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Western corn rootworm in eastern Oregon, Idaho, and eastern Washington

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Western corn rootworm (WCR), *Diabrotica virgifera virgifera* LeConte (Chrysomelidae), is a notorious pest of corn throughout much of the continental United States (U.S.), particularly in the Corn Belt (Figure 1). This insect has consistently damaged corn in the U.S. for over a century. Western corn rootworm was first found in sweet corn in 1909 in Colorado and spread from there across the Midwest, becoming known as the “billion-dollar pest.” In the Pacific Northwest (PNW), WCR has been found in corn crops in eastern Oregon, Idaho, and eastern Washington. Though it is not as abundant in the PNW as it is in the Midwest, WCR still has the potential to damage corn in the region.

Currently, WCR is a sporadic pest in the PNW, though isolated infestations can be relatively severe. As corn acreage increases in the region, the potential for WCR to become a serious pest also increases. It is important to identify and manage small outbreaks of WCR now to prevent larger, more significant pest problems in the future.

Identifying WCR

WCR gets its name from the damage the larvae (“worms”) cause to corn roots. These larvae can be difficult to locate and identify, but they may be observed feeding on or around corn roots. The mature larvae are white or cream-colored “worms,” approximately 0.5 in (12 mm) long. They are extremely soft-bodied with a red-brown head and a distinctive dark patch on the tail end, called an anal plate. There are several similar beetle larvae that live in the soil, including some other agricultural pests known as wireworms. Wireworms are cream-colored or yellow larvae that develop into click beetles. In contrast to WCR, they are not soft-bodied, and they do not have a dark anal plate (Figure 2, page 2).

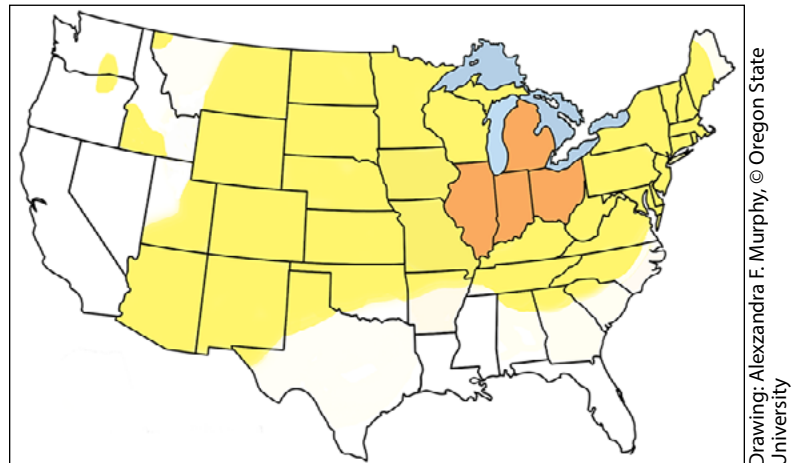


Figure 1. Distribution of western corn rootworm (WCR) in the United States. The yellow area represents WCR distribution and establishment in the US; orange indicates distribution of the WCR variant. Adapted from Edwards 2011, using information from O’Neal et al. 2002, Rice and Tollefson 2006, National Agricultural Statistics service (NASS), and Steve Hines.

Drawing: Alexzandra F. Murphy, © Oregon State University

The adult beetle is the easiest life stage to identify. WCR is a small beetle (about 0.25 in, or 6 mm) in the family Chrysomelidae (leaf beetles). Males are black with a small yellow patch on the end of the abdomen and have extremely long antennae. Females are slightly larger and yellow with three longitudinal black stripes (Figure 3, page 2). Both sexes have solid black or brown legs. Males usually emerge before females, though they are smaller and more elusive.

There are only a few other beetles in the PNW that resemble WCR, and they are rarely associated with corn (Figure 4, page 2).

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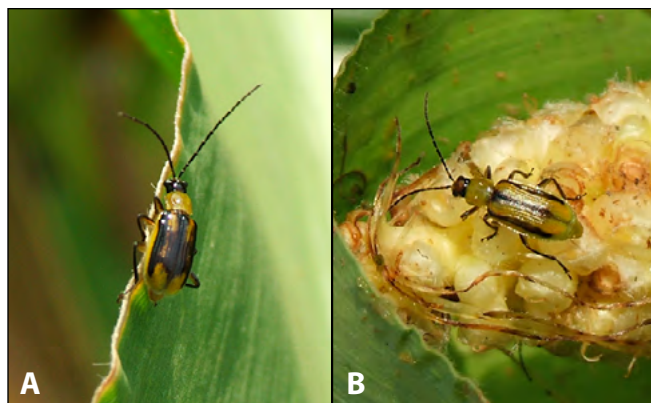


Photo: Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Photo: Frank Peairs, Colorado State University, Bugwood.org

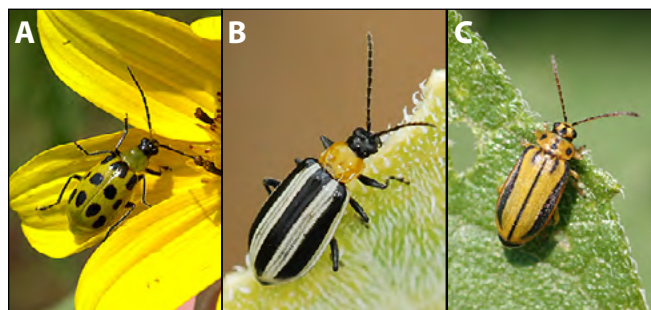
Figure 2. Identifying western corn rootworm larvae. (A) western corn rootworm larvae; (B) click beetle larvae, called wireworms

- The spotted cucumber beetle (*Diabrotica undecimpunctata* Mannerheim), also called the southern corn rootworm, is a bright yellow-green beetle (about 0.25 in or 6 mm) with eleven black spots (Figure 4). Spotted cucumber beetle is more common in western Oregon and Washington than it is in eastern Oregon, Idaho, and eastern Washington.
- The western striped cucumber beetle (*Acalymma trivittatum* Mannerheim) does not feed on corn, but it closely resembles WCR. Western striped cucumber beetles are larger (0.33 in or 8 mm) than WCR, and the three yellow stripes extend all the way to the tip of the abdomen. Also, western striped cucumber beetle has a solid black head and red thorax that may be used to distinguish it from the female WCR.
- The elm leaf beetle (*Xanthogaleruca luteola* Müller) does not feed on corn either, but it could be mistaken for WCR in the PNW if collected near corn. Elm leaf beetle has a lighter, yellow-brown head and thorax with black spots. There are two short, extra stripes on the back of the elm leaf beetle, making five stripes



Photos © Alexandra F. Murphy

Figure 3. Western corn rootworm beetles. (A) male; (B) female



Photos: (A) © Charles Lewallen. (B) © Ron Hemberger. (C) Whitney Cranshaw, Colorado State University, Bugwood.org

Figure 4. Beetles that resemble western corn rootworm. (A) spotted cucumber beetle (also called southern corn rootworm); (B) western striped cucumber beetle; (C) elm leaf beetle

total. Elm leaf beetles have solid yellow legs, in contrast to the solid dark legs of WCR.

Hosts

All types of corn (*Zea mays* L.—sweet, field, silage, and seed corn) are suitable and preferred hosts for WCR. Several potential weed hosts include green foxtail (*Setaria viridis* L.), yellow foxtail (*S. pumila* Poiret), and wheatgrass (*Agropyron* spp., *Thinopyrum* spp., and *Elymus* spp.) (Figure 5, page 3). These weed hosts should be managed in fields intended for corn production.

While other crops, including wheat and barley, may serve as low-quality hosts for WCR, they are not considered true hosts. Grass species may serve as holdover or temporary hosts, but larvae feeding on these plants usually do not reach adulthood. WCR adults frequently feed on the foliage and flowers of cucurbits (i.e., pumpkins, squash, and cucumbers) during the summer, but the larvae cannot feed and develop on the roots of these plants.



Photos: (A) Ohio State Weed Lab Archive, The Ohio State University, Bugwood.org. (B) Robert Vidéki, Doronicum Kft., Bugwood.org. (C) Howard F. Schwartz, Colorado State University, Bugwood.org.

Figure 5. Alternative weed hosts for western corn rootworm. (A) green foxtail; (B) yellow foxtail; (C) wheatgrass

Life Cycle

Rootworms overwinter as eggs buried in the soil. WCR eggs may be identified by a specific “honeycomb” pattern on their surface (Figure 6). In the spring, the eggs hatch and the tiny larvae go in search of corn roots. The larvae must find a suitable host plant relatively soon after hatching, or they will die. Larvae that find suitable roots feed and develop until late spring or early summer, when they pupate in the soil and then emerge as adult beetles.

Male beetles emerge from the soil first, and begin feeding on corn silks or tassels. The females begin emerging a week or two later and often mate within hours after emergence. Although females mate only once, they will continue to feed and lay eggs until they die, which is usually at the first frost in the fall. Eggs are laid almost exclusively in the soil around current-season corn plants. Female beetles produce an average of 500 eggs during their lifetime.

Damage

Most damage is caused by the larvae (“worms”), not the adult beetles. Western corn rootworm larvae feed on corn roots, which decreases root mass, interferes with water and nutrient uptake, and weakens the plant so it is more susceptible to infection by other organisms (Figure 7, page 4). Severely damaged roots may not be able to anchor the plant in the soil, resulting in the corn

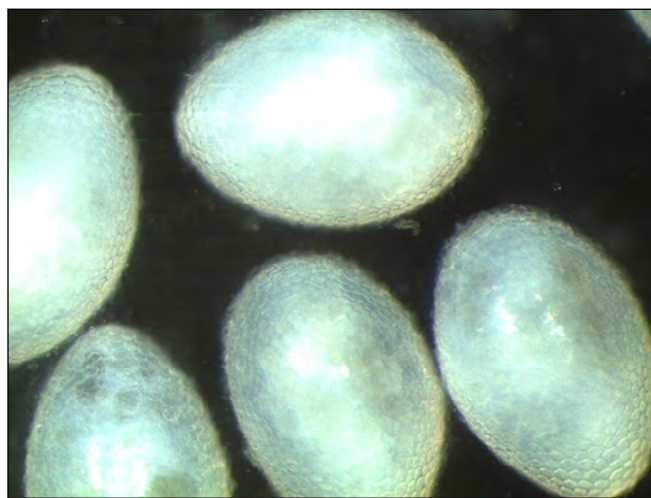


Photo © Alexandra F. Murphy

Figure 6. Western corn rootworm eggs, magnified. The “honeycomb” pattern helps identify them as WCR.

lodging (falling over) in strong winds. Lodged corn is equivalent to lost yield.

When WCR populations are extremely high, beetles feeding on the silks (called “silk clipping”) can interfere with pollination of the ears. Adult beetles may also feed on exposed ears or foliage if tassels and silks are unavailable (Figure 8, page 4). These two forms of damage have been observed in the PNW, but they cause minimal yield loss and do not warrant any chemical control.



Photos © Alexandra F. Murphy

Figure 7. An example of root damage caused by rootworm feeding. (A) extreme damage; (B) minimal damage. Extreme damage, as pictured in (A), has not been observed in eastern Oregon, Idaho, or eastern Washington.



Photo © Alexandra F. Murphy

Figure 8. Western corn rootworm feeding on corn kernels. This kind of damage usually does not warrant insecticide application and is uncommon in the Pacific Northwest.

Rootworm Management

Crop rotation

In the PNW, the most effective and highly recommended method of WCR control is crop rotation. Rootworms are almost entirely dependent on corn roots as a food source in the larval stage. If corn roots are not available, they will most likely starve and die. The eggs are always laid in current-season cornfields; thus, as long as corn is grown in rotation with other crops, no significant damage will occur. (However, adult WCR beetles are extremely mobile, so it is not uncommon to see them migrating through and feeding in first-year, rotated corn fields.) While WCR usually thrive in a continuous corn cropping system, they generally do not require any additional control measures in a rotational system in the PNW.

There are documented cases of a rotation-resistant WCR in the Midwest. This rotation-resistant form is known as the “WCR variant.” Rather than laying its eggs only in corn, it also lays eggs in soybeans, oats, and alfalfa. The WCR variant is not present in the PNW, and it is not anticipated to become a problem in this region. The PNW has a diverse agricultural landscape that prevents development of the WCR variant and rotation resistance.

Monitoring

Scout for adults during the current growing season to determine the management needs for current and future crops. While the beetles can sometimes be seen feeding along field edges, they are often elusive, so the use of regular, quantifiable monitoring techniques is recommended. Monitor WCR adults by placing unbaited, yellow sticky cards along the edges of the field (Figure 9). Check traps weekly throughout the season, as WCR populations can build quickly and are relatively mobile.



Photo: Alexandra F. Murphy, © Oregon State University

Figure 9. Example of a yellow sticky card used to monitor WCR. Place cards approximately at ear height along the edges of the field.

Insecticides

There are many insecticides available for controlling rootworm larvae. Some are applied as a seed treatment, but most should be applied at planting, either in-furrow or over the row in a band. Applications for adult beetle control are not recommended. They are less effective, and adults usually do not cause significant yield loss. In the Midwest in the 1990s, insecticidal baits were developed for adult WCR, but these proved to be ineffective and impractical.

As with any insecticide, it is important to read the label and follow the recommendations precisely. Consult the *Pacific Northwest Insect Management Handbook* (<http://insect.pnwhandbooks.org/>) or your local Extension agent for current insecticide rates and recommendations.

Use pesticides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the pesticide label—even if you've used the pesticide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

Genetically-modified, rootworm-resistant hybrids

Some of the more recent and most effective control options are genetically-modified (GM), rootworm-resistant corn hybrids, which first became available in 2003. These GM plants produce one or more specific proteins (called *Bt*, Cry3Bb1, or Cry34/35Ab1) that are toxic only to the tiny rootworm larvae and kill them when they feed. A few rootworms feeding on these GM plants may survive because they are naturally resistant to the toxin, but most will die.

However, continuous use of rootworm-resistant corn can result in further selection pressure for resistant beetles, so that the proportion of susceptible rootworms in the population decreases, and eventually the resistant insects become the dominant form in the population. To slow the development of resistance to GM corn in WCR populations, it is important to plant a refuge of

non-GM plants that sustains and promotes susceptible rootworm populations. Refuges are required by law and defined by the EPA for each hybrid as a way of diluting and delaying resistance. See “What is a refuge?,” below, for more information about refuges and how they work.

New rootworm-resistant hybrids are being developed that use novel technologies, including RNA interference (RNAi). This new RNAi technology produces a kind of “fake virus” that kills only rootworms when they feed on the plants. These new hybrids are expected to be available from several companies by or before 2020.

Resistance Management

In the Midwest, western corn rootworm has developed resistance to several insecticides and other control tactics. For example, in 1961 WCR was reported to be resistant to aldrin (which was banned in the 1970s). In Illinois and Indiana, most WCR populations have been resistant to crop rotation since 1995. More recently, in 2009, a population of WCR was documented to be resistant to GM rootworm-resistant corn in Iowa.

To avoid creating WCR resistance in the PNW, it is important to follow responsible pest management practices, including:

- Crop rotation
- Rotating between chemical classes that have different modes of action
- Rotating between different control methods (e.g., chemical control, GM corn)
- Planting refuges along with rootworm-resistant corn when using GM hybrids

What is a refuge?

As with all insect control methods, GM rootworm-resistant corn does not kill 100 percent of the rootworms. A few rootworms always survive to become resistant beetles: the “super bugs.” A refuge is a portion of the field that is planted with crops that do not have the *Bt* rootworm-resistant protein. The idea is to sustain just enough beetles in the refuge (that are susceptible to rootworm-resistant corn) to mate with any resistant beetles that may emerge from the GM crop. The resulting offspring will be a mixture of susceptible and resistant larvae; therefore, the resistant genes are “diluted.” All rootworm-resistant varieties on the market today require the use of a refuge.

Refuges may be planted in many configurations, including blocks, strips, and seed mixes (refuge plants

will be randomly distributed) (Figure 10). In most regions of the U.S. and Canada, the refuge in GM corn is required to be approximately 20 percent of the total acreage. Refuge size requirements differ by region and hybrid, so it is important to consult the seed label and your seed dealer if you have any questions.

Many hybrids come with a refuge already incorporated into the seed (known as refuge-in-the bag, seed mix, or seed blend). A seed-mix refuge is one of the better options for two reasons:

1. It is easy to plant, since the required amount of refuge (non-GM) corn seed is pre-incorporated.
2. It makes it easier for the susceptible beetles to “dilute” the resistant beetles (because susceptible and resistant beetles will already be mixed together).

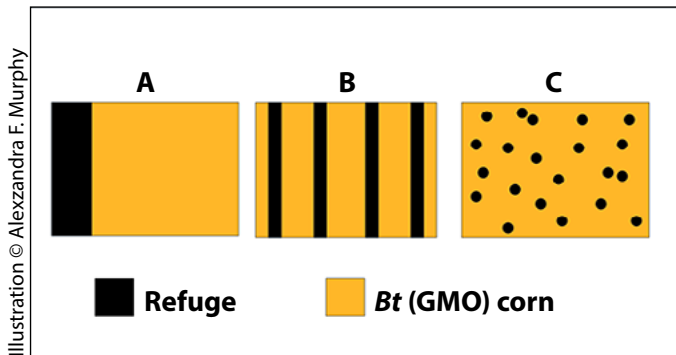


Figure 10. Examples of refuge options for genetically-modified, rootworm-resistant hybrids that use *Bt* proteins. (A) block; (B) strip; (C) seed mix or refuge-in-the-bag

Natural enemies

There are several natural enemies of WCR. Most general predators such as spiders, ground beetles, predatory mites, and ants have been reported to attack WCR. Ants are exceptionally good at feeding on rootworm larvae. Pathogenic nematodes also infect and kill WCR larvae.

A fungal pathogen, *Beauveria bassiana* (Balsamo), was demonstrated to reduce WCR adult beetle populations by as much as 50 percent. There are also some less common predators of rootworm beetles, such as birds.

Many of these natural enemies are present in the PNW and may contribute to natural WCR control. However, the ability of natural enemies to control WCR has not been effectively evaluated in this region.

Challenges with continuous corn

Continuous corn is sometimes practiced in the PNW, particularly where corn supports a local industry (such as dairy). While planting corn in the same field each season has some immediate economic advantages and appeal, those incentives are counteracted by long-term risks and challenges. Where WCR is concerned, continuous corn systems are at a substantially higher risk for large outbreaks and development of resistance to a variety of tactics. In fact, continuous corn is one of the factors that contributed to WCR resistance to GM hybrids in the Midwest.

For this reason, it is extremely important to monitor WCR populations using yellow sticky cards (see “Monitoring,” page 4) in a continuous corn system, particularly if GM rootworm-resistant hybrids are a major method of WCR control and/or fields are clustered in one region. In a continuous corn system, it is even more crucial to practice good resistance management:

- Plant a refuge with rootworm-resistant GM corn.
- Rotate between chemical classes when applying insecticides.
- Rotate between insecticides and GM crops for WCR control.
- Avoid planting corn in the same field for more than 2 or 3 consecutive years.

Report severe or unexpected WCR outbreaks to your local Extension agent.

Is the PNW at risk of WCR resistance to crop rotation?

Populations of WCR in the Midwest are extremely large compared to those in the PNW. Corn is grown there on a large percentage of the landscape (frequently over 75 percent). In contrast, only a small percentage of the PNW is planted to corn every season (approximately 1 percent of all farmland in Oregon, Idaho, and Washington). Farming practices in the PNW (that is, minimal corn acreage in a diverse landscape) prevent the WCR from developing resistance to crop rotation, and make controlling WCR in the PNW relatively easy compared to the Midwest.

In spite of the advantages for managing WCR in the PNW, it is still extremely important to rotate between chemical classes and use the prescribed refuges for rootworm-resistant corn hybrids. Practicing responsible integrated pest management will ensure that rootworms remain easy to control in the PNW for years to come.

For More Information

OSU Extension publications

Find the OSU Extension publication listed below, and other pest management publications, in the OSU Extension Catalog.

<http://extension.oregonstate.edu/catalog/>

Pacific Northwest Insect Management Handbook

<http://insect.pnwhandbooks.org/>

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