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APPLE REPLANT DISEASE *WSU TREE FRUIT IPM STRATEGIES*

Written by **Shashika S. Hewavitharana**, Assistant Professor, California Polytechnic University, San Luis Obispo; **Tianna DuPont**, Tree Fruit Extension Specialist, Agricultural and Natural Resources, Washington State University; and **Mark Mazzola**, Research Plant Pathologist, USDA-ARS

Replant disease is a widespread problem in areas that grow tree fruit and nuts, greatly impacting intensive apple production. It is characterized by reduced productivity in fields repeatedly planted to the same or closely related tree fruit or nut crops. It can also occur in tree fruit and nut nurseries. In apple orchards, the disease reduces productivity costing growers \$70,000 to \$150,000 an acre during the first four years of orchard production (Mazzola and Mullinix 2005; Mazzola and Brown 2010; Mazzola et al. 2015). It is also called by multiple names, such as soil sickness, soil exhaustion, replant disorder, and replant problem.

Research suggests that harmful soil microorganisms are the main cause of replant disease; however, abiotic factors, including low soil fertility, residual herbicide activity, and degraded soil structure have also been linked to replant problems. In this factsheet we will describe replant symptoms, disease causing organisms, and management recommendations.

Symptoms

Disease symptoms include uneven growth between trees in the block with patches to large areas of stunted trees and shortened internodes (Figure 1). Symptoms generally become visible in the first two years after planting. When a tree is uprooted, discolored roots, root tip necrosis, and reduced root biomass can be seen. Young trees may die within the

first year. Many will survive, but overall fruit production and quality are reduced.

Causal Organism and Disease Cycle

The disease is caused by a pathogen complex that consists of fungi, oomycetes (fungi-like organisms), and nematodes. Individual orchards may have one or multiple organisms causing the syndrome (Figure 2). In Washington State, the disease is caused by multiple species within several genera of fungi, such as *Rhizoctonia* and *Ilyonectria*, and oomycetes, such as *Phytophthora* and *Pythium*; and also lesion nematode: *Pratylenchus penetrans* (Mazzola 1997; Mazzola 1998).

Contaminated soil, irrigation water, or planting stock can all be sources of inocula. The fungal and oomycete pathogens produce overwintering structures like sclerotia (*Rhizoctonia*), chlamydospores (*Ilyonectria*), and oospores (*Phytophthora* and *Pythium*) that can survive in dead or dormant roots and in soil. Lesion nematodes survive in the soil and plant residues as eggs and as multiple generations of juveniles and adults (Agrios 2005).

In the spring when newly planted or recently dormant roots become active, the pathogen propagules germinate, and nematode eggs hatch in response to exudates from the roots. Fungi and oomycete mycelia grow from the propagules and infect the fine roots.



Figure 1. Trees on the left are in a site with replant disease compared to healthy trees on the right. Photo credit: Mark Mazzola, USDA ARS.

While fungi such as *Rhizoctonia* cause extensive root rot, *Pythium* spp. strip plant root hairs, diminishing the plant's capacity to take up water and nutrients. Lesion nematodes feed from inside and outside the root. Nematode feeding kills root cells, for example, when the nematodes move through the root they damage and disrupt root tissue, inhibiting water and nutrient movement into the plant. Feeding damage also provides access channels for fungi, bacteria, and other organisms. Oomycete pathogens in the complex can be dispersed by free water during irrigation as they have motile spores called zoospores.

Cultural Controls

Plant nematode-free trees.

If the nursery site where trees were propagated had significant replant disease pressure, young trees likely carry inocula in the roots which may serve to infest a grower's site.

Crop rotation.

Many other crops can host the pathogens in this complex, thus, crop rotation is not a guaranteed strategy to lower potential disease pressure. However, a five year or more rotation to a non-woody crop, such as grass hay, can help reduce pressure. Some sources say that for replanting on a small scale, soil in the planting hole can be replaced with good quality soil from a non-orchard site. In order to effectively replace the soil, the planting hole should be 7 feet (length) by 7 feet (width) by 2 ½ feet (depth) (Benson 1976; Smith 1994).

Water management.

Limit periods of soil saturation. Oomycetes in the apple replant disease complex can disperse between trees if the soil is saturated, conditions that will also aid the root infection process. Dispersal of the pathogen can be reduced by minimizing periods of soil saturation.

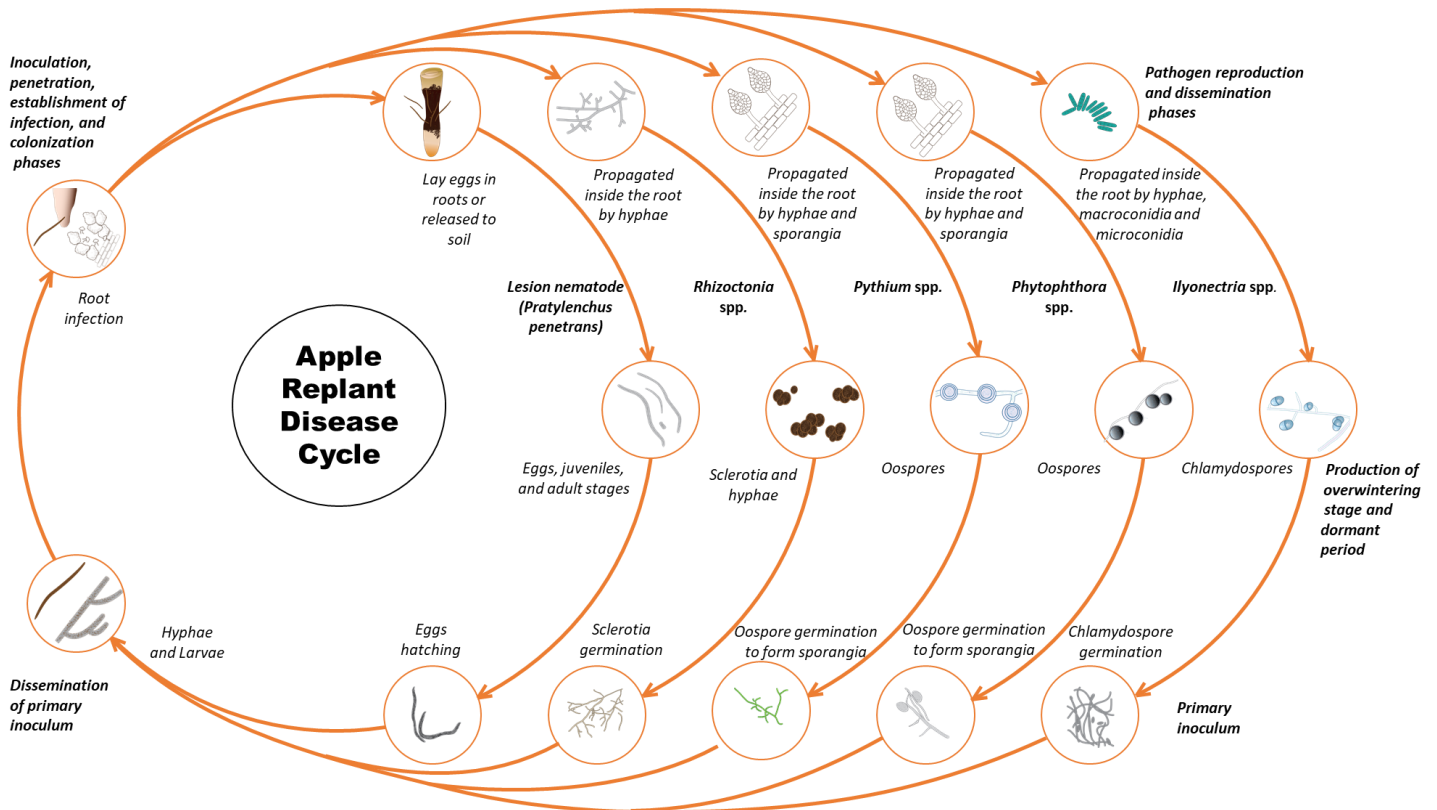


Figure 2. Apple replant disease cycle: pathogens overwinter in soil and plant residues. The infective stages penetrate, infect, and propagate in the roots during the growing season. Secondary infections of oomycetes by zoospores may occur in wet soil. *Ilyonectria* spp. may produce substantial numbers of asexual spores causing secondary infections. Nematodes may migrate from decaying roots to attack new roots. Towards winter, as the roots get ready to become dormant, pathogens produce their overwintering structures and release them into the soil as root tissues decay. Illustration credit: Indika Ratnayake.

Choose well drained soils. Choose orchard sites with good drainage.

Maintain and improve soil structure. Add organic matter to improve aggregate stability and water infiltration and reduce compaction.

Choose tolerant rootstock.

The most important cultural control you can use is a disease tolerant rootstock. Apple rootstock varieties have varying levels of tolerance to replant disease (Table 1). In general, Geneva series rootstocks are tolerant to the disease, while Malling or Malling-Merton series rootstocks are susceptible to the disease (Leinfelder and Merwin 2006). Some rootstocks are moderately tolerant to the disease.

Table 1. Tolerance levels of apple rootstocks to replant disease.

Tolerant	Moderately tolerant	Susceptible
G935	G11	G13 (CG.4013)
G30	G16	M7
G65		M9
G210		M26
G41		MM106
G214		MM111
		M9.Nic 29

From Atucha et al. 2014, Fazio and Mazzola 2004, Isutsa and Merwin 2000, Leinfelder and Merwin 2006, and Yao et al. 2006.

Planting position.

Planting in old, inter-row grass lanes has improved the tree growth. Planting in old grass strips spatially avoids the areas where pathogen contamination of soil is greatest (Leinfelder and Merwin 2006).

Chemical Controls

Soil fumigation.

Two registered soil fumigants have shown long-term efficacy in Washington orchard trials: metam sodium (or metam potassium), and 1,3-dichloropropene plus chloropicrin. It is important to follow soil

temperature and preparation guidelines prior to fumigation. Usually, optimum soil conditions are in October and early November, and in April or later in spring. Cool, wetter, and finer texture soil will retain the fumigants longer and, therefore, have higher efficacy. Materials will disperse quickly and have reduced efficacy in dry or overly warm soil. To prevent phytotoxicity to new trees, delay tree planting after fumigation for the period recommended on the label. Dig planting holes, disturb the planting area, or work the soil a few days before planting.

1,3-Dichloropropene plus chloropicrin. e.g., InLine, Tri-Form 80, Telone C-17 (Leinfelder and Merwin 2006), Telone C-35. Untarped shank and tarped shank injection have different rates of application. Follow the label specification. 1,3-dichloropropene is nematicidal while the chloropicrin is fungicidal.

Metam Sodium or Metam Potassium. Metam is a water-soluble liquid which is moved through irrigation water into the targeted soil zone. After the downward movement is stopped, the fumigant converts into methyl-isothiocyanate, a more toxic gas which only moves a few inches. Therefore, it is important that the liquid solution moves to the desired depth.

- **Potassium N-methyldithiocarbamate.** For example, K-PAM HL, a liquid soil fumigant that can be applied using chemigation, soil injection, or soil bedding equipment.
- **Metam Sodium (Sodium methyldithiocarbamate).** For example, Metam CLR 42%, Sectagon-42, Vapam HL. Some products are soil fumigant solutions that are compatible with chemigation, soil injection, or soil bedding equipment.
- **Metam Potassium (Potassium methyldithiocarbamate).** For example, Metam KLR 54%, Sectagon-K54. Soil fumigant solution that is compatible with chemigation, soil injection, or soil bedding equipment.

Dazomet. For example, Basamid is also a methyl isothiocyanate (MITC) generator. The product is a granular formulation.

Biofumigants and biopesticides.

Biopesticides are certain types of pesticides derived from natural materials, such as animals, plants, bacteria, and certain minerals. Several new biofumigants and biopesticides are labeled as such. Only limited data is available about efficacy of these products.

- **Allyl isothiocyanate.** For example, (Dominus) broadcast application, flat fume application, chemigation.
- **Azadirachtin.** Botanical nematicide. For example, Ecozin Plus 1.2 % ME (emulsifiable concentrate).

Additional Resources

WSU Tree Fruit, Comprehensive Tree Fruit Site. n.d. Washington State University.
<http://treefruit.wsu.edu/>.

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Use pesticides with care. Apply them only to plants, animals, or sites listed on the labels. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

YOU ARE REQUIRED BY LAW TO FOLLOW THE LABEL. It is a legal document. Always read the label before using any pesticide. You, the grower, are responsible for safe pesticide use. Trade (brand) names are provided for your reference only. No discrimination is intended, and other pesticides with the same active ingredient may be suitable. No endorsement is implied.

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