade and cause extensive rot. This disease, however, is very rare in Arizona. Another pathogen, *Phytophthora capsaci* occurs only in the Sulfur Springs Valley of Cochise County. This invades uninjured bolls under wet conditions and can cause extensive decay, but disease, is not widespread, and no chemical treatment is recommended for control.

Although a large number of fungi have been implicated as causal agents in boll rots, most of these organisms cannot penetrate healthy boll tissue. Infection is caused by airborne spores that invade bolls after opening. If insects such as the pink boll worm, tobacco budworm, or any other factor that causes premature opening exists, then the incidence of boll decay is increased.

The most significant problem associated with boll and fiber development is the aflatoxin disease caused by the fungus *Aspergillus flavus*. Because of the importance of this disease it will be discussed in detail.

## AFLATOXINS

Aflatoxins are carcinogens produced in many nuts, grains and cottonseed by the fungus *Aspergillus flavus*. The fungus occurs throughout the United States, but aflatoxin problems in cotton are serious only in Western Arizona, the Southern California desert, and the lower Rio Grande Valley in Texas. In Arizona, aflatoxin is significant only where cotton is grown below 2,000 feet elevation. When *A. flavus* infects lint and cottonseed, the main problem created is the production by the fungus of aflatoxins. Two factors, high temperature and lint moisture content above 15 percent are necessary for the fungus to infect and produce these carcinogens.

### Boll and seed invasion by *A. flavus*

*Aspergillus flavus* colonizes dead organic matter and produces large numbers of spores. The entry point into the cotton boll is often the exit hole of the larval stage of the pink bollworm. Once colonization takes place, *A. flavus* invades the cotton fiber. This lint invasion results in weakened fiber and discoloration called

“yellow stain.” After initial lint invasion, the fungus penetrates the seed coat and colonizes the meat portion of the seed. Aflatoxins are produced in this portion, but not in the seed coat or lint. Seed invasion and the formation of aflatoxins will continue as long as seed moisture is in excess of approximately 15 percent.

### Climate and aflatoxin production in cottonseed

Temperature and humidity are the primary factors influencing boll invasion by *A. flavus* and the subsequent formation of aflatoxins in cottonseed. The high temperatures and humidities found in Arizona and Southern California cotton fields favor boll invasion by *A. flavus*, and moist lint of an opening boll is very susceptible to infection.

The critical period for boll invasion and contamination by aflatoxins in Arizona is early August to mid-September when bolls start to open. Approximately 95 percent of the seed infection and formation of aflatoxins takes place in bolls on the lower one-third to one-half of the plant, where dense leaf canopies maintain high humidities and prevent air movement.

The average level of aflatoxins detected in the cottonseed crop fluctuates from year to year. Temperature is the most important factor that determines whether contamination by aflatoxins of seed will take place. When nighttime minimums are consistently below 70° F for this period, as is the case at the higher elevations in Arizona, the San Joaquin production areas of California, and other production areas of the United States, aflatoxin seed contamination is insignificant.

### Insects and aflatoxin production

The pink bollworm, *Pectinophora gossypiella*, is a major factor contributing to the aflatoxin problem. Larvae of this moth invade bolls of upland cottons 14 to 21 days after flowering when they are most susceptible. Under dry conditions yield reductions are not significant unless over 25 percent of the bolls are infected. With the occurrence of high humidities and rainfall, however, during the latter half of July into August and September, extensive losses can occur because damaged bolls are invaded by miscellaneous fungi that cause boll rots. The exit hole of the pink bollworm becomes an entry point for infection by airborne spores of *A. flavus*. Bollworms (*Heliothis spp.*) feeding sites as well as any other insect punctures also enable *A. flavus* to enter into boll tissue. *Aspergillus flavus* is not able to infect and penetrate undamaged, intact boll tissue.

**Control**- Currently, there is no practical field control of cottonseed invasion by *Aspergillus flavus* and subsequent contamination by aflatoxin. In Arizona, approximately 80 percent of the whole seed produced is processed for meal, oil, linters, and hulls. In the delinting, dehulling, and oil extraction process, almost all of the aflatoxin resides with the meal. The meal represents only about 40 percent to 50 percent of the seed weight, so, in effect, the aflatoxin level doubles in this by-product of whole cottonseed processing. In reality, a seed producer must control to 10 parts per billion (ppb) in order for the processor successfully to produce 20 ppb meal.

Humidity may be regulated by improving air movement through the lower leaf canopy. Skip-row planting in a 2 x 1 or 4 x 1 mode will improve air movement around the bolls in a lower canopy and will result in less aflatoxin than is encountered in similar solid planted fields. Unfortunately, skip-row cultivation will only maintain aflatoxin levels below 10-20 ppb when a very light season is encountered. Currently there is no way to predict at planting time the degree of aflatoxin contamination that will occur during August and September.

“Rank” cotton is usually more susceptible to the problem. Careful management of water and fertilizer on land known to produce rank cotton will add in maintaining lower levels. Reduction of the growing season, and limiting the number of irrigations in August show promise for reducing aflatoxin levels.

Good midseason insect control, particularly that of the pink bollworm complex, from mid-July to early September, is important for the maintenance of low levels of aflatoxin.

There is a piece of equipment, common to cotton production, which has the ability of segregating seed with lower levels of aflatoxin from highly contaminated seed. The spindle harvester was designed to remove fluffed lint efficiently and is inefficient in removing unfluffed or tight locules and/or PBW-bollworm complex damaged bolls, which contain most of the aflatoxin. Unfortunately, this advantage is lost when a ground gleaner follows the spindle harvester. Ground gleaners will retrieve most of the seed cotton remaining on the plant from the ground. This seed is then routinely mixed with spindle-picked seed at the gin. In several studies in Arizona, aflatoxin levels were 50 times higher in seed retrieved by ground

harvesters. Segregation on the basis of harvester type during a light aflatoxin year would serve to provide a large quantity of seed with acceptable levels of aflatoxin.

Cottonseed and meal above the tolerances set by the U.S. Food and Drug Administration (20 to 300 ppb) depending on the intended use of the feed must be treated with ammonia or mixed with uncontaminated feeds to produce a mixture within the limits of the tolerance.



Symptoms of cotton leaf crumple on leaves of Upland cotton.

### COTTON LEAF CRUMPLE VIRUS

**History** - This disease was first described from California in 1954 and from Arizona in 1960. A major epidemic of cotton leaf crumple occurred in Arizona cotton in 1981. The epidemic was associated with high populations of the sweet potato whitefly (*Bemisia tabaci*) and large acreages of perennially grown (stub) cotton.

**Symptoms** - Leaves on infected plants are small in size, cupped downwards and crinkled in appearance. Leaf veins are distorted and thickened. Plants infected when young are stunted.

**Host range** - Studies in 1986 indicated that Stoneville germ plasm is less susceptible than Deltapine germ plasm. Pima cotton is also susceptible. Cheeseweed (*Malva parviflora*) and bean (*Phaseolus vulgaris*) are hosts of the virus in inoculated greenhouse plants, but its natural host range is not known.

**Epidemiology and control** - Cotton leaf crumple, a geminivirus, is the only virus disease of cotton described in the United States. It is vectored only by the whitefly. The virus is not mechanically transmitted. The disease was most important in Arizona when ratooning of cotton was practiced in the warmer western and central production areas. The ratooning of infected plants enabled the virus to establish itself systemically in young plants, causing significant yield losses. Seed cotton was never as seriously damaged. Currently, the disease is scattered throughout areas where whiteflies exist. Cotton is no longer ratooned in Arizona and the disease is economically important only when young plants are infected. Infections that occur in late July or August cause symptom development but little or no yield loss.

### ROOT-KNOT NEMATODE

The Southern root-knot nematode (*Meloidogyne incognita*) is the only nematode affecting cotton in Arizona. The nematode is restricted to sandy soils where it attacks both short and long staple varieties.

**Symptoms** - Galls and root swellings are small but visible on roots. The galls appear as early as one month after planting. Galls on cotton roots are smaller than root-knot galls on other hosts such as tomato, cucurbits, and other vegetables.

Rotation may be the best method for control. In Arizona, cotton can safely be planted following lettuce and most nondormant varieties of alfalfa. Summer fallowing can be an effective means of control, providing there is root destruction of the previous crops, and susceptible weeds are prevented from growing.

When crop rotation is impractical, consideration must be given to soil treatment with a suitable nematicide. The decision is based on the cost of treatment, the number of root knot nematodes in the soil, the anticipated temperature during seed germination and development of the tap root, the percent of the field with sandy areas that exceeds 60 percent or more sand and the anticipated price of cotton. At present, soil fumigants remain the most effective and economical method of controlling root knot nematodes attacking cotton. The only soil fumigants presently available for use in cotton are various formulations of 1-3, D (dichloropropene). These liquid compounds must be injected into the soil before planting. Soil should always be in excellent tilth with temperatures between 60° F and 80° F. The manufacturer's label carries instructions for the correct dosage. For best

results with soil fumigants, the beds should be listed and irrigated before the material is applied.

## NONPATHOLOGICAL COTTON PROBLEMS

### NUTRIENT DEFICIENCY SYMPTOMS

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#### Nitrogen

Nitrogen (N) is the plant nutrient required in largest amounts and the only mineral nutrient to which cotton has consistently been shown to respond in Arizona. In Arizona, with the exception of water, N is the first limiting nutrient for plant growth. Practically all soils will respond to applications of fertilizer N in terms of cotton growth and development. Nitrogen is one element that growers have control over, and it proves to be very important in Arizona cotton production.

In the plant, N is a mobile nutrient in that as deficiencies develop, N-containing components in older tissues (lower on the plant) break down, releasing N forms which are then translocated to younger, developing portions of the plant (near terminal areas). Therefore, when N deficiencies develop, they are commonly seen first as yellow or red leaves on the older, lower portions of the plant. A crop that is developed under a continual deficiency of N will tend to mature early and have reduced yields.

The N nutritional status of a cotton crop can be evaluated in-season by use of petiole sampling and analysis for NO-N. Guidelines for use of this technique in N fertility management is outlined by Pennington and Tucker, 1984 (The Cotton Petiole, a Nitrogen Fertilization Guide, the University of Arizona College of Agriculture, Publication No. 8373). Preseason soil samples for residual NO-N can also be of benefit to managing a N fertility program for cotton. In general, split applications of fertilizer N throughout the growing season are highly recommended on all soils, particularly medium- and coarse-textured soils versus larger one-time applications. Also, unfavorable soil physical conditions such as compaction, saturation, or dryness can reduce N uptake by cotton.

#### Phosphorus

Phosphorus (P) is an essential plant nutrient used in the storage and transfer of energy within the plant. Important functions of P include formation and transfer of energy, and formation and utilization of carbohydrates.

Although soils of Arizona are often high in total P, the amount of P available for plant uptake and utilization often has been a point of concern. Arizona soils commonly used for cotton production generally have high pH conditions (pH  $\geq$  7.5) and are very calcareous in nature. These conditions often lead to a considerable degree of P "fixation." However, research results, show no consistent response of cotton to P fertilization. Several experiments have been carried out with broadcast P methods for a number of years, and experiments with banded P fertilization have been conducted only on a limited basis thus far. Therefore, P deficiencies in Arizona cotton are very rare. This is often attributed to the very warm conditions in the growing season, and possibly to cotton's low requirement for P.

Symptoms of P deficiency include slow early growth with darkened or red plant tissue (anthocyanin accumulation) particularly at early stages of growth. Plants generally grow out of symptoms as the soil temperatures warm, allowing greater root growth. Correction of suspected P deficiencies after planting is very difficult.

#### Potassium

Potassium (K) is the third macronutrient (besides N and P). Within the plant, K is not incorporated into any compounds and tends to remain in ionic form ( $K^+$ ). Potassium is essential for photosynthesis, starch formation, and translocation of sugars within the plant. K is necessary for chlorophyll development, but it is not an actual part of its molecular structure.

Arizona soils are generally high in plant-available K, and deficiencies have not been confirmed. Accordingly, responses to K fertilization by cotton have not been documented in Arizona. Deficiency symptoms, therefore, are not likely to be encountered. If, however, one suspects K deficiency, symptoms include: bronzing and scorching of leaves, weak stems, and reduced boll size and fiber development. For most plants, K is considered as a mobile nutrient in the plant leading to deficiency symptoms developing first on the lower, older leaves of the plant. However, when K deficiencies have been diagnosed on cotton, it has proven to be somewhat of an exception. In cotton, characteristic K deficiency symptoms often develop first on younger leaves. This is particularly true when symptoms develop late in the season as bolls are developing, and symptoms appear on leaves adjacent to rapidly filling bolls. This is attributed to strong sink demand by the bolls, causing export of K from adjacent tissue (leaves) which are often in younger portions of the plant.

Similar to P, in-season corrections of suspected K deficiencies are very difficult to accomplish. If K deficiencies are suspected, one should have soil samples analyzed for exchangeable soil-K by 1-foot increments to a depth of 3 to 4 feet.

## Zinc

Zinc (Zn) is a micronutrient essential for plant growth and development. Its designation as a “micronutrient” does not reflect any lesser degree of importance in terms of essentiality, only that it is required in very small amounts relative to the macronutrients (N, P, and K) or secondary nutrients (Ca, Mg, and S). Zinc is essential as an activator (cofactor) for many plant enzymes during all stages of plant growth. Zinc is relatively immobile in the plant and therefore, small but consistent levels of Zn must be taken up by cotton plants all season. In agricultural soils from Arizona, extractions performed with DTPA that result in  $\leq 0.65$  parts per million (ppm) Zn are considered to be sufficient for cotton production. In recent experiments working with soil and/or foliar applications of Zn, no yield responses were measured in upland or Pima cotton.

When Zn deficiencies have been confirmed on cotton plants, symptoms often include: shortened internodes and small leaves with interveinal chlorosis (white or bleached-out tissue between the veins of leaves). Later in the season, very small bolls (“ping-pong” bolls) develop under Zn-deficient conditions. When Zn-deficiency symptoms develop early in the season, it is often due to poor root development. Poor root development could be caused by soil compaction or cold soil conditions. In the latter case, plants will often grow out of the Zn-deficient symptoms when soil temperatures warm.

## SALINE/SODIC SOIL CONDITIONS

Many soils in the desert southwest are naturally saline and/or sodic. These soils are usually the object of reclamation and management techniques to control and minimize salt and sodium problems. Saline and/or sodic soil conditions often are the cause of difficulties in getting and keeping a good stand of cotton in many fields.

### Saline Soils

Saline soils are defined as “nonsodic soils that have sufficient soluble salt to affect adversely the growth of most plants.” Salt contents which result in electrical conductivity measurement of 4 mmhos per cm or greater from a saturated extract ( $EC_e$ ), are generally referred to as saline soils. Cotton plants are considered

to be moderately salt-tolerant. This is certainly true and cotton plants are often pushed to their limits in terms of salt tolerance. When present, excessive salts ( $EC_e$  values of 10 mmhos per cm or greater) cause stunted, slow-growing plants. They often are characterized as having very short internodes, tough leathery textured leaves, and often a burn or scar mark at the soil surface, as well as poorly developed roots.

Prevention is usually the best cure for salt problems. Saline conditions are often the result of irrigation water high in soluble salts. In such cases, rotation to crops such as small grains or alfalfa, which permit border irrigation, is found to be helpful. Actually, it is the leaching of the salts that is of most benefit from the border flooding. Also, alternate row irrigation can be helpful in preventing a salt accumulation at the top of the bed (in the row) which will occur with every-row irrigation.

### Sodic Soils

Sodic soils are defined as “nonsaline soils containing sufficient exchangeable sodium to affect adversely crop production and soil structure.” Sodic soils have exchangeable sodium percentages (ESP) of 15 or greater. They are characterized as having sodium adsorption ratios from the saturated extract ( $SAR_e$ ) of 13 or greater. Soils high in sodium are found to have water penetration problems due to dispersing soil particles, which in turn causes a sealing of the soil. Soil sealing due to dispersion is often seen as a crusting problem and the associated difficulties with poor seedling vigor. However, additional irrigations and cultivations will not solve this problem, perhaps only making it worse.

In some cases, the sodic conditions within a field may be within tolerable limits, only to be pushed into a dangerous excess by an inadvertent act of management. Many growers apply fertilizer nitrogen (N) as anhydrous ammonia directed through the irrigation water. This may cause an increase in the pH of the irrigation water due to the ammonium hydroxide that is formed upon the addition of the anhydrous ammonia. The resultant increase in the pH of the water may cause soluble calcium and magnesium in the water to precipitate from the solution by combining with bicarbonate, while any sodium in the water remains in solution. This may then result in irrigation water that is high in its proportion of sodium to calcium and magnesium. Continuous use of this practice and the resulting water, can create a sodic soil and field conditions that are increasingly difficult to manage. This can be a particularly tough problem at the time of seedling establishment.

There are several approaches to correcting a sodic problem after it has been properly identified. One soil amendment that can be used is gypsum. The first step in this reclamation process is the incorporation of the gypsum at a satisfactory rate. The calcium from the gypsum will exchange for the sodium in the soil, leaving a soluble form of sodium. The second step is then to leach the soluble sodium (often sodium sulfate) with excess (good quality) irrigation water. The use of sulfuric acid on sodium-affected soils can also serve as a good reclamation effort when the soils contain sufficient free lime (calcium carbonate). The soil reactions involved are similar as when gypsum is used. In each case, the calcium is exchanged for the sodium, which then can be leached down through the soil profile with sufficient (quality and quantity) irrigation water. These efforts at reclamation should be beneficial when exchangeable sodium percentages (ESP) approach or exceed 10.

## OTHER POSSIBLE NUTRITIONAL AND PHYSIOLOGICAL PROBLEMS

### Excessive Nitrogen

A key principle in managing the nitrogen (N) fertility of a cotton crop is to supply the N to the plants in adequate, but not excessive, amounts. In cotton production, a critical management objective is to optimize the vegetative/reproductive balance in the crop so as to obtain the highest lint production as possible. Growers in Arizona recognize the responsiveness of cotton to both water and N. However, due to the indeterminate nature of the cotton plant, conditions such as excessive N or water at the right (or wrong) time can stimulate vegetative growth in the process of sacrificing reproduction and yield potential. Excessive N particularly late in the growing season, can promote vegetativeness, delay maturity, and create further problems with crop termination and defoliation.

Symptomatically, one may look for excessive N conditions by sampling petioles and analyzing for NO-N over a period of several weeks. These values should be referenced against guidelines outlined by Pennington and Tucker, in accordance to stage of growth. Research results indicate that petiole NO-N levels can be drawn below 2,000 ppm and 1,000 ppm by late in the season (mid-September) without sacrificing yield potential and providing for plant development conducive to senescence and defoliation.

The best management against excessive N fertility

status of cotton is to employ diagnostic tools such as pre-season soil samples to evaluate residual soil NO<sub>3</sub> levels, irrigation water analysis to estimate NO<sub>3</sub> contributions with each irrigation, and in-season sampling and analysis of cotton petioles for NO-N content. Historically, water stress has been a management tool used in some cases to counteract the vegetative tendencies brought on by elevated N fertility in cotton. However, it is not an advisable practice to impose intentionally a water stress on a crop, recognizing the sacrifice in yield potential that results from water stress conditions. The best advisable practice is to manage N fertility with available tools from the beginning of the season so as to provide adequate levels of N for crop production, but avoiding excesses.

### Ammonia Toxicity

One of the occasional consequences of fertilization with anhydrous ammonia as a sidedress application, is that of plant damage due to direct exposure to the ammonia (NH<sub>3</sub>) gas. When side-dressing young cotton plants with an application of anhydrous ammonia, it is important to make the application a sufficient distance away from the crop row so as to avoid damage to the cotton roots. Also, it is important to make applications under proper soil moisture conditions so that the soil seals after the passage of the shank applicator. Otherwise ammonia gas can escape causing both the loss of fertilizer N and damage to the aboveground portion of the plants.

Anhydrous ammonia gas is very hydrophilic (water-loving) and therefore, exerts a severe and caustic burn to any plant tissue (root or shoot) that comes into direct contact with it. Direct exposure to anhydrous ammonia gas severely damages cell membranes and causes a blackening of the exposed tissue. Wilting also may occur upon direct root exposure shortly after application of the anhydrous ammonia. Damaged plants usually will recover despite a setback before recovery. It is also important to point out that applicators themselves should exercise necessary precautions when using anhydrous ammonia due to the hazards associated with exposure to any skin tissue (particularly the eyes).

### Reddened Leaves

A condition that often draws some attention in a cotton field is the development of reddened leaves. This phenomenon can be caused by several different factors. It seems that a natural response of the cotton plant (particularly upland) to a variety of stressful situations is to lose its chlorophyll content, which of

course diminishes the green coloration of the leaves. With the loss of the chlorophyll, another natural plant pigment becomes readily apparent which are the anthocyanins, leading to the distinct red coloration on the leaves. The senescing of plant tissue, whether natural or induced by some stress, also often accelerates the formation of anthocyanin. Therefore, a natural development of red coloration of the leaves could be expected to some extent late in the season as the crop is naturally aging on senescing. This is particularly true in conditions where much cooler weather is experienced.

There are also some other causes of red leaves, which one must be conscious of if the condition develops. Nitrogen deficiency symptoms often are noted as reddened leaves on the older, lower portions of the plant. This possibility could be further diagnosed by use of tissue sampling (petioles) extent of the affected areas in the field, age of the crop, and other possible problems. Another very common cause of red leaves is that of spider mite infestations. In the case of spider mites, the development of red leaves and red leaf spots will be restricted to small, localized areas within a field, particularly at early stages of the population's development. Often it will also be restricted to the older, lower portions of the plant at very early stages of development. One can pursue this possibility by inspecting the leaves (underside particularly) for the presence of spider mite colonies. The mites and their eggs can easily be seen with the aid of a hand lens, and also with the naked eye. Spider mite colonies usually have a substantial amount of webbing developed on the surface of affected leaves. Control of both spider mites and N deficiency is possible, but early detection and diagnosis is very important in that regard. Another possible cause of reddened leaves, particularly a distinct pattern of red leaf spots, may be due to some types of insecticides. One should consider recent insecticide applications, extent of the affected areas, and any patterns when considering this as a possible cause.





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