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report on
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DISEASE

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BACTERIAL SOFT ROT OF VEGETABLES, FRUITS, AND ORNAMENTALS

Soft rot, caused by several types of bacteria, but primarily subspecies and pathovars of *Erwinia carotovora* and *E. chrysanthemi*, is a widespread and destructive disease of fleshy fruits, vegetables, and ornamentals throughout the world. Other bacterial species that cause soft rot include *Pseudomonas cichorii, P. marginalis,* and *P. viridiflava*. Soft rot losses may occur in the field, garden, greenhouse, or after harvest during transit, storage, or marketing. The bacteria chiefly attack succulent, tender tissues of storage organs such as fleshy tubers, fruits, roots, bulbs, corms, and rhizomes, as well as bud, stem, petiole and leafstalk tissues. The host range is large, and includes genera from nearly all plant families (Table 1).

Figure 1. Bacterial soft rot affecting cabbage plant (photo courtesy of M.A. Cubeta, NC State).

The causal organisms are common in most soils, particularly those frequently cropped with susceptible plants. Soft-rot bacteria are a constant threat because of their extensive host range and widespread distribution.

SYMPTOMS

The symptoms of soft rot are similar on most plants. The disease starts on leaves, stems, and underground parts as small, water-soaked, translucent spots (lesions). These rapidly enlarge in both diameter and depth. The host tissue softens and becomes mushy or watery (Figures 1-5). Slimy masses of bacteria and cellular debris frequently ooze out from cracks in the tissues. Within 20 to 72 hours, entire fleshy fruits, roots, tubers, stems and rhizomes, bulbs, corms, buds, leafstalks, and leaves may rot and collapse, sometimes leaving only the outer "skin" intact. Decaying tissue, which may be opaque, white, cream-colored, gray, brown, or black frequently gives off a characteristically putrid odor. The odor is caused by secondary invading bacteria that are growing in the decomposing tissues.

Figure 2. Bacterial soft rot of green onions.

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Potato seed tubers may rot in wet soil (Figure 4). Shoots arising from infected tubers become watery, wilt, and then collapse. this potato disease is commonly called blackleg. Blackleg is simply soft rot that spreads from rotting seed pieces into the stems of the new potato plants. If the soil moisture level is lowered, the base of the shoots may become soft, brown to inky-black, and shriveled. The leaves on such shoots are dwarfed, stiff, curled upward, and are yellowish, red, or bronzed. Affected shoots are also stunted, more upright, and pale in color. Such plants often die prematurely or their yield is reduced.

Figure 3. Early stage of bacterial soft rot on potato tubers. Note skin discoloration at points of infection.

When the fleshy roots, rhizomes, tubers, corms, and crowns of such plants as calla lily, carrot, cyclamen, iris, parsnip, and turnip are attacked in the field, garden or greenhouse, the foliage may turn yellow or wilt, later withering or collapsing (Figures 6 and 7). The soft-rot bacteria invade the plant at the crown; and the slimy decay frequently extends deeply into the underground parts, while the outer tissues remain firm and apparently healthy.

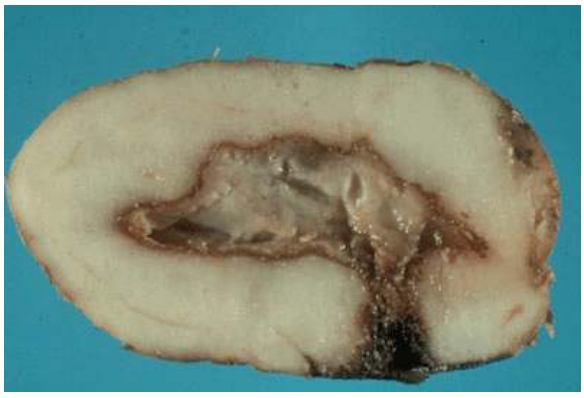

Figure 4. Advanced decay of blackleg, soft rot entering thru wound.

Leafy crops including lettuce, endive, escarole, chicory, and spinach may turn into watery, green, slimy masses within a day or two at room temperature if stored in plastic containers or in warm, humid storage areas.

DISEASE CYCLE

Soft-rot bacteria overwinter in infected fleshy tissues in storage, in the field, garden or greenhouse, in the soil (especially in the rhizosphere around the roots of many plants), and on contaminated tools, equipment, containers, and in certain insects.

The bacteria enter primarily through wounds made during planting, cultivating, harvesting, grading, and packing and through freezing injuries, insect and hail wounds, growth cracks, and sunscald. They may also follow other disease-producing organisms. Uninjured tissues may become infected when the humidity approaches 100 percent or when free moisture is present. Rains, poorly drained or waterlogged soils, and warm temperatures favor infection in the field, as does high humidity in storage or transit.

Free moisture on the surface of the host is essential for bacterial penetration. After infection the bacteria multiply profusely in the intercellular spaces where they produce enzymes that dissolve the middle lamella, the compound that binds host cells together. Affected tissues disintegrate into a mushy mass of disorganized cells surrounded by bacteria and their enzymes. The cells lose water and their contents shrivel (plasmolyze). Finally, parts of the cells are dissolved and cells are invaded by bacteria.

The bacteria multiply rapidly by dividing in half every 20 to 60 minutes under ideal conditions at temperatures between 65° and 95° (18° and 35°C). Minimum temperatures for development is between 35° and 46°F (2° and 6°C); and maximum between 95° and 105°F (35° and 41°C), depending on the

species of bacterium involved. The bacteria are killed at temperatures above 122°F (50°C).

The bacteria are spread by direct contact, hands, tools and farm machinery, insects, running or splashing water, contaminated water in washing vats, clothing, and decayed bits of tissue.

Figure 5. Chrysanthemum topple caused by a species of Pseudomonas (courtesy British Ministry of Agriculture).

CONTROL

1. Promptly and carefully destroy infected plants and rotted bulbs, corms, rhizomes, tubers, roots, or other affected plant parts when first found.

2. Plant only disease-free planting stock free of cuts and bruises. Plant certified, blue tag seed potatoes. Use small, whole tubers (B-sized), or allow cut seed to cork over well before planting. Cold, wet soil inhibits the wound-healing processes, therefore delay planting until the soil is warm. Start with cultured, indexed cuttings of carnation, chrysanthemum, geranium, poinsettia, and other available plants.

3. Do **not** plant in poorly drained, unfertile soil. Avoid close planting, poor air circulation, overhead irrigation, overwatering (saturating the soil), excessive nitrogen fertilization and too much shade.

   In greenhouses and plant beds, steam-sterilize the soil or use sterile soil mixes. Plant into new or clean pots, packs, or other containers.

Figure 6. Wilted cyclamen plant affected by bacterial soft rot. The rot, which progressed through the corm is caused by Erwinia carotovora subsp. carotovora (Il Natural History Survey photograph).

4. Where feasible, rotate vegetables and fruits with corn, small grains, grasses, alfalfa, or clovers.

5. Where called for, treat the soil before planting with a recommended insecticide. Spray or dust the field or garden to control foliage-feeding insects. Follow the recommendations of University of Illinois Extension entomologists and your county Extension adviser. Insecticides applied to the soil or foliage control borers, grubs, wireworms, maggot flies, stinkbugs, beetles, and other insects that commonly cause wounds and disseminate the soft-rot bacteria.

Figure 7. Bacterial soft rot, following invasion by an iris borer, caused these iris leaves to collapse.

6. Control foliage blights, fruit and root rots, and other diseases as described in Midwest Vegetable Production Guide for Commercial Growers. Home vegetable growers should follow the suggestions outlined in Report on Plant Diseases No. 900, "Controlling Diseases in the Home Vegetable Garden." All of these publications are available through your nearest Extension office.

7. Avoid wounding plants when cultivating, digging, handling during and after harvest, packing, and storing. Harvest during dry weather.

8. Store only dry, sound, healthy, mature, blemish-free plants, produce, and storage organs in a clean, dry, well-ventilated area at the recommended temperature and humidity.

   If diseased material has been stored previously, first sweep the area clean and then thoroughly spray all surfaces, from ceiling to floor, with a disinfectant solution (Table 2). Disinfect tools by dipping in 70 percent denatured alcohol, 5 percent formaldehyde solution, Physan 20 or LF solution. Dispose of diseased plant material before it comes into contact with healthy plants.

   Precool leafy vegetables, fruits, and root crops to 45°F (5°C) or below, and then place in cold storage (32°C to 39°F or 0° to 4°C) as soon after harvest as possible. Store potatoes at 40°F (4.5°C), after first curing at a moderate temperature (50° to 75°F or 10° to 24°C) and high humidity (85 percent) for several days following harvest to allow injured surfaces to "cork over." Do not place freshly harvested or washed tubers directly into refrigerated storage.

   The appearance of soft-rot symptoms in storage or transit can be delayed by holding plants and produce at a temperature of 39° to 45°F (4° to 6°C). Low temperatures do not prevent bacterial infections, but they do slow down development of soft rot. Holding fresh produce in prepackaged containers just above freezing is probably the best way to preserve it.

   Soft rot may develop rapidly after the plants and plant parts have been removed from refrigerated storage. Layers of dry material (straw, sawdust, dry sand, and the like) between layers of rot crops (e.g., carrots, parsnips, turnips, and beets), bulbs, corms, tubers, and rhizomes help to keep down moisture and slow down the spread of soft rot through the storage area.

9. If vegetables and fruits are washed before storage or shipment, use a disinfectant such as chlorine in all wash water to reduce the chance of soft-rot bacteria infecting through wounds. Chlorine gas, sodium hypochlorite (household bleach), and calcium hypochlorite (chlorinated lime) are the most common chlorine-containing disinfectants in general use. All chlorine containing chemicals form the same disinfecting ingredient, hypochlorous acid, when added to water.

   When using chlorine as a disinfectant to vegetable and fruit wash water, the pH, organic matter, temperature, and concentration should be closely monitored.

   a. The disinfectant activity of a chlorine solution is determined by its pH. The lower the pH (more acid), the greater the amount of hypochlorous acid available for disinfection. However, vegetables and fruit are damaged by low-pH chlorine solutions; therefore, maintain the pH between 6.0 and 7.5 to provide the greatest effectiveness without damage. The pH may be measured with litmus paper, commercial test kits, or pH meters.

   b. Organic matter "ties up" chlorine in solution, thereby reducing the effective concentration. The more organic matter there is in the solution, the more chlorine is tied up. Sources of organic matter in the wash tank include soil organic matter, stems, leaves, broken skin, etc. Although this interaction of chlorine and organic matter does present problems in maintaining an effective chlorine concentration, this very feature makes possible the use of chlorine on fruits and vegetables.

c. As the temperature increases, so does the effective chlorine concentration. The tie-up by organic matter also increases with higher temperatures. For example, low temperatures in hydrocoolers require more chlorine to achieve the desired effective concentration.

d. Concentrations of chlorine must be monitored so that enough is present to kill soft-rot bacteria in the wash water. To maintain adequate levels (50 to 70 parts per million), chlorine should be metered into the water. Chlorine concentrates may be monitored by using kits such as those used to check chlorine levels in swimming pools. The most effective treatment results when chlorine is continuously metered into the water. However, the most common method is to occasionally add chlorine to the tank.

After washing the vegetables and fruits in chlorine solution and rinsing in clean, fresh water, dry them in warm, forced air. Immediate drying greatly reduces the chance of soft rot.

10. During hot weather, coordinate digging, sacking, packing, and trucking so that freshly harvested produce does not lie on the soil surface exposed to the sun for more than 15 minutes.

11. For calla lily and iris, cut out rotted portions in bulbs, corms or rhizomes. Dry thoroughly for a day or two then soak for an hour in a 2 percent formaldehyde solution. Drain and plant immediately.

Table 1. Partial list of plants susceptible to bacterial soft rot

aechmea	chives	hoya
African violet	chlorophytum	hyacinth
alliaria	chrysanthemum	India rubber plant
alocasia	citron	iris
aloe	clitoria	ixia
amorphophallus	collard	Jerusalem-artichoke
aphelandra	comfrey	Jerusalem-cherry
apple	corn	kafir lily
artichoke	cotton	kalanchoe
arum	cowpea	kale
asparagus	crassula	kohlrabi
asparagus-bean	crocus	larkspur
aspidistra	cucumber	leek
asters	cyclamen	lettuce
avocado	cycnoches	lily
balsam-pear	cyphomandra	lockhartia
banana	dahlia	lupine
beans, garden and broad	dandelion	lycaste
beaucarnea	dasheen	mangel
beet, garden and sugar	daylily	mango
begonia	delphinium	mangold
bletilla	dieffenbachia	marguerite
borage	dracaena (*Coryline)*	Mexican prickly poppy
brachiaria	dragonroot	monstera
brassaia	eggplant	mushrooms
brassavola	elephants-ear	muskmelon
broccoli	endive	mustards
Brussels sprouts	epiremnum	Napier grass
cabbage	escarole	narcissus
cacti	eucharis	nicandra
caladium	eutrema	nightshade
calla	fennel	nopalea
calla lily	ferns	okra
camomile	feverfew	onions
canna	fig	orange
canola	finocchio	orchids
cantaloupe	fittonia	pansy
carnation	fritillaria	papaya
carrot	garlic	parsley
casaba	geranium	parsnip
cauliflower	ginger	pea
celeriac	gladiolus	peach
celery	gourds	pear
century plant	grape hyacinth	peperomia
chicory	guayule	pepper
Chinese cabbage	Guinea grass	petunia
Chinese evergreen	hamanthus	philodendrons
Chinese waxgourd	horseradish	pineapple

pinks, garden	sansevieria	Swiss chard
plantain	scarboro-lily	syngonium
poinsettia	schizanthus	tobacco
poppy	scindapsus (pothos)	Tomato
potato	sedums	trillium
prickly pear	shallot	tritonia (Montbretia)
primrose	Shasta daisy	tuberose
pumpkins	sorghum	tulip
radish	soybean	turnip
rape	spinach	vanda
rhubarb	squash	vegetable-marrow
rice	stock	violet
rutabaga (swede)	strawberry	wallflower
salacca	sugarcane	watermelon
salpiglossis	sunflower	xanthosoma (Yautia)
salsify	sweet potato	zinnia

Table 2. Disinfectants for storage rooms, bins, crates or boxes, packing areas, and dump tanks

	Concentration	Comments
Sodium hypochlorite	1,000 to 1,900 ppm	Do not rinse
Sodium O-Phenylphenate	0.1 to 0.3%	Do not rinse
Peracetic acid (peroxacetic acid)	3,000 ppm	Dip or spray
Formaldehyde	1 pt/15 gal	Wet surfaces thoroughly. Close tightly and ventilate before entering.
Calcium hypochlorite	700 to 5,000 ppm	Rinse all surfaces which will contact plant parts.
Alkyd dimethyl benzyl ammonium chlorite	1,600 ppm	Spray on precleaned, rinsed surfaces. Rinse all food-contacting surfaces with clean water before use.