

**University of California**  
**Fusarium Race 4 Grower Information Summary**

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Over the past ten years, race 4 of *Fusarium oxysporum* spp. *Vas infectum* (race 4 FOV) has increasingly impacted fields in California's San Joaquin Valley. Field evaluations have provided information for a number of generalizations: (1) most Pima cultivars show more severe symptoms and suffer higher levels of stunting and plant mortality from race 4 FOV than seen with most Acala and non-Acala Uplands; (2) some moderate to highly-resistant commercial Pima cultivars have been identified from several seed companies and private breeders; (3) several USDA-ARS experimental Pima germplasm or breeding lines with moderate to high resistance to race 4 FOV have been identified; and (4) most Acala and non-Acala Upland germplasm tested for susceptibility to race 4 FOV, while less severely impacted than most Pima cultivars, were infected by race 4 FOV at infested sites.

We have determined that for race 4 FOV, plant sampling and scouting for disease symptoms are best done between early seedling development through no later than first flower. Race 4 FOV has been observed in the field to affect and even kill plants as early as the 1 to 2 leaf stage, but more typically at the 3 to 6 node stage. This observed damage is much earlier in the growing season than the past typical timing (after peak bloom, early boll maturation) for field inspections for seed and production fields. In addition, some of the easily evident symptoms (dead or dying seedlings, obvious foliar FOV symptoms) can be less apparent later in the season, due to both abscission of damaged leaves and continuing growth of neighboring "survivor" plants.

In fields where the fungal disease has been confirmed as present in the plants and soil, recommended management considerations have been suggested, which include: (a) removal of infected plants to the degree possible; (b) limitations for irrigation and tailwater movement out of infested areas; and © restricting personnel/equipment traffic through and out of infested areas. Improvement in sanitation practices to reduce movement of pathogen-containing soil will not eliminate all movement of pathogen inoculum, but can significantly reduce amounts moved out into non-infested areas. To date, no crop rotation or short-term fallow practices are known to greatly reduce survival of resting stages of this pathogen, but there is indirect evidence that full summer dry, weed-free fallow will accelerate reductions in inoculum survival more than other crop rotations tested to date. The most effective current approach for growers wanting to continue with cotton plantings in infested soil areas or where there is a threat of infestations is to plant cotton cultivars already known to possess a good level of resistance to race 4 FOV.

**MANAGEMENT RECOMMENDATIONS**

A major concern with race 4 FOV is that it has been found capable of producing major plant damage even in the absence of significant root knot nematode (*Meloidogyne incognita*) populations, meaning that it can expand inoculum and cause problems potentially in a wide range of soil textures/types. In fact we have identified this disease and significant plant damage and mortality in soils ranging in texture from sandy loams to clay loams. The disease-causing FOV organism (both race 1 and race 4 types) are nearly impossible to eradicate from soil, and currently-available soil fumigants and other chemical control measures tested to date are typically expensive and not anywhere near 100% effective in killing inoculum once widely distributed. This means that primary efforts in fields where the problem is identified should be directed toward containment and avoidance of practices that can cause further spread of the organism.

**Scouting fields for FOV problems.** The most useful timing for plant sampling and scouting to evaluate plant foliage and roots for disease symptoms is different (earlier) than what is done looking for weed problems or *Verticillium* when checking seed or production fields. Race 4 *Fusarium* has been seen to

affect cotton plants as early as the 1-2 leaf stage (seen in many fields recent years) or more typically around 3 to 6 main stem nodes. Symptoms can be evident at later growth stages if plants survive, but plants of many susceptible cultivars will die often before reaching the 6-7 node stage. After some initial die-back of plants or partial defoliation during these growth stages, it has also been typical to see some additional plants in affected areas develop additional damage and die, and other plants in affected areas to experience some partial leaf loss followed by recovery (“survivor plants”). The relative number of survivor plants in impacted areas is likely affected by fungal inoculum populations in soil, the variety of cotton planted (relative resistance or tolerance) and environmental conditions (impacts of other stresses). For pictures of plant symptoms, see *Fusarium* updates on the UC cotton web site: <http://cottoninfo.ucdavis.edu> (on this web site’s home page, click on “GUIDELINES”). Symptoms of different races of *Fusarium* (race 1 and race 4) on cotton look similar, so finding plants with symptoms doesn’t necessarily confirm race 4 *Fusarium*. A wide variety of species of *Fusarium* are present in most agricultural soils, so it is not useful to have a simple, general soil test done to detect the presence of *Fusarium*.

**FOV Race Identification.** For the purposes of University of CA and USDA-ARS cotton evaluations in California cotton related to our studies and grower evaluation requests, one research laboratory (University of CA Davis, Plant Pathology Dept., Dr. Michael R. Davis) is also set up to identify the race of FOV using methods including phylogenetic analyses of multiple genes, pathogenicity assays and specific restriction digests (Kim et al., 2005) and macroarrays (Gilbert et al, 2008).

**For grower / commercial sampling for race 4 Fusarium in plant tissue:** A relatively new development within the past three years has been that a commercial company (AgDia) has worked with Dr. Michael Davis of the University of CA Davis and the CA Cotton Growers Association and CA Cotton Alliance to develop a “quick test” which can be used with root tissue (preferable) or lower stem tissue of symptomatic plants. This test when properly administered can provide confirmation if the plant tissue tested is positive for race 4 *Fusarium*. The equipment and test strips for this race 4 FOV “quick test” to use with plant root tissues are available from AgDia Company (more information at: <http://www.agdia.com> (look under: **AmplifyRP® Acceler8™** test on that website). Please note: *While University of CA staff have evaluated and used this quick test, the information provided here does not constitute an endorsement or guarantee from the University.*

**When cotton plants are identified with FOV symptoms, and FOV race 4 is confirmed, consider:**

**Plant Removal:**

- Destroy affected plants and plants in immediate adjacent rows
- If the affected area is large, leave plants & kill with a herbicide
- If the affected area is relatively small, pull or hoe out affected plants and destroy / burn them in place within the affected area
- Make a note of the affected area so you can check again later and destroy additional affected plants if practical
- Remember that remaining infected plants represent a place for inoculum to reproduce

**Limit Soil and Plant Debris Movement:**

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- Irrigation water and tailwater recovery systems can move both soil and infested plant parts across fields.

It is proper to acknowledge that field sanitation practices have some significant potential to slow the rate of spread of inoculum, but these practices will not eradicate it once established.

#### **Care in Production of Planting Seed:**

Do not produce planting seed in fields confirmed as affected by FOV (race 4 or other races), or in fields adjacent to known affected fields. FOV race 4 can be seed-borne (Bennett et al, 2008), and although the chance of it getting into seed is extremely low, it is an unacceptable risk to grow planting seed in or near an infested field.

#### **Utility of Crop Rotations and Fallow:**

Prior studies with race 1 FOV in California have found that multiple-year rotations to some non-host crops or summer fallow can reduce disease symptom severity and relative levels of plant mortality, but we are not aware of evaluations completed that indicate good efficacy in reducing inoculum survival with one or more years of rotation or fallow for race 4 FOV. At this time, inoculum management with rotation or fallow approaches is a highly questionable practice in terms of efficacy until more detailed information is available, and not an approach to consider except with cotton cultivars already showing a good level of resistance to race 4 FOV. Some chemical treatments with expensive fumigant materials or solarization may have utility as spot treatments in the early stages of disease development in fields (when affected areas are very small). However, such treatments will not eradicate the disease but are more likely to serve as means to reduce inoculum population in combination with use of resistant varieties.

#### **Resistant Cultivars – Issues and Progress:**

Long-term management of FOV race 4 in cotton will be enhanced by development of resistant varieties. Early field and greenhouse tests of cultivar susceptibility to race 4 FOV indicated that multiple Pima varieties were infected at higher rates and damaged more seriously than Acala varieties in the same tests. Subsequent tests conducted in field trials in confirmed, race 4-FOV infested fields, and in greenhouse inoculated trials are consistent in showing that most Acala and non-Acala varieties can also be infected by this FOV race, albeit with significantly less plant damage than in most Pimas tested. In the Pima types of cotton, commercial seed companies including PhytoGen (Corcoran, CA) and Monsanto have commercially available cultivars out that have some relatively high levels of resistance to race 4 FOV. There remains less progress currently in identifying experimental germplasm or commercially available Upland or Upland/Acala cultivars with high levels of race 4 FOV resistance, but those efforts have been stepped up in the field screening work done in CA the past 2 years. Germplasm evaluations through 2013 can be summarized as follows: (1) most Pima varieties show more severe symptoms and higher levels of stunting and mortality than Acala/Uplands; (2) some moderate to highly-resistant commercial Pima varieties have been identified from several seed companies, (3) several USDA-ARS experimental Pima germplasm or breeding lines have been identified; and (4) most Acala / Upland germplasm tested, while less severely impacted than most Pima varieties, were infected by the race 4 FOV when present in soil at field sites or when inoculated in greenhouse trials. Growing varieties resistant to FOV race 4 is currently the primary component in strategies for economically-effective management of cotton production in areas impacted by Fusarium wilt (FOV) race 4 in the San Joaquin Valley.

#### **Thanks for support to:**

- **Grower and PCA Cooperators**
- **Cotton Incorp. State Support Committee, California Department of Food and Agriculture**
- **CA Cotton Ginners & Growers Association**
- **California Cotton Alliance**
- **National Cotton Council – Cotton Foundation**
- **seed companies, associated cotton industry companies, Supima Association**



TYPICAL EARLY INFESTATION AREA WITH MANY PLANTS THAT DIED VERY EARLY IN DEVELOPMENT (This is what an infested area might look like 2-3 years after initial infestation)

TYPICAL SEEDLING LOSSES WITH FUSARIUM – LEAF YELLOWING AND NECROSIS



LEAF YELLOWING ASSOCIATED WITH FUSARIUM RACE 4 – note yellow and brown patterns in Leaves (somewhat reminiscent of verticillium Wilt, but verticillium wilt is a late season disease, While Fusarium is an early season disease where Most damage is evident at the seedling stage.



BROWN, CONTINUOUS ROOT VASCULAR STAINING FOUND WITH FUSARIUM RACE 4