IPM Decision Aid: Managing corn rootworm BT resistance

Introduction

Corn rootworms (CRW) are a major economic threat to agriculture in Wisconsin due to the damage they can have on corn crop yields.

Detection of field-evolved resistance of the western corn rootworm to certain plant incorporated Bt proteins (GMO hybrids) has recently focused attention on resistance management. ***Integrated pest management techniques can be used to effectively 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. This publication includes sections on corn rootworm identification, scouting methods, economic thresholds, resistance management, agronomic management options, and validating management decisions.

Corn rootworm profiles

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 light 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 body, 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. Rootworms overwinter as eggs laid in the upper soil profile. Eggs hatch in early June. First instar larvae feed on the smaller branching corn roots. Second and third instars feed on larger roots at the base of the corn plant. Adults emerge late June through

August and oviposit (lay eggs) almost exclusively in corn fields beginning in early August, peaking in mid-august. In the southeast part of Wisconsin adult Western corn rootworms adults may lay eggs in soybean fields. There is one complete generation/year.

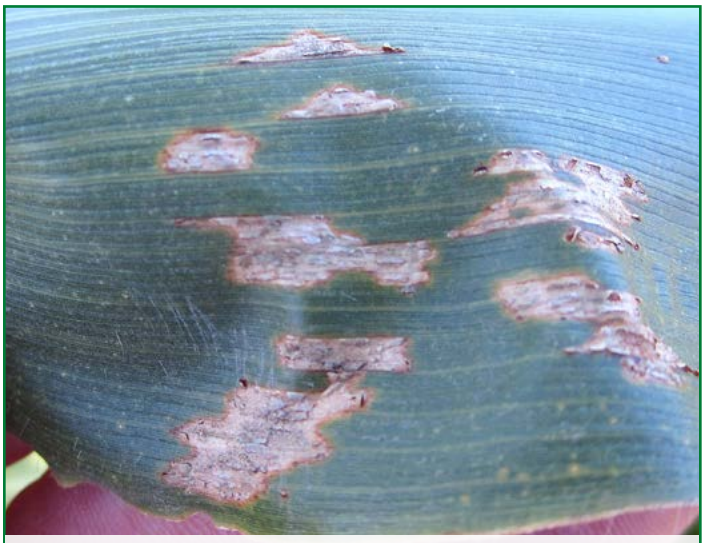
Damage Symptoms

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 pruning.

Lodging, sometimes called goose-necking, is an above ground symptom of larval feeding and is commonly observed after 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. 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 also 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.

Lodging caused by larval feeding



Leaf feeding cause by adult western corn rootworm.

Silk clipping by adult rootworm beeatles.

Scouting Method and Economic Threshold

There are two reasons to scout for corn rootworm adults:

- Pollination protection
- determining the damage potential for next year's corn crop.

Pollination protection

For pollination protection, begin scouting when silks first appear and continue until corn is pollinated. Count the number of beetles on 5 nonconsecutive plants in 10 random areas of a field. First, grasp the ear tip tightly enclosing the silks in the palm of your hand and count beetles on

all other areas of the plant. The silks often have the most beetles on the plant, so a tight hold on the ear tip keeps beetles from dropping out. Pull leaves away from the stalk to examine leaf axils and expose hiding beetles.

Once the entire plant is examined, open your hand slowly and count the beetles that come out of the silks as you strip the husk away from the ear tip. Record the total number of beetles and divide by the number 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.

Determining damage potential for next year's corn crop

To determine the damage potential for larval feeding in continuous corn, count the number of beetles on five non-consecutive plants in each of 10 random areas of the field using the same sampling method detailed in the previous section. Scout corn acreage at weekly intervals during the egg laying period (early to late-August).

By establishing the level of adult infestation during the current year, you can determine whether preventative treatments will be necessary in the following year's corn crop. The grower will need to manage corn rootworm larval populations if you find an average of 0.75 beetles per plant during any one of the three field samplings.

In areas of southeastern Wisconsin, western corn rootworm females have adapted to a corn/soybean rotation and may lay eggs in soybeans. This can cause significant economic damage to the first year corn that follows. To avoid unnecessary insecticide applications in first year corn, it is important to monitor western corn rootworm beetle populations in soybean.

Use Pherocon AM yellow sticky traps (unbaited) 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.

IPM Management Options

Corn rootworm beetle populations vary from field to field and year to year. Many factors influence their population level including crop phenology and environment. Therefore, all management decisions should be based on field scouting information. Field averages greater than 0.75 beetles/plant in continuous corn or trap catches great than 5 beetles/trap/day in a corn soybean rotation can be expected to have significant egg-laying that would justify larval management the follow year.

Crop Rotation

Crop rotation continues to be a viable management alternative for corn rootworms in the majority of the state's corn growing regions. However, in the southeast portion of Wisconsin, western corn rootworm beetles have adapted to a corn/soybean rotation and been known to lay eggs in soybean fields. For fields in southeast Wisconsin use the yellow sticky trap method to determine damage potential in corn planted after soybean.

In states other than Wisconsin, Northern corn rootworms have adjusted to a corn/soybean rotation through adoption of a two year life cycle called "extended diapause". This

phenomenon requires two winter chilling periods before eggs hatch. Extended diapause is not known to be present in Wisconsin but occasional monitoring of first year corn is suggested for early detection.

Seed Treatments

Seed treatments containing clothianadin and thiamethoxam are two active ingredients which can give limited rootworm control. These products are applied by the seed supplier and are available in either a high or low rate. The higher rate is labeled for effective corn rootworm larval control only if populations are low to moderate. Efficacy of these products can be questionable when rootworm populations are high. However, the insecticide labels do not indicate what is considered a low or moderate population. Therefore, field scouting for rootworm beetles is very important to determine if seed treatments will be an effective management option.

At-plant, Soil Applied Insecticides

Several liquid and granular soil applied insecticides can be used to control rootworm larvae at planting time. Calibration is important and settings on the insecticide label should only be used as a starting point for granular applicators. Rates for granular insecticides are typically expressed in amount of product/1000 row feet. However, there can be use restrictions (pounds of product/a) on row spacing narrow than 30 inches. Reading and following label restrictions is also important because some products have specific use constraints that include set back restrictions and/or buffer strips near aquatic habitat.

Rootworm management has had several challenges that includes resistance to some foliar and soil applied insecticides, genetically modified hybrids and crop rotation. Currently, there are only 3 modes of action available for larva control. Because of the rootworm's ability to become resistance to several management practices, rotating insecticide modes is an extremely important management tool that will help delay resistance.

Transgenic (Genetically Modified Organisms or GMO) Corn Hybrids

Transgenic corn hybrids contain a Bacillus thuringiensis (Bt) toxin(s) and are regulated by the Environmental Protection Association (EPA). Currently (2014), there are four different Bt proteins that are labeled 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.

Transgenic hybrids which control corn rootworm are widely adopted and have, in most cases, provided reliable control. However, western corn rootworms have demonstrated field-evolved resistance to the Cry 3Bb1 and mCry3A proteins in some Iowa and Illinois corn fields. Resistance is suspected in other Midwestern states including Wisconsin. However, these fields are not yet confirmed.

Insect Resistance Management (IRM) plans are required for transgenic hybrid and are mandated by EPA. IRM plans are more commonly referred to as refuges and are designed to delay resistance by producing susceptible adults from a non-Bt plant to mate with resistant beetles that survive from a transgenic hybrid. Thus, diluting the number of individuals carrying a resistant gene. Refuge requirement 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 within a bag" and contain a pre-mix of seed containing Bt toxins w/ seed that does not. Contact your seed representative for the refuge requirement of each hybrid you plant.

Resistance Management

At-plant, Soil Applied Insecticides.

Management of corn rootworms is challenging because of past and current resistance issues. Currently there is no known resistance of corn rootworm larvae to currently labeled soil-applied insecticides. However, there was widespread resistance to the cycloydiene class of insecticides in the 1960's and 1970's. Also, in the Great Plains area of the United States, adult corn rootworms have become resistant to foliar applications of carbamate and organophosphate insecticides. Although not considered insecticide resistance, carbofuran and isofenfos have been lost to the corn rootworm market because of enhanced microbial degradation. Enhanced microbial degradation happens when soil microbes use a pesticide as a food source, thereby reducing

its concentration in the soil to a point where it no longer effectively controls the target species. Repeated use of an insecticide can predispose a soil to breakdown a pesticide.

An awareness of these management issues highlights the importance of insecticide resistance management. Use insecticides only when necessary. Rotate modes of action to avoid both resistance and enhanced microbial degradation. Furthermore, improper calibration can promote insecticide resistance through repeated exposure to sub-lethal rates.

Transgenic Corn Hybrids

As previously mentioned, western corn rootworm have developed resistance to the Bt-hybrids in two Midwestern states and suspected in others. The development of resistance was quicker than expected and likely a result of several factors including;

- Expression of the Bt toxin at a low to moderate dose within the corn plant
- Repeated use of similar Bt-toxins
- Resistance was not a recessive trait as originally thought

To delay the development of Bt-resistance in rootworm populations it is important to use several IPM techniques including:

- Scouting.
  - Scout to determine if rootworm management is needed in next year's corn crop
  - Scout to choose appropriate management practice based on beetle populations and expected damage
- Crop Rotation
- Implementation of refuges
- Rotation of Bt modes of action

Validating Management Decisions

Verify accuracy of each management decision by scouting for root injury in mid to late July after the majority of 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.

Healthy corn roots show no signs of larval feeding.

Only outside roots show larval damage.

Severe larval damage to roots.

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.

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