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VEGETABLE VIEWS

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2021 Research and Extension Projects

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My 2021 vegetable crop applied research and extension program will continue focusing on three main areas: pest management of insects, weeds, and diseases; evaluating production practices of vegetable grafting and biologics; and optimization of irrigation management with an online decision support tool.

Pest management of insects, weeds, and diseases

Screening potential pre-and post-emergence herbicide for use in basil. The basil herbicide screening project has come into its third year. In 2019 and 2020, I tested two pre-emergence herbicides (Zeus XC and Ultra Blazer containing Sulfentrazone and sodium salt of Acifluorfen as the active ingredients, respectively) on five commercial basil fields at Ratto Bros. in Modesto. The results were presented in trade magazines, in previous issues of my newsletter, and at scientific and grower pest management meetings. In 2021, I will continue my collaboration with Ratto Bros. and Western Region IR-4 to carry out screening trials of post-emergence broadleaf herbicides. Tough 5EC (Pyridate as the active ingredient), a post-emergence herbicide for the selective contact control or suppression of actively growing annual broadleaf weeds, will be applied to basil fields at various rates. Weed control effect, basil plant injury, growth inhibition, and leaf biomass will be evaluated to figure out the efficacy and potential for the registration of use on basil.

***NOTE*: The herbicides tested in these trials are currently not registered for use on basil in California. The application rates that were and will be tested are for research purposes only and do not necessarily reflect the actual use on your crops. Always follow the herbicide label directions because the label is the law.**

Monitoring beet leafhopper population and incidence of curly top virus on processing tomatoes. The purposes of our efforts are to monitor the dynamics of the beet leafhopper population from pre-plant to the end of the season, understand the association between leafhopper population and beet curly top virus incidence in the nearby processing tomato fields, and eventually help with the guidance of treating beet leafhopper in the vicinity of processing tomato fields. With the support of the California Tomato Research Institute, we already set a total of 30 yellow sticky insect traps at 10 monitoring sites from Patterson to Crows Landing this March. The 10 monitoring sites include 22 processing tomato fields with a gross acreage of 2,200. Traps were set at a height of 3 feet, facing west (Interstate 5 and foothills), and near various landscapes and vegetations (e.g., roadside, wild grassland, weedy ditches, edges of tomato and almond/walnut fields, and canals) (**Figure 1**). All traps will be checked biweekly for the presence of beet leafhoppers. Old traps will be replaced by new traps and brought back to count the population of insects collected. In the growing season, we will use sweep

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netting to catch and collect beet leafhoppers. In the meantime, visual inspections and lab diagnoses will be conducted to identify and estimate the curly top virus incidence in monitored tomato fields until the end of the season.

Identifying tomato fields with Fusarium falciforme. Fusarium falciforme is a newly recognized and widespread cause of foot and stem rot and premature tomato vine decline. However, it is an emerging fungal disease of tomatoes, currently with no known control strategy. Developing an effective management strategy for F. falciforme in the processing tomato project will be led by Drs. Cassandra Swett and Brenna Aegerter, with the support of the California Tomato Research Institute. As a collaborator, I will work with the local growers to scout for infected processing tomato fields, identify the presence and severity of F. falciforme, and make a summary of susceptible varieties in Stanislaus County.

Figure 1. The yellow sticky traps were placed in various landscapes and vegetations, including a weedy ditch and road and at the edge of a walnut field.

Evaluation of production practices

Rootstock evaluations of grafted processing tomato and seedless watermelon. The grafted processing tomato project has entered its sixth year since 2016. With the continuous support of the USDA-Specialty Crop Research Initiative, the 2021 trial will be a repeat from 2020 involving two scions grafted onto three rootstocks. Each grafted and nongrafted treatment will be planted under a regular 12” in-row spacing and doubled spacing of 24” (50% population reduction). The goal is to compare fruit yields among all grafting combinations and nongrafted regular plants and identify the most economically viable combinations. View the virtual field tour video from last year for detailed treatment information at http://cestanislaus.ucanr.edu/Agriculture/Vegetable_Crops/.

After a discontinuation in 2020 due to COVID-19, the 2021 grafted watermelon trial will include the identical rootstock-scion combinations as in 2019 and a new rootstock, Carolina Strongback, which has not been tested in California. Grafted plants are being produced by the California MasterPlant nursery (**Figure. 2**) and will be transplanted to the commercial field of Dan Avila & Sons in Ceres, CA. Seedless watermelon varieties, 7187HQ and Fascination, will be grafted onto five rootstocks (**Table 1**). All grafted and nongrafted controls will be transplanted into 3 different in-row spacings: 3 feet, 4 feet, and 6 feet with a corresponding per acre plant population of 2,200, 1,675, and 1,100. Like the tomato trial, the purpose is to figure out the balance among yield, quality, population, and production cost.

Table 1. The arrangement of treatments for the 2021 watermelon grafting trial.

Treatment no.						Scion	Rootstock
3 feet apart (Treatment no. 1-12)	1	4 feet apart (Treatment no. 13-24)	13	6 feet apart (Treatment no. 25-36)	25	7187HQ	RS841
	2		14		26	7187HQ	Flexifort
	3		15		27	7187HQ	UG29A
	4		16		28	7187HQ	XSQ9901
	5		17		29	7187HQ	Carolina Strongback
	6		18		30	7187HQ	non-grafted control
	7		19		31	Fascination	RS841
	8		20		32	Fascination	Flexifort
	9		21		33	Fascination	UG29A
	10		22		34	Fascination	XSQ9901
	11		23		35	Fascination	Carolina Strongback
	12		24		36	Fascination	non-grafted control

No endorsement of named varieties is intended, nor is criticism implied of similar varieties which are not mentioned.

Optimizing the use of crop biologics on vegetable crops. The 2020 UCCE Biologics Educational Webinar invited four speakers to present topics related to the regulation and practical use of different types of crop biologics (biostimulants, plant growth regulators, and entomopathogenic biopesticides). The four webinars attracted over 400 attendees from 16

Figure 2. Clockwise: germinated rootstock seedlings, germinated scion seedlings, close-up of a finished grafted plant, and grafted plants in the greenhouse.

countries. You may view the Biologics Educational Webinar YouTube presentations at http://cestanislaus.ucanr.edu/Agriculture/Vegetable_Crops/. In 2021, I will continue collaborations with biologics companies to conduct evaluation trials of biostimulants and biofungicide on tomato, watermelon, and other vegetable crops.

Optimization of irrigation management

Irrigation and nitrogen management for watermelon using CropManage. Water is precious in the Central Valley. Since the spring of 2021, over 90% of the state began experiencing drought conditions. Applying crop- and site-specific quantities of water and adopting sustainable and productive farming methods are key to maintain productivity and conserve water resources. This year I will leverage the irrigation online decision support tool, CropManage, to guide water application and nitrogen fertilization for vegetable crops. The first crop to be tested this year is watermelon. The testing trials will be conducted on a commercial watermelon field at Van Groningen & Sons near Stockton. Currently, I am working with the grower to adjust their irrigation system to incorporate a flow meter, a datalogger, and other supportive devices. More details, including the images of the finished layout, will be shared soon.

CropManage (https://cropmanage.ucanr.edu/), which was developed and is maintained by the University of California Agriculture and Natural Resources, has been used for research efforts by Farm Advisors, Specialists, and growers since 2011. Vegetables that have been adapted to CropManage include lettuce, carrot, spinach, cole crops, celery, and oriental species. For over 10 years, CropManage has been a credible, free-access, and long-term online decision support tool for efficient irrigation and nitrogen management. Watermelon is the first cucurbit crop to be adapted into the CropManage. Since a ripe watermelon consists of over 90% water, an efficient and adequate irrigation supply is a critical component in the production of watermelons for an attractive fruit quality. In many cases, unlike other vegetable crops, external rind appearance of a watermelon does not always respond to the inappropriate irrigation practice or predict the internal flesh quality. It is too late to correct irrigation practices when hollow heart, internal cracks, and low sugar contents of mature watermelon fruit are detected. Nitrogen fertilization and irrigation are inter-related. Feeding the plant with the needed amount of nitrogen at the right time can maximize the nutrient use efficiency and reduce the impacts of leaching and other losses on water quality.

On the other hand, the demand for grafted watermelon plants skyrocketed in 2021. According to interviews with main watermelon growers and greenhouse managers in the San Joaquin Valley, the total acreage of grafted watermelons has at least tripled compared to three years ago, reaching 1,200 acres (1/8 of the total watermelon acreage in California). This number excludes the acreage of producers from California's southern desert area and the Sacramento Valley. Therefore, it is reasonable to estimate that the 2021 statewide grafted watermelon acreage will exceed 2,000, accounting for more than 20% of the state watermelon production. In addition to disease resistance, massive information indicates that the most prominent advantages of growing grafted vegetables are the increases of yield and water/fertilizer use efficiency compared to regular plants due to the stronger root system and vigorous vegetative growth and flower formation. To maximize the yield potential of grafted plants, irrigation and fertilization management may have to be adjusted to accommodate their unique growth pattern after grafting and differentiated from the practices routinely used for nongrafted plants. This project will utilize the CropManage to develop crop (grafting vs. regular) and site-specific irrigation and nitrogen management practices through real-time monitoring of water applied, weather-based estimates of evapotranspiration, and measurements of volumetric soil water and tissue sample nitrate contents.

Fusarium Wilt of Tomato, Caused by *Fusarium Oxysporum f. sp. Lycopersici* Race 3– A Soil-borne Killer

Kelley Paugh and Cassandra Swett, Vegetable Crop Pathology, Department of Plant Pathology, UC Davis

DISEASE PROFILE

Fusarium oxysporum f. sp. *lycopersici* (Fol) race 3 causes Fusarium wilt, a disease currently affecting most tomato-producing counties in California. Fol is divided into groups called races, based on the ability to overcome genetic host resistance. Fol race 3 is the most recent race, which overcame genetic resistance to race 2. Fol race 3 was long restricted to the Sutter Basin but began spreading in the early 2000s and is now present in every county with large-scale tomato production – making this one of the greatest economic threats to the industry.

Growers are seeking solutions for this damaging soil-borne disease. In this article, we provide an issue overview as well as the latest information on Fusarium wilt race 3 spread, control, and prevention. The focus is on current research that is shining a light on new prospects for management of Fusarium wilt in tomato. This research is ongoing, and updates may be available from your local farm advisor.

Key characteristics of disease. Bright yellow foliage on one or several shoots on an otherwise normal plant are the earliest symptoms, typically starting at about 60 days after planting. The one-sided yellowing of a branch or whole plant can help distinguish this disease from other wilt pathogens (e.g. Verticillium wilt) and other causes of chlorotic conditions (e.g. nutrient disorders) (**Figure 1A**). From time of initial symptoms to harvest, disease symptoms progress from shoot yellowing to branch death. Disease progression may include decline of multiple branches, leading to partial or entire canopy collapse (**Figure 1B**). Fruits in this exposed canopy typically develop sunburn and may rot. Another important diagnostic feature of Fusarium wilt of tomato is the presence of chocolate-brown vascular discoloration in the plant stem (**Figure 1C**). Vascular discoloration is also a symptom of Verticillium wilt, which can lead to misdiagnosis, though usually tan in color instead. At advanced stages of Fusarium wilt, the general canopy collapse is similar to other tomato diseases, such as southern blight, bacterial canker, and Fusarium crown rots. Because of the potential for misdiagnosis of Fusarium wilt even by experienced scouters, it is prudent to submit plant samples to a diagnostics laboratory prior to making management decisions.

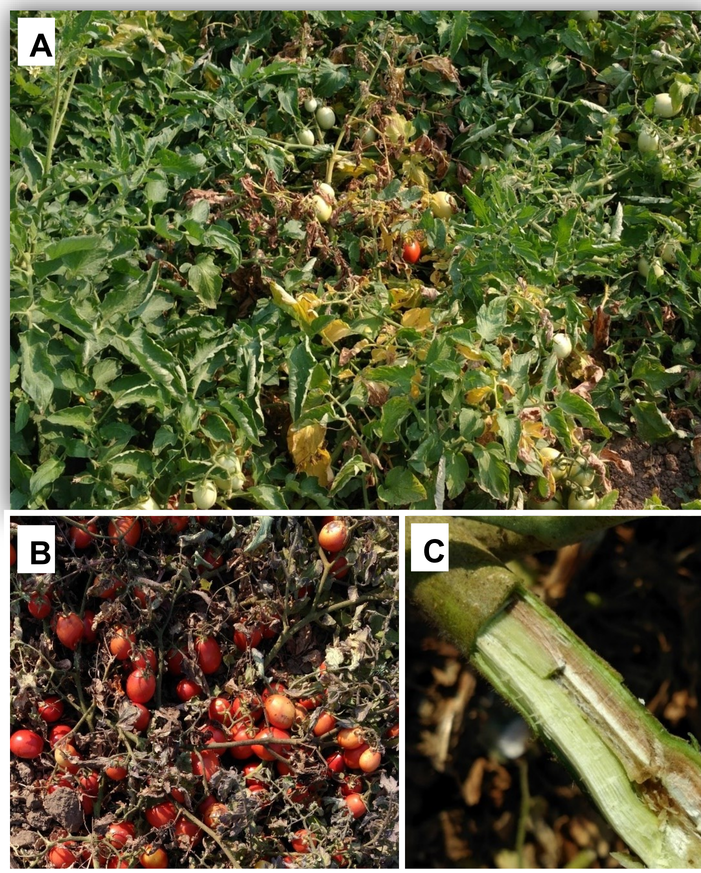

Figure 1. Symptoms of Fusarium wilt in tomato plants, shown here as a shoot with bright yellow and dying foliage (also known as “yellow flagging”) on an otherwise healthy plant (A), collapse of the vine (B), and chocolate-brown discoloration inside a stem (C). Photos taken by Kelley Paugh.

Survival and spread. Fusarium wilt race 3 occurs across Central Valley counties from the Sacramento Valley region (Colusa, Sutter, Yolo, Sacramento, and Solano) to the central San Joaquin Valley (San Joaquin, Stanislaus, Merced, Fresno, and Kings) and, most recently, to the southern end of the San Joaquin

Valley (Kern) (**Figure 2**). The pathogen is thought to move within a field and locally from field to field by hitching a ride on farm equipment that is contaminated with plant debris and soil. Hence, the increased movement of farm equipment across processing tomato regions may have facilitated spread of this disease. There is also speculation that the pathogen could move between fields or within a field in pathogen-laden irrigation water. For example, furrow irrigation may disperse the pathogen down planting rows with the flow of water. At present, there are no studies to substantiate this means of spread.

Once present in the field, this pathogen can persist for several years in soil. Although Fol can only cause *disease* in tomatoes, it can infect many different non-tomato crops, including melons, pepper, and sunflower and without causing any symptoms, and persist in both tomato and non-tomato crop residue in soil. Thus, Fol can feasibly be introduced into a field that has never had tomato, propagate on these silently-infected crops, and cause severe losses in the first year the field is planted to tomato. These "silent" hosts may be the reason that Fusarium wilt has historically been considered extremely long-lived in the

Figure 2. California counties with documented cases of Fusarium wilt race 3, as highlighted in red.

field, especially in cases where rotation out of tomato was ineffective. Of note, there are also many Fusarium wilt diseases of rotation crops (e.g., Fusarium wilt of cotton, garbanzo, melon, lettuce), but these Fusarium wilts are all caused by completely different pathogens. Therefore, the pathogen causing Fusarium wilt in these other crops will not cause Fusarium wilt in tomato.

MANAGEMENT

Overview of IPM for Fusarium wilt. The most effective tool for Fusarium wilt management is preventing pathogen introduction. If introduced into a field, then the disease can usually be successfully managed with resistant cultivars (F3 cultivars), although there are some caveats in F3 efficacy. If F3 cultivars are not available for management, pathogen-tolerant cultivars and early season chemical management options are also available. Crop rotation can help reduce pathogen pressure and reduce the risk that an F3 resistance-breaking race will emerge (race 4). At present, Fol race 4 has not been detected anywhere in the world, but UC Cooperative Extension advisors and specialists continue to monitor for its emergence annually. If you see Fusarium wilt symptoms in your F3 field, contact your local farm advisor to submit samples for testing.

Effective management of Fusarium wilt requires accurate diagnosis. As noted above, there are many diseases that look like Fusarium wilt, and at present, it is challenging to differentiate these diseases in the field. Before developing a Fusarium wilt management plan, it is critical to submit samples for analysis by a diagnostic lab. Soil testing tools for Fol race 3 are also under development at UC Davis (contact C. Swett for more information).

Management with host (genetic) resistance. Fol race 3 resistant cultivars, called F3 cultivars, typically develop no disease and are an excellent management tool. The tomato industry has worked hard to overcome challenges in F3 cultivar quality, yield, and seed availability. In addition, certain F2 cultivars are "tolerant" of Fusarium wilt race 3 – in that their yield does not appear to be significantly impacted in mildly infested fields. Fusarium wilt tolerance is not a listed trait for existing commercial cultivars, but this information is often available through seed dealers.

In some cases, F3 cultivars develop Fusarium wilt due to Fol race 3. This is typically attributed to either the presence of off-type plants which did not get the resistance gene (when incidence is below 2%) or environmental stresses (when incidence is higher). Abiotic and biotic stresses appear to play a role in influencing stability of resistance. Recent studies have demonstrated that salt stress can compromise F3 resistance and lead to Fusarium wilt development in up to 30% of F3 plants in a field. Likewise, root knot nematode and herbicide damage have both been associated with higher incidence of Fusarium wilt in F3 plants; previous studies have shown that root knot nematode could compromise genetic resistance to Fol race 1. While the role of various stresses in mediating Fol race 3 resistance is not well characterized, research in this area is ongoing. Management of these stresses may help maintain the efficacy of host resistance against Fol race 3.

Chemical control pre- and post-planting. Fol race 3 is notoriously difficult to control once established in soil. Although host resistance is the gold standard for management, F3 cultivars are not always an option. Chemical management may function as a short-term alternative. Recent studies have shown promising results for pre-plant fumigation as chemigation via buried drip irrigation with K-Pam HL (AMVAC Corporation) at 30 gal/A or higher (maximum rate of 60 gal/A) for optimal efficacy (**Figure 3**). Further work is needed to understand the cost-benefit aspects of using K-Pam HL to increase yield in infested fields.

Crop rotation. Rotation with non-host crops can reduce pathogen build up and survival in soils. However, the efficacy of this method relies on the inability of the pathogen to infect rotation crops. In multi-year studies we have found that several rotation crops are poor hosts and/or suppressive to pathogen build up in soils; these include cotton, bean crops (i.e., garbanzo, fava, lima, and green bean), grass crops, including wheat and potentially corn and rice (poor hosts, not field tested), as well as onion (**Figure 4**). These appear to be good crops to grow either right after tomato or the year before planting to tomato. Some crops, such as pepper, melons, pumpkins, and sunflower, are extensively colonized by Fol race 3 – even though these crops do not develop symptoms. Rotation with these heavily colonized crops can result in Fusarium wilt losses similar to what occurs with a repeat planting of tomato. Therefore, rotation with these crops should be avoided when possible, especially within a

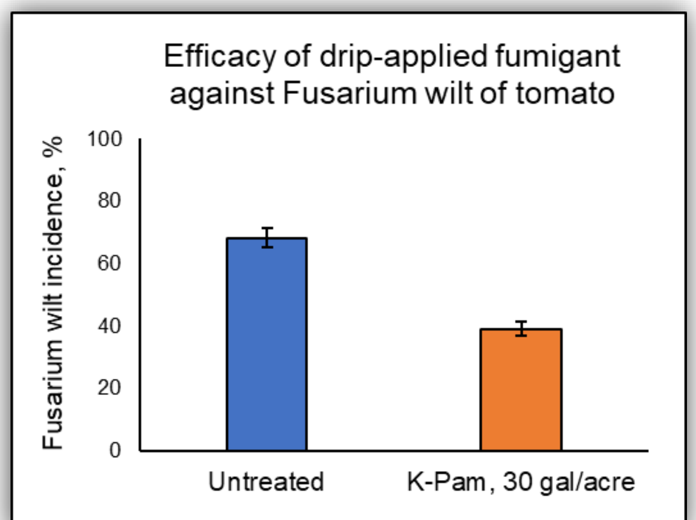

Figure 3. Results for a 2019 small plot trial at the UC Davis Plant Pathology research farm on the efficacy of the drip-applied fumigant, K-Pam HL, against Fusarium wilt of tomato. The experimental plot was too highly infested with the pathogen to observe a significant effect on yield; accordingly, K-Pam HL may be unsuitable for use in fields with high disease pressure.

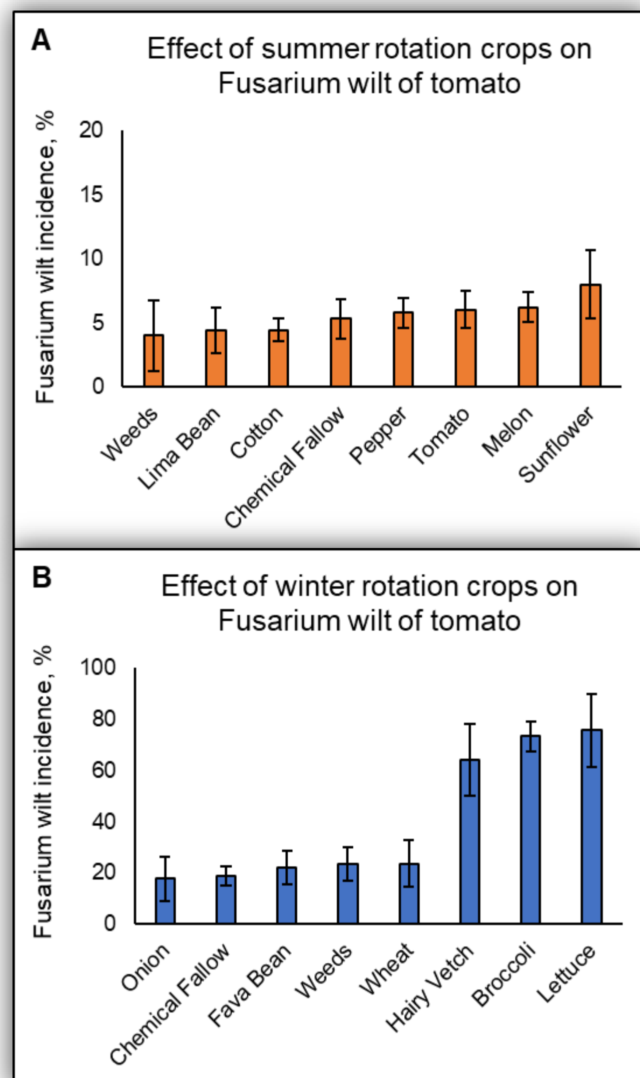

Figure 4. Results for small plot trials on the effect of rotation crop on development of Fusarium wilt in tomato. Plots at the UC Davis Plant Pathology research farm were previously planted to either a summer or winter rotation crop or tomato or left in chemical fallow (i.e. maintained vegetation-free through herbicide applications) or unmanaged fallow (="weeds"; weed species were not catalogued) in summer 2019 (A) or winter 2019-2020 (B), respectively. Plots were artificially infested with pathogen propagules during summer and winter rotation crop plantings. Yield impacts were not assessed in these experiments.

year before or after planting to tomato. Ongoing studies will further clarify the minimum duration that is needed for crop rotation to suppress disease.

No free rides for pathogens. The most effective tool for Fusarium wilt management is preventing pathogen introduction. This is best achieved through sanitation of equipment between fields. There is limited information on which equipment is the most important to target for sanitation, but *Fusarium* has been found at high levels on harvesters which retain large amounts of plant debris (**Figure 5**). Only using equipment that remains within the farm and avoiding use of shared equipment can help reduce the chances of pathogen infection and spread. However, this option is not available for many producers and is ineffective for preventing pathogen spread within a grower-controlled farm. There may be potential to minimize spread using an effective sanitation regime – perhaps including chemical disinfection or steam sterilization and using scrapers for physical removal of the bulk of plant debris and soil. There is a strong need for further study of the relative efficacy and logistics involved in implementing effective disinfestation practices.

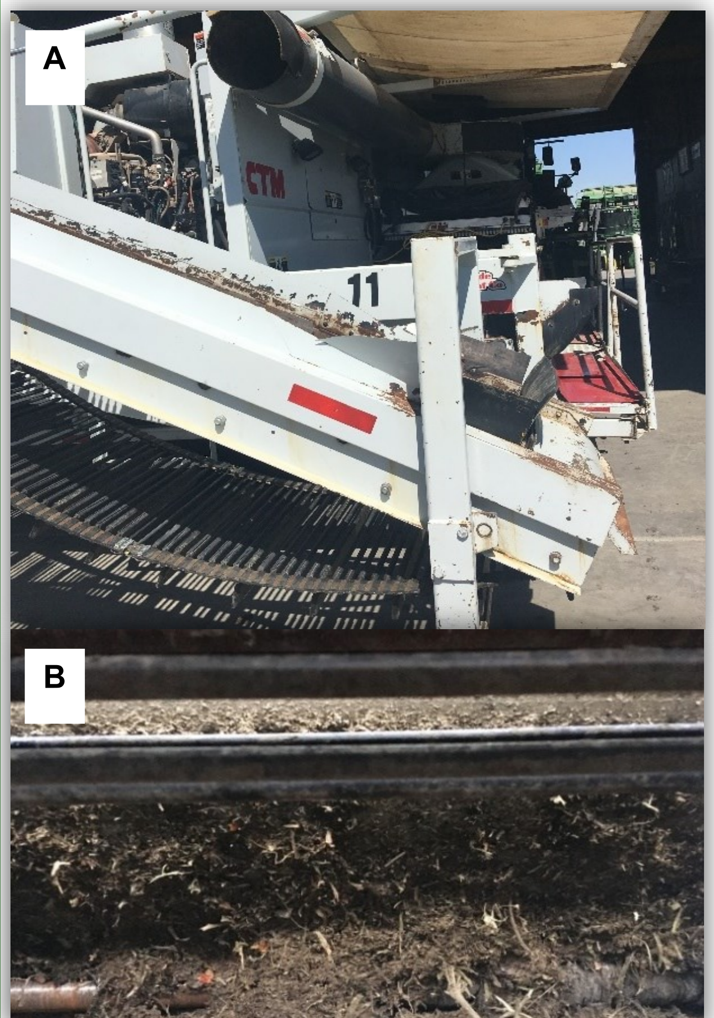

Figure 5. A tomato harvester (A) and soil and plant debris buildup on parts (B). Photos taken by Cassandra Swett.

Further management options under study. Compost amendments are commonly used for soil fertility management, and our recent studies suggest that composts may also suppress pathogen survival in soil. Pathogen-infested tomato residue decomposes more rapidly in soil with long-term inputs of poultry manure compost. Similarly, cover crops such as hairy vetch and broccoli are reported to suppress other Fusarium wilts, and these are being examined for Fusarium wilt of tomato in ongoing work.

WHERE TO GO NEXT

There are no documented cases of Fol race 4 in California – but, given the history of this pathogen, it is almost inevitable that a new race (race 4) will emerge that overcomes the genetic resistance that is effective against Fol race 3. As a result, race 4 monitoring continues to be a top priority across the state. Another concern is that Fol race 3 has been documented as causing disease in multiple F3 tomato fields, with indication that F3 resistance is compromised by stress. Understanding how biotic and abiotic plant stresses affects host resistance can help growers prioritize management strategies. In addition, long term studies of pathogen survival in soil are important for establishing both the optimal duration for rotating out of tomato and best choices for rotation crop. There are still several common rotation crops with unknown risk status, including corn, rice, safflower, alfalfa, and potato. To improve decision support, more accurate and rapid diagnosis and detection tools are needed for Fol race 3; the UC Davis Vegetable Pathology program is working to improve molecular tools for both soil detection and diagnosis in plants. Industry innovations in effective sanitation of farm equipment could also provide a breakthrough in slowing spread of Fusarium wilt and other soil-borne pathogens. Developing comprehensive strategies that minimize damage wrought by this disease will be critical for achieving healthy tomato production in California.

For more information, please contact: Cassandra Swett, clswett@ucdavis.edu