

IPM Decision Aid:

Managing corn rootworm BT resistance

Introduction

Western corn rootworm resistance to plant incorporated Bt proteins (GMO hybrids) has refocused attention to effective and economical management of the corn rootworm complex. *Integrated pest management techniques can be used to successfully manage corn rootworm populations and to reduce the potential of future resistance issues.* However, a thorough understanding of rootworm biology and management techniques is essential.

Corn Rootworm Profiles

Identification

Western Corn Rootworm Adult: ¼ inch long, lime green color with black lines on wing covers. Males may have a uniform black area on wing covers instead of lines. Adults feed on corn silk, leaves and pollen of numerous plants including corn.



Western corn rootworm adult feeding on corn silk.

Northern Corn Rootworm Adult: ¼ inch long, solid green color, no markings. Adults feed on corn silk and pollen from various plants including corn.



Northern corn rootworm adult.

Larvae (northern and western): Up to ½ inch long, cream colored, brown head and anal plate. Larvae feed almost exclusively on corn roots.



Corn rootworm larvae. Photo Credit: Richard C. Edwards, Purdue University, Bugwood.org

Life Cycle

Both species have similar life cycles. There is one complete generation/year. Rootworms overwinter as eggs laid in the upper soil profile. Eggs hatch in early June and larvae feed on corn roots. Adults emerge late June through August and lay eggs almost exclusively in corn fields be-

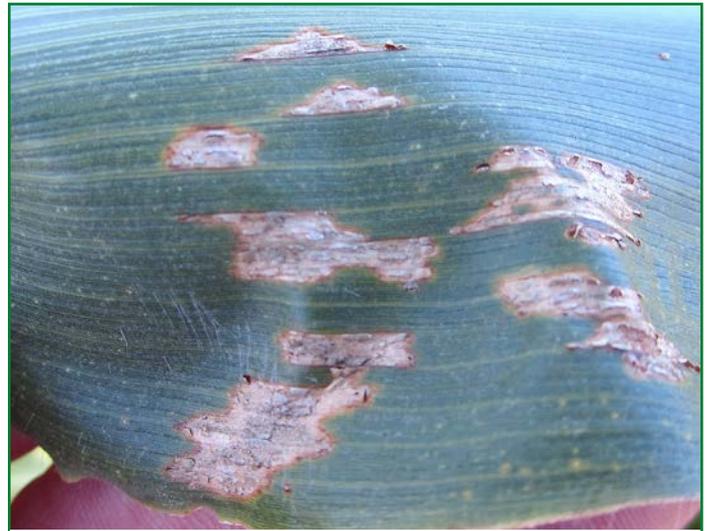
ginning early August through early September. In southern counties, adult Western corn rootworm adults may lay eggs in soybean fields. However, this specific behavior has not been commonplace.

Damage

Rootworm larvae damage corn roots by feeding on the exterior root surface or by tunneling within the root. Evidence of larval feeding consists of brown, elongated scars on the root surface, tunnels within the roots or complete root pruning.

Lodging, sometimes called goose-necking, is an above ground symptom of larval feeding and is commonly observed following storms with heavy rains and/or high winds. Slight to moderate lodging can result in reduced ear weight. Severe lodging may cause additional harvest losses from the combine's failure to gather lodged plants off the ground. Do not assume all lodging is a result of corn rootworm feeding. Heavy rains, winds, compaction, stalk diseases or other insects may cause similar symptoms. Verify larval rootworm feeding by digging and power washing suspected plants when field damage is first noticed.

Adult corn rootworm beetles feed on green corn silks which can inhibit kernel fertilization. Early and/or late planted corn is more susceptible because beetles migrate to these more attractive fields. Leaf feeding by the western corn rootworm is frequent but rarely an economic concern.



Leaf feeding cause by adult western corn rootworm.



Silk clipping by adult rootworm beetles.



Lodging caused by larval feeding

Scouting Methods and Economic Threshold

Monitoring pest populations is the backbone of any pest management program. Without field specific information practical decisions cannot be made. There are two reasons to scout for corn rootworm adults. The first is predict the potential for larval damage the following year. Assessing beetle abundance during the egg laying period can give us essential information so the most appropriate and cost effective control recommendation can be made. The second is to monitor for beetle feeding on corn silks and prevention of pollination.

Determining damage potential for next year's corn crop

Count rootworm beetles on 5 nonconsecutive plants in 10 random areas of a field during the egg laying period (early/mid-August to early September). First, grasp the ear tip tightly enclosing the silks in the palm of your hand. The silks often have the most beetles on the plant, so a tight hold on the ear tip keeps beetles from dropping out. Count beetles on all other areas of the plant. Once the entire plant is examined, open your hand slowly and count those beetles. Corn rootworm will need to manage next year if you find an average of 0.75 beetles per plant during any one of the three field sampling dates.

Recently, in areas of southern Wisconsin, the female western corn rootworm has adapted to a corn/soybean rotation by laying eggs in soybeans. This can cause significant economic damage to first year corn. To avoid unnecessary insecticide applications in first year corn, it is important to monitor western corn rootworm beetle populations in soybean. Use Unbaited Pherocon AM yellow sticky traps to predict damage potential in first year corn. These traps are a visual attractant; no lure is needed.

Evenly distribute 12 traps/soybean field beginning in early August. Traps should be placed a minimum of 100 feet from the field edge and approximately 100 paces between traps depending on field size. Place traps on a stake above the soybean canopy. Count beetles and replace traps (if needed) on a weekly schedule. Trapping can conclude the first full week in September when egg laying is complete.

A preventive control practice (crop rotation, insecticide or transgenic corn rootworm hybrid) should be used if a field average of greater than 5 western corn rootworm beetles are caught/trap/day.

For example, if you counted a total of 1680 WCR beetles in twelve traps over a 28 day period this would equal an average of 5 beetles/trap/day {1680 divided by 12 (#traps/field) divided by 28 (# days you trapped) = 5}.

Research conducted by entomologists at the University of Illinois, suggest an average of 5 beetles/trap/day would likely result in a corn root rating of 0.25 on the Iowa State node-injury scale. An average of 10 beetles/trap/day would result in a root rating of 1.00. However, root feeding damage by corn rootworms can be difficult to interpret into yield loss.

Pollination protection

For pollination protection, begin scouting when silks first appear using the scouting method mentioned above and continue until corn has completed pollination.

Record the total number of beetles and divide by the num-

ber of plants counted (50) and record the number of plants with silks clipped to 1/4 inch or less. In addition, record the number of plants that haven't begun to silk, the number with fresh silk and the number with brown silk.

Typically, it will take an average of 5-6 beetles/plant to cause significant yield reduction. Treat before the field is 50% pollinated. Make sure silks are being clipped before control practices are used. Sometimes the threshold of 5-6 beetles/plant may be exceeded but silks are not being clipped. If this is the situation do not treat the field but return in a few days and reaffirm that silks are not being clipped.

IPM Options for Corn Rootworm Control and Resistance Management

Scouting should serve as the foundation for a comprehensive rootworm management program. Corn rootworm populations vary from year to year and field to field. Therefore, all management decisions should be based on field-specific scouting data. Create a diversified management plan that utilizes all appropriate control methods instead of a one size fits all plan.

Crop Rotation

Crop rotation continues to be a viable corn rootworm management option and is widely considered the most effective management tactic for corn rootworms. It is especially useful as a part of a diversified management program that reduces reliance on Bt hybrids.

However, as previously mentioned in southern Wisconsin, western corn rootworm beetles have adapted to a corn/soybean rotation by laying eggs in soybean fields. *This characteristic has not been common in recent years.* However, in these area of Wisconsin it would still be advisable to periodically use the yellow sticky trap method to determine damage potential in corn planted after soybean and to monitor corn roots in first year corn fields for signs of damage.

Seed Treatments

Results from the [Wisconsin Pest Bulletin](#) (Wisconsin Department of Agriculture, Trade and Consumer Protection) indicates that beetle populations are the lowest on record since 1971. Under current population trends the use of a seed treatment can be both cost effective and a potential resistance management tool. Seed treatments containing the active ingredients clothianidin or thiamethoxam can provide effective control if populations are low to moderate. These commercially applied products are available in several rates. The lower rates do not control rootworm larvae but the higher rate (1.25 mg/seed) is labeled for control of low to moderate rootworm populations. Product

efficacy can be questionable when rootworm populations are high. Therefore, field scouting for rootworm beetles is very important to determine if seed treatments will be an effective management option.

Soil Insecticides Applied to Conventional (non-GMO) Hybrids

Prior to the widespread adoption of transgenic corn hybrids, soil applied insecticides were the primary control tactic used by growers when crop rotation wasn't an option. Many products continue to offer effective and economical control and can be considered an alternative to transgenic hybrids even when rootworm populations are considered high.

Several liquid and granular insecticides are labeled to control rootworm larvae. Calibration is important and settings on the granular insecticide label should be used as a starting reference only. Rates for liquid and granular insecticides are typically expressed in amount of product/1000 row feet. However, there can be use restrictions for pounds of product/acre on row spacing narrow than 30 inches. Reading label restrictions is important because some products may have specific use restrictions that include placement, set back restrictions and/or implementation of buffer strips near aquatic habitat.

Currently, there are 2 modes of action available for larval control. Because of the rootworm's ability to become resistance to several management practices, rotating insecticide modes of action is an extremely important management tool that will help delay resistance.

Transgenic (Genetically Modified Organisms or GMO) Corn Rootworm Corn Hybrids

Transgenic corn hybrids contain *Bacillus thuringiensis* (Bt), a soil dwelling bacteria which produces toxin(s) that kill rootworm larvae when they feed on the roots. Currently (2017), there are four Bt proteins that are labeled by EPA and marketed for rootworm control. They are YieldGard (Cry3Bb1), Herculex RW (Cry34/Cry35Ab1), Agrisure RW (mCry3A) and Agrisure Duracade (mCry3A + eCry3.1Ab). It is important to recognize the Bt proteins, as indicated in parenthesis, so specific modes of action can be identified.

Bt proteins are marketed in one of four ways, 1) Single traits 2) Stacked traits 3) Pyramid traits and 4) Stacked pyramid traits. Single traits (which are not readily available in today's market) incorporate a single Bt toxin and target one insect. Stacked Traits contain two Bt proteins, each targeting a different species of insect. Pyramid traits have multiple Bt toxins (with distinctly different modes of action) and target a single insect. Pyramid Stacked hybrids

have multiple Bt toxins for controlling corn rootworms and other above ground insects.

Insect Resistance Management (IRM) plans are required for transgenic hybrids and are mandated by EPA. IRM plans are commonly referred to as refuges which are designed to delay resistance by producing susceptible adults from a non-Bt plant to mate with resistant beetles that survive from transgenic hybrids. Therefore, diluting the number of individuals carrying a resistant gene. Refuge requirements are complicated, yet are an important resistance management technique. Specific refuge requirements are available from your seed company representative.

Refuges may be of two different types, 1) structured and 2) Seed mix. Structured refuges are typically blocks of susceptible corn hybrids planted within or immediately next to a field containing the Bt toxin and can vary in size from 5% to 20% of the corn field. Seed Mixes are commonly referred to as a "Refuge In a Bag (RIB)" and contain a pre-mix of seed containing Bt toxins with seed that does not. Contact your seed representative for the refuge requirement of each hybrid you plant.

Transgenic hybrids that control corn rootworms are widely adopted and have, in most cases, provided reliable control. However, some western corn rootworm populations in the Midwest have developed resistance to each of these proteins. In Wisconsin, development of resistance is in the early stages and not considered wide spread. For this reason, an IPM approach to corn rootworm management using diversified management practices that delay resistance is advisable.

To maintain efficacy of the Bt hybrids and avoid resistance, use these products on fields which have been verified (through scouting) to have above threshold rootworm populations. Prophylactic use on fields with sub economic populations will predispose rootworm to unnecessary selection pressure. Do not use the same protein more than two years in a row. However, annual rotation is preferable. Monitor roots on a regular basis for signs of feeding which may indicate resistance development.

Soil Insecticides Applied to Transgenic Hybrids

Using a soil insecticide along with a corn rootworm transgenic hybrid is rarely advisable and should only be considered if scouting information reveals extremely high beetle pressure and control using a CRW transgenic hybrid alone would be questionable. This would be a rare situation in Wisconsin, especially given our low beetle populations. This management option is not considered a resistance management tool even though two different modes of action are used.

Adult Control

In some areas of the Midwest, controlling rootworm adults with foliar-applied insecticides has been tried but with limited success. Its use in Wisconsin is not advisable because application timing must coincide with peak oviposition. Proper timing is not always possible because of our long egg laying period. Improper timing may result in significant eggs being laid before application or after residues wear off.

Validating Management Decisions

Verify accuracy of each management decision by scouting for root injury in mid to late July after the larval feeding is complete.

Corn rootworm larval damage is cryptic and easily overlooked or misidentified. Corn does not have to be lodged to suffer economic injury. Conversely, just because corn is lodged does not mean the damage was caused by rootworm feeding.

Dig several roots from each field. Wash each root with a power washer and observe the root for injury. Regardless of the management practice used, some injury is possible and light feeding is economically acceptable.

To determine extent of the damage, rate each root using the 0-3 Nodal Injury Scale developed by research entomologists at Iowa State University. This rating system is based on a decimal system. The number to the left of the decimal indicates the number (or equivalent number) of root nodes pruned back to within 1 ½ inch of the corn stalk. The number to the right of the decimal indicates percentage of the next node of roots pruned to within 1 ½ inch of the stalk.

For example, a root rating of 1.20 indicates the equivalent of one complete node of roots is pruned and 20% of the next node of roots.

If the field average is lower than 0.50 it is assumed there isn't enough rootworm feeding to cause economic loss.

If the field average is greater than 0.75 one should assume that there was enough root feeding to cause economic yield loss over and above the cost of a control practice.

For averages between 0.50 and 0.75 economic loss may depend on other plant stresses that include, fertility, disease, compaction, environment, etc.

Summary

Effective corn rootworm management must begin with both adult beetle scouting and monitoring corn roots for damage. Using this field specific information will provide the foundation for a diversified management approach utilizing multiple control tactics that focus on efficacy, economics and resistance management.



Healthy corn roots show no signs of larval feeding.



Only outside roots show larval damage.



Severe larval damage to roots.

References

2017 Pest Management in Wisconsin Field Crops (A3646)

https://patstore.wisc.edu/secure/browse_cat.asp?category_id=39

Handy Bt Trait Table, Chris DiFonzo

Michigan State University

<https://lubbock.tamu.edu/files/2017/12/bt-corn-trait-table-2018.pdf>

Evaluating Corn Roots for Corn Rootworm Damage

UW IPM Program

<http://ipcm.wisc.edu/download/pubsPM/Corn-rootRate-card2015hx.pdf>

Corn Rootworm Scouting

UW IPM Program

<http://ipcm.wisc.edu/download/pubsPM/Corn-rootworm-card2015hx.pdf>

Video: *How to validate your management decision*

https://www.youtube.com/watch?v=UZG_p8_HLpY



Video: *How to scout for corn rootworm beetles*

<https://www.youtube.com/watch?v=hYQCJmKNFMo>



Video: *Corn rootworm damage and root node injury scoring*

<https://www.youtube.com/watch?v=Rpau3fuBjv8>



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