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Vegetable Diseases Caused by *Phytophthora capsici* in Arizona

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Figure 1. Several spore types of *P. capsici*. A: thread-like mycelia and lemon-shaped sporangia containing zoospores; B: swollen mycelia and chlamydospores 22 to 39 µm in diameter; and C: oospores 22 to 35 µm in diameter (oospore image courtesy of M. Babadoost).

Introduction

Phytophthora capsici is responsible for some of the most important diseases of peppers and cucurbits worldwide. The diseases are commonly referred to as Phytophthora blight, Phytophthora crown and root rot, Phytophthora fruit rot, and damping off. *P. capsici* was first described by Leon H. Leonian on chile pepper in New Mexico in 1922. This pathogen subsequently has caused severe disease epidemics on susceptible vegetables in North, Central and South America, Europe, Asia, and many states across the United States. In Arizona, the disease has become a chronic problem for pepper, squash, and melon production in the southern part of the state. *P. capsici* can cause extensive losses on peppers and cucurbits under favorable weather conditions during the summer monsoon season.

Pathogen and Hosts

Phytophthora blight is caused by *Phytophthora capsici*, an oomycete, which is "fungus-like" but not a true fungus. *Phytophthora* and related organisms are commonly referred to as "water molds" because they are well adapted to an aquatic environment and require the presence of water for infection to occur. They thrive, grow, reproduce, and infect plant roots in saturated soil conditions, or aboveground plant parts covered in a film of water. The pathogen produces abundant sporangia containing zoospores (Figure 1 A). Under moist conditions, each sporangium releases numerous single-celled, motile zoospores (asexual spores), which are effectively dispersed in short distance by splashing water or air movement. *P. capsici* also produces chlamydospores (thick-walled asexual spores, Figure 1B) and oospores (thick-walled sexual spores, Figure 1C). Oospore production usually occurs late in the growing season.

More than 72 plant species from 27 diverse families including cultivated crops, ornamentals, and native plants, have been reported to be hosts of *P. capsici* under laboratory and greenhouse conditions. However, under natural field conditions, *P. capsici* attacks only a small subset of these hosts in the plant families of Cucurbitaceae, Fabaceae, and Solanaceae (Table 1).

Table 1. Vegetable crops susceptible to *Phytophthora capsici* under natural field conditions

Plant family	Common name	Scientific name
Brassicaceae	Radish	*Raphanus raphanistrum* subsp. *sativus*
Cucurbitaceae	Acorn (winter squash)	*Cucurbita pepo* var. *turbinata*
	Butternut squash (winter squash)	*Cucurbita moschata*
	Cantaloupe	*Cucumis melo* var. *cantalupo*
	Cocozzelle (summer squash	*Cucurbita pepo* var. *inoga*
	Crookneck (summer squash)	*Cucurbita pepo* var. *torticollia*
	Cucumber	*Cucumis sativus*
	Gourd	*Lagenaria sp.* and *Cucurbita sp.*
	Honeydew melon	*Cucumis melo*
	Pumpkin (winter squash)	*Cucurbita maxima* and *C. pepo* var. *pepo*
	Muskmelon	*Cucumis melo*
	Scallop (summer squash)	*Cucurbita pepo* var. *clypeata*
	Straightneck (summer squash)	*Cucurbita pepo* var. *recticollis*
	vegetable marrow (summer squash)	*Cucurbita pepo* var. *fastigata*
	Watermelon	*Citrullus lanatus* var. *lanatus*
	Zucchini (summer squash)	*Cucurbita pepo* var. *cylindrica*
Fabaceae	Broad bean	*Vicia faba*
	Common bean	*Phaseolus vulgaris*
	Pea	*Pisum sativum*
Solanaceae	Bell pepper and chile pepper	*Capsicum annuum*
	Eggplant	*Solanum melongena*
	Tomato	*Solanum lycopersicum*

Figure 2. Damping-off of seedlings. Brown water-soaked lesions on the roots.

Figure 3. Root and crown rot, and black stem lesion beginning at fork of a branch.

Figure 4. Root rot that kills root and causes wilting of the plant without the appearance of black stem lesions or cankers.

Symptoms and Signs

P. capsici causes seed rot and seedling blight in solanaceous and cucurbit crops. Seedling blight includes both pre-emergence and post-emergence damping-off. Rotting of stem and root tissues occurs at and below the soil surface. Fruit touching the ground or near the soil are most prone to infection and rot. Infected plants become water-soaked and mushy, fall over at the base and die. On mature plants, the pathogen may infect virtually every part of the plant and produces a wide variety of symptoms including root rot, crown rot, collar rot, fruit rot, blight, and stem canker. The symptoms vary by hosts. The primary inoculum persists in soil, so infections start at the roots and work up the plant. Initial symptoms often occur in low-lying areas of a field where excess rain or irrigation water accumulate.

Pepper

Both bell peppers and chile peppers are susceptible to the disease, especially in waterlogged soils. Damping-off with rapid onset of wilting may occur on seedlings in low-lying areas of a field (Figure 2). *Rhizoctonia* spp. may also contribute to seedling damping-off symptoms. On mature plants, *P. capsici* may causes a root and crown rot as well as distinctive black lesions on the stem (Figure 3). Root infections may kill roots and cause wilting of the plant without the appearance of black stem lesions (Figure 4). The inoculum in the soil can be dispersed to leaves and fruit through splashing water under favorable conditions. Infected leaves first show small dark green spots that enlarge and become

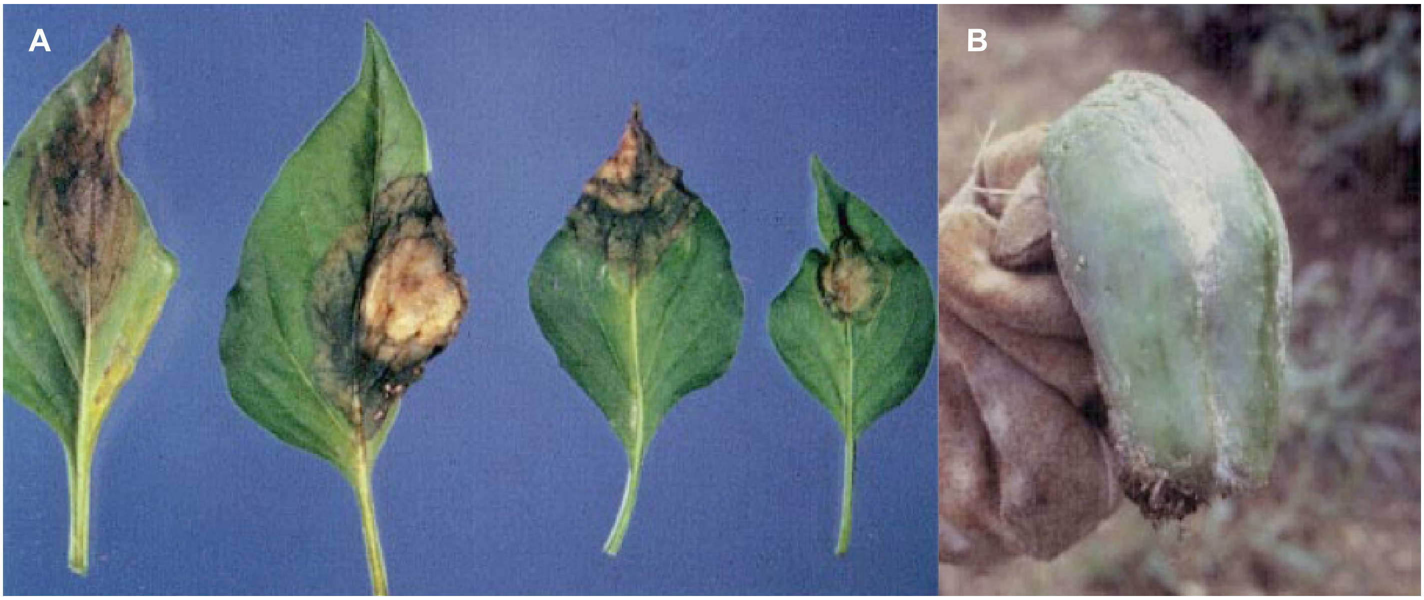

Figure 5. Foliar and fruit symptoms. A: leaf with dark green, grayish brown and water-soaked lesions; B: fruit lesions coated with white mold and spores (Image courtesy of J.B. Ristaino).

Figure 6. Phytophthora blight of pepper in a chile pepper field, caused by *P. capsici*.

circular or irregular, grayish brown, and water-soaked (Figure 5A). Extensive defoliation may occur during extended rainy and warm weather. Infected fruit first develop dark, water-soaked areas, which then shrivel, darken and become covered with white mold (Figure 5B). Phytophthora blight causes significant yield losses of up to 100% in Arizona (Figure 6).

Cucurbits

All cucurbits are susceptible. Rotted crown tissue is a common symptom (Figure 7A). Dark-green, water-soaked lesions develop on the crown or vines, girdling them and causing the entire plant to turn yellow or brown and die. Foliar symptoms are less common and include leaf lesions and wilting (Figure 7B and C). Fruit rot symptoms appear as water-soaked, sunken areas with

Figure 7. Foliar symptoms A: crown rot; B: leaf lesions; C: wilting (Image courtesy of G. Holmes, California Polytechnic State University, Bugwood.org).

Figure 8. Fruit rots on cucurbits. A: summer squash; B: zucchini squash; C: gourd, D: pumpkin; E: acorn squash; F: cucumber; and G: watermelon (Image courtesy of G. Holmes, California Polytechnic State University, Bugwood.org).

white mold (spores) that resemble powdered sugar (Figure 8A-G). Infected fruit rot may become colonized by other secondary bacterial and fungal organisms. Some squash and pumpkin cultivars, such as butternut, acorn squash, and jack-o-lantern pumpkins, become more resistant to rot as the fruits mature; however, many other cultivars remain susceptible.

Eggplant

Symptoms on eggplant are similar to those of cucurbits. The entire plant is susceptible. Black stem lesions often develop at a branching point where water accumulates, resulting in dark, girdling cankers and wilting of leaves and fruit (Figure 9A and B). On infected leaves, circular or irregular, dark green, water-

Figure 9. Phytophthora blight on eggplant. A: dark stem lesion; B: dark stem lesions with diseased fruit; C: leaf lesions; D: fruit rot (Image courtesy of Image courtesy of G. Holmes, California Polytechnic State University, Bugwood.org).

soaked lesions initially form, which subsequently dry and appear light tan (Figure 9C). Fruit lesions are common where fruit contact the soil and begin as water-soaked and sunken areas that enlarge rapidly and are covered with white mold that looks like powdered sugar (Figure 9D).

Tomato

Several *Phytophthora* species including *P. capsici, P. infestans, P. nicotianae*, and *P. drechsleri* can cause similar symptoms on tomato. The most typical symptom is root rot with brown lesions on affected roots. The xylem tissue within the plant stem (water-conducting vessels) often appears yellow or brown (Figure 10A). Common foliar symptoms include stem girdling just above the ground, rapid wilting, and dark stem lesions (Figure 10B-D). Fruit lesions are tan or brown spots with concentric rings, which may be coated with white mold that looks like powdered sugar (Figure 10E-F).

Disease Cycle

Soilborne oospores or mycelia in infected tissue are the main sources of primary inoculum, but other potential sources of inoculum may exist. For example, *P. capsici* can be seedborne and may be spread by contaminated seeds. Weeds such as geranium and common purslane are alternate hosts and may serve as an inoculum reservoir. Transplants can also carry the pathogen. Initial infection often occurs in plants growing in low-lying, poorly drained areas of fields.

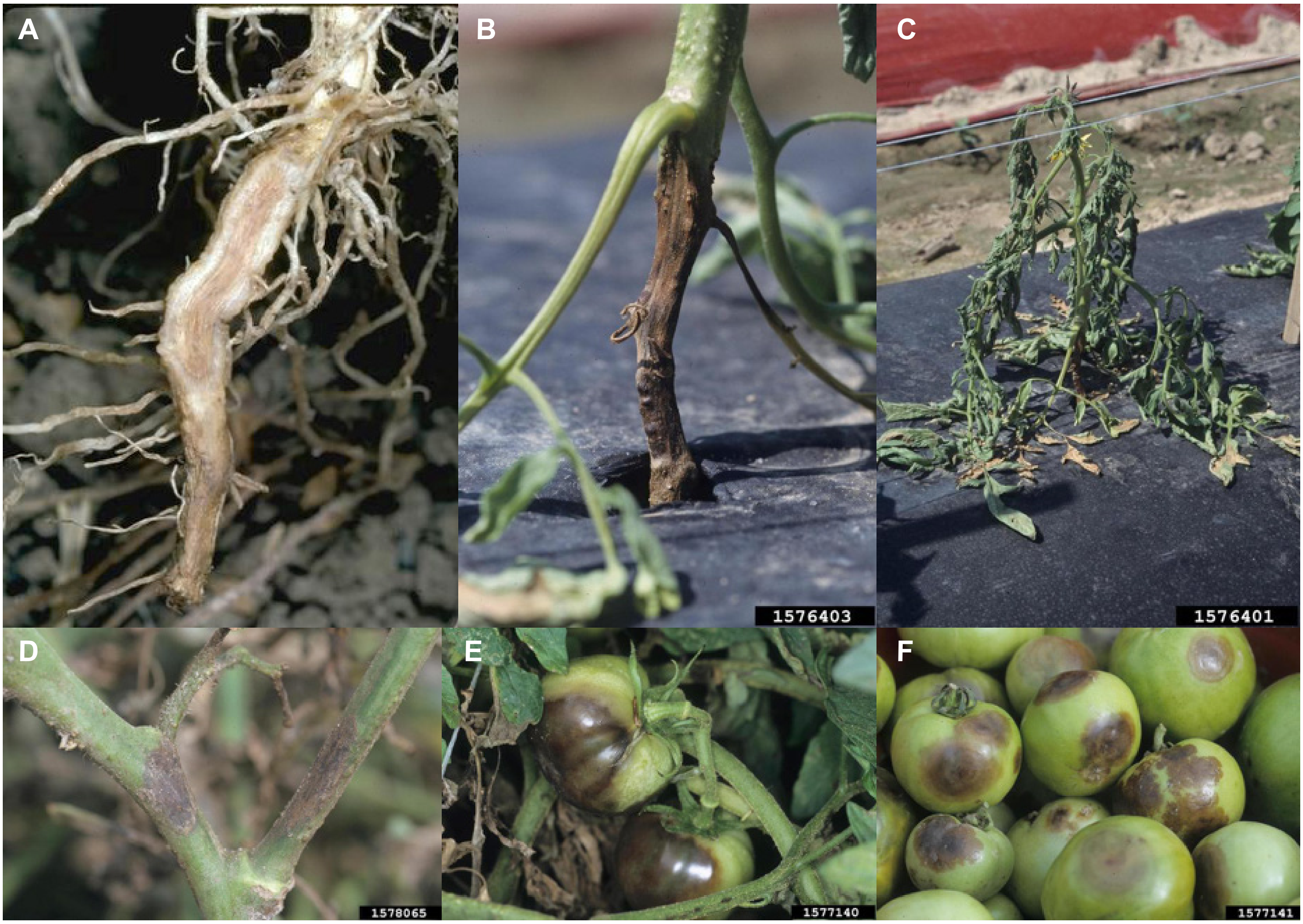

Figure 10. Phytophthora blight on tomato. A: yellow or brown xylem tissue of infected roots; B: girdled stem at the soil line; C: wilting; D: dark stem lesions; E and F: buckeye rot (Image courtesy of Image courtesy of K. Clark and G. Holmes).

Sexual oospores are produced when mycelia of two opposite mating types (similar to male and female) come into close proximity. They remain dormant in soils until wet conditions favor germination. Thick-walled oospores are highly resistant to desiccation, cold temperature, and other extreme environmental conditions, and are able to survive in the soil, in the absence of a host plant, for years. Dormant oospores germinate during wet conditions to produce sporangia, which may directly infect host tissues, or release swimming zoospores. Sporangia and zoospores are produced abundantly on infected roots, crowns, and fruit, and are dispersed by rain, irrigation, and surface run-off water. Zoospores can swim for several hours and initiate infection upon contact with host tissue. The pathogen can continuously produce multiple cycles of zoospores, driving disease development throughout crop season.

The disease is favored by excessive soil moisture conditions as well as warm and wet weather. Heavy rainfall, excessive-irrigation, saturated soils and temperature ranging from 75 to 85 °F (ideal temperature 80.6 °F) are conducive for rapid disease development. The pathogen may spread between fruit during transit if temperatures are above 70 °F. Disease progress slows down when dry weather returns. Sporangia form and release zoospores when soil is saturated (soil pores are filled with water). Frequent irrigation increases the incidence of the disease.

Control

Early detection, pathogen containment and good water management are key preventative tactics to manage Phytophthora blight on vegetables. Waiting until the disease is detected in a crop to begin control measures is often fighting a losing battle if conditions favor disease development. Ideally, an integrated approach should be used to reduce disease incidence and severity. This integrated disease management approach can be achieved by using a combination of measures including exclusion, preventative tactics, cultural practices, sanitation, resistance, and chemical control.

1. Select fields with no history of Phytophthora diseases and practice crop rotation with small grain crops or other non-susceptible crops for a minimum of 3 years. Avoid planting sites on poorly drained fields with heavy and compacted soils. Keep current production fields away from fields previously infested with Phytophthora. Avoid using a Phytophthora-contaminated water source (run-off water from infested fields). Avoid using seeds saved from infested fields.
2. Plant pathogen-free seeds and transplants. Scout for the presence of typical disease symptoms in low areas of fields after heavy rainfall or prolonged periods of leaf wetness.

The drainage area of the field should be kept free of weeds and volunteer crop plants. Avoid excessive use of nitrogen fertilizer, which promotes succulent tissue that is more prone to infection, and large foliar canopies that favor leaf wetness and make foliar application of chemicals difficult.

3. If only a few diseased fruit or plants are found, and it is feasible, they should be removed and destroyed. Avoid working in wet fields. Work in fields without diseased plants before working in infested fields. Clean farm equipment of soil residues between fields.
4. Plant resistant cultivars, if available. Plant crops in well-drained soil on a ridge or elevated dome-shaped bed (about 9 inches high). Avoid excessive irrigation, preferably using drip or furrow irrigation instead of overhead irrigation. Irrigate in the morning to promote drying of foliage. Reduce leaf wetness by increasing plant spacing, limiting canopy size, and staking the plants. Using straw mulch to reduce water-splash dispersal. Harvest healthy fruit from infested area as soon as possible and keep them dry and cool.
5. Chemical control should be combined with other practices described above to manage foliar blight and fruit rot. Seed treatment with fungicide is also recommended. Apply fungicides preventatively prior to a rainstorm or before conditions are favorable for disease development. Apply at the early stage of plant growth to avoid large and dense canopies, which requires proper application equipment and a significant water volume to penetrate the canopy. A limited number of fungicides are available for combating this disease. Major compounds include metalaxyl or mefenoxam, fluopicolide, cyazofamid, ethaboxam, mandipropamid, ametoctradin, dimethomorph, oxathiapiprolin, mancozeb, and copper compounds. Since resistance to both metalaxyl and mefenoxam has occurred in many parts of the US, it is important to rotate with compounds containing different modes of action to prevent populations of Phytophthora from developing resistance. Refer to the product label for application instructions and, because product labels frequently change, refer to a pesticide database, such as Crop Data Management Systems Inc. (www.cdms.net) or the product manufacturer's website for updated labels.

Resources

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