PURDUE UNIVERSITY

PURDUE EXTENSION

E-49-W

Field Crops

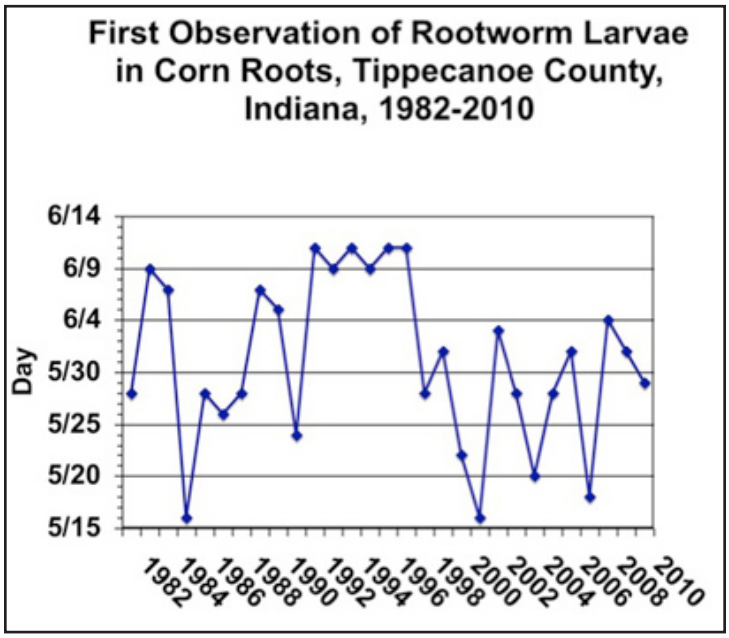
Department of Entomology

Managing Corn Rootworms

Larry W. Bledsoe and John L. Obermeyer, Extension Entomologists

The western corn rootworm (WCR) is the dominant rootworm species in Indiana. Two other species, the northern and southern, are also found in the state but are considered of no economic importance in Indiana. Pictures of the beetles, larvae, and damage to corn roots and ears are shown in Purdue Extension Publications E-83 and E-84.

WCR egg hatch, which is primarily dependent on the accumulation of soil heat units, begins in mid-May to mid-June (Figure 1), the warmer the soil, the earlier the eggs hatch. The larvae pass through three growth stages (instars). The first and second instars tunnel from root tips to the plant base, leaving visible feeding scars. Third instars generally feed on larger nodal roots near the plant stalk. Brace roots are often damaged once they enter the soil. Third instars pupate in earthen cells from mid-June to early August. Adults emerge from their underground pupal cells over a period of about six weeks, beginning in late June to mid July. Adult feeding begins immediately upon emergence. The adults will feed on pollen, corn silk, corn leaf tissue, and exposed corn kernels. WCR beetles may move back and forth between corn, soybean, and alfalfa where they feed on pollen, flowers, and leaf tissue.



They also feed on the pollen of several weed species. Mating begins shortly after emergence and eggs are deposited in moist soil from midsummer through early September. The minute oval eggs lie dormant (diapause) in the soil through the winter.

The potential risks for most rootworm adult and larval injury can be estimated by scouting fields.

Beetle Sampling and Management

Adult Counts to Determine Corn Silk Damage

Begin checking cornfields for the presence of beetles shortly before silk protrudes from the tip of developing ears. If, after examining 5 plants in each of 5 areas of the field, you see no rootworm beetles or silk damage, check the field again within 3 days. Even if no beetles are found, sample twice weekly until silk has turned brown.

Table 1. Insecticides for Rootworm Beetle Control in Corn

Insecticide	Formulation	Rate/Acre
bifenthrin (Capture)[a]	2 EC	2.1 oz.
carbaryl (Sevin)	XLR+	1 qt.
chlorpyrifos (Lorsban)[a]	4 E	1 pt.
chlorpyrifos and gamma-cyhalothrin (Cobalt)[a]	EC	13 oz.
cyfluthrin (Baythroid XL)[a]	2 E	1.6 oz.
deltamethrin (Delta Gold)[a]	1.5 EC	1.5 oz.
esfenvalerate (Asana XL)[a]	0.66 EC	5.8 oz.
gamma-cyhalothrin (Proaxis)[9]	0.5 EC	2.6 oz.
lambda-cyhalothrin (Warrior)[a]	1 CS	2.6 oz.
malathion (Malathion)	57 EC, EL	1 1/2 pt.
methyl parathion (Penncap-M)[a]	2 FM	1 pt.
permethrin (Ambush)[a] (Pounce)[a]	 2 E 3.2 EC	 6.4 oz. 4 oz.
zeta-cypermethrin (Mustang Max)[a]	0.8 EW	2.7 oz.

Most Indiana corn does not require a spray for silk protection. However, when tassels are shedding pollen and green silk is continuously clipped back to 1/2 inch or less before 50% pollination has taken place and beetles are present, a yield loss may result. Refer to Table 1 for insecticides that control rootworm adults.

Adult Counts to Determine Potential for Larval Problem Next Season

Corn: Fields should be surveyed for beetles from mid July through early September. For whole plant counts, make 2 counts in each of at least 20 equally separated locations in a field and at least 25 rows from field margins. Each count is made by randomly selecting a plant and counting the beetles on the leaves, stalk, tassel, around the ear, and on or in the silk. To determine the number of beetles on or in the silk, grab the ear tip in your hand, slowly open your hand, count the number of beetles in the silk, and record the number. Repeat this procedure for a second plant that is within 10 feet of the first plant. Then move to the next area of the field and sample two more plants. Determine the average number per plant. Remember, when beetles are present, samples to determine the average number per plant must be made weekly. Where economic populations of rootworm beetles (Table 2) were observed in cornfields that will return to corn the following season, a soil insecticide should be applied.

Soybean: Agriculturists in areas of Indiana, Illinois, Michigan, Ohio, Wisconsin, and Ontario, Canada have observed first-year cornfields showing damage due to WCR larval feeding. Larval damage in first-year corn following soybean have primarily occurred in the northern half of Indiana (Figure 2). Years of intensive corn/soybean crop rotation resulted in greater survival of offspring when eggs were laid in fields other than corn.

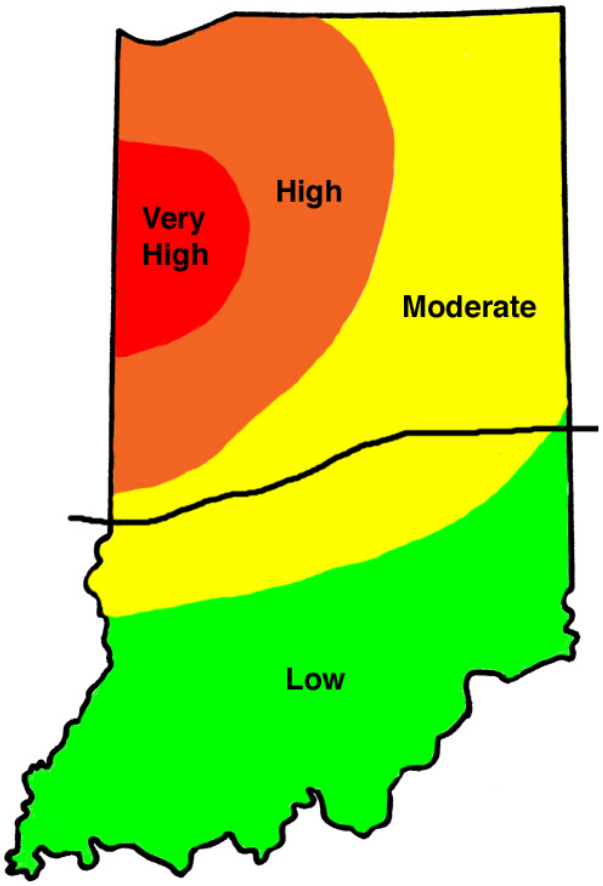
Table 2. Average Number of Beetles Per Corn Plant Which is Likely to Produce an Economic Larval Population the Following Year

Avg. No. of Corn Plants/Acre	Avg. No. of Beetles Per Corn Plant	
	Continuous* Corn	First-Year** Corn
14,000	1.4	1.0
16,000	1.3	.9
18,000	1.1	.8
20,000	1.0	.7
22,000	.9	.6
24,000	.8	.6
26,000	.8	.5
28,000	.7	.5

* Based on 1:1 ratio females to males. Corn following corn

**Based on 7:3 ratio females to males. Corn following soybean or alfalfa

Figure 2. Perceived First-Year Corn Rootworm Risk Areas



Very High - Indicates that consistently high numbers of WCR beetles have been found in soybean fields. First-year WCR damage is likely and may be severe in parts of or whole fields.

High - Risk indicates that most soybean fields sampled or observed in that area contained high numbers of WCR beetles coupled with the fact that first-year corn rootworm damage frequently occurs.

Moderate - Risk means that WCR beetle numbers vary from field to field and that significant first-year rootworm damage is expected to be spotty.

Low - Risk areas have consistently low WCR beetle numbers in soybean with few, if any, damaged first-year corn fields expected.

At the beginning of the last full week of July, place 6 Pherocon AM (non baited) yellow sticky traps (sticky surface out) on stakes at least 100 paces apart in a soybean field, keeping at least 100 feet away from the field edges or waterways. Place the traps in any random pattern, but consider efficiency as they need to be visited weekly. Each week for 6 weeks or until the beetle threshold is reached (see "Criteria for Applying Corn Rootworm Control"), remove the traps and position new ones just above the soybean canopy. Count and record the number of the rootworm beetles on the cards. Calculate the average number of WCR beetles/trap/

day. Pherocon AM yellow sticky traps can be purchased from several distributors. Refer to publication E-218, Monitoring and Decision Rules for Western Corn Rootworm Beetles in Soybean, for more details. Where numbers of WCR beetles on Pherocon AM yellow sticky traps in soybean fields averaged five (5) or more beetles/trap/day during any trapping week, the application of a soil insecticide in these fields the following season is likely needed. NOTE: In research fields where at least 5 WCR beetles/trap/day in soybean were observed, >95% of the cornfields reached significant root damage the following year.

Male (left) and female (right) western corn rootworm beetles (*Photo by B. Christine*)

Larval Sampling and Management

Corn producers planting in late March or in early April, or those preferring a post-emergence application, should examine plants before lay-by to determine need for a soil insecticide. Sampling a field before lay-by will also give an indication of the performance of a soil insecticide, if one was applied at planting.

From early to mid-June, depending on the time of hatch (only second and third instars can be readily seen), randomly select 1 plant in each of at least 10 representative areas of a field. Using a spade or shovel, cut a 7-inch cube of soil around the base of each plant, making certain that the blade of the tool enters the soil vertically. Lift the plant and soil out of the ground, and place it on a piece of dark cloth or plastic. Slowly break the soil away from the roots and carefully examine the soil and roots for rootworm larvae. Look for small, slender, white larvae with brown head and tail sections.

As an alternative sampling method, the soil and root sample can be washed in a pail of water to extract the larvae. The larvae will float to the top and can be counted. Saturating the water with salt will cause the worms to float to the top more easily.

Count and record the number of larvae found. Repeat the sampling procedure for each plant. After all samples have been processed, determine the average number of rootworms per plant and note whether the numbers are the result of hand sorting or washing the soil and roots.

Where the average number of larvae in soil samples is approximately 2 or more per plant by hand sorting or 8 or more per plant by washing, a soil insecticide may be needed before lay-by. Apply a soil insecticide according to post emergence application instructions on the product label.

Other Soil Pests

The above discussion is based on assessment of risk of damage from corn rootworm. An insecticide may be needed if other soil insect pests are present in damaging numbers. Whenever soil insecticides are used, we encourage producers to leave small, untreated strips in order to evaluate product performance for other soil pests and the economics of using insecticides.

Performance of Soil Insecticides

Research and Extension entomologists at Purdue and other Midwestern universities in the Corn Belt continually evaluate insecticides to obtain performance data for use in making recommendations. All the labeled rootworm control products listed in Table 3 may vary in level of performance. None provide complete control of the larvae (60-80% control more likely), and protection of the primary portion of the root system from economic rootworm attack is the goal. Occasionally some economic damage may occur depending on the larval population, weather, planting date, insecticide rate, plant development, and time of larval hatch. All of these factors can ultimately impact product performance and must be considered when using a soil insecticide. The important thing for producers to understand is the positive and negative aspects of each product, and determine which one(s) fits best within their farming system. Also, one needs to understand what the warranty for each product really means. Additionally, it is valuable to have untreated check strips in fields to gauge the performance and economics of the products used.

All granular and liquid insecticide applicator units should be calibrated each year to ensure the proper amount of insecticide is applied. Placement of the insecticide is also very important, primarily because placement and incorporation are closely related. Experiments conducted at Purdue University and elsewhere have demonstrated that even in corn no-tilled into heavy surface residue, in-furrow and banded applications are equally effective provided, when banding, the bander is placed such that the product is placed in front of and lightly incorporated by the action of the furrow-closing wheels or press wheels.

Date of planting can also affect the performance of rootworm insecticides. In Indiana, the majority of soil insecticides for rootworm control is applied at planting in April or early May. However, rootworm larvae do not begin hatching from the overwintering eggs until mid May or early June (Figure 1). The greater the time between insecticide application and egg hatch (i.e., early planting), the greater the opportunity for the concentration of the insecticide to be reduced to an ineffective dosage in the soil. Thus when planting before May 1 and rootworms are expected to be a problem, use the highest labeled rootworm rate.

Ideally, the insecticide should provide the best control if applied at, or shortly before, the time larvae are present. Indeed, rootworm insecticides can be applied in this manner as postemergence or cultivation-time treatments. Producers applying liquid 28% (UAN) nitrogen postemergence at the base of the plants in a 6-8 inch band could possibly mix it

Table 3. Factors to Consider When Choosing a Product for Corn Rootworm Protection*								
Insecticide Class	**Organophosphates**			**Pyrethroids**		**Fiproles**	**Nicotinoids**	**Transgenic**
Chemical Name	**chlorethoxyphos**	**chlorpyrifos**	**tebupirimphos & cyfluthrin**	**bifenthrin**	**tefluthrin**	**fipronil**	**clothianidin**	**Cry3Bb1**
Trade Name & Formulations(s)	**Fortress 2.5G Fortress 5G (SmartBox)**	**Lorsban 15G Lorsban 4E generics**	**Aztec 2.1G Aztec 4.6G (SmartBox) generics**	**Capture 2E**	**Force 3G**	**Regent 4SC**	**Poncho 1250 (treated seed)**	**YieldGard RW**
Factors:								
Performance: test plots - band application	Fortress 5G	Lorsban 15G	Aztec 2.1G	Capture 2E	Force 3G	n/a	n/a	n/a
Root damage rating[1]	0.22	0.29	0.23	0.42	0.30			
Consistency of performance (%)[2]	91	80	88	70	81			
Performance: test plots - infurrow application	Fortress 5G	Lorsban 15G	Aztec 2.1G	Capture 2E	Force 3G	Regent 4SC	n/a	n/a
Root damage rating[1]	0.36	0.35	0.21	0.42	0.31	0.63		
Consistency of performance (%)[2]	70	79	87	55	71	61		
Performance: test plots - treated seed	n/a	n/a	n/a	n/a	n/a	n/a	Poncho 1250	n/a
Root damage rating[1]							0.40	
Consistency of performance (%)[2]							79	
Performance: test plots - genetically modified	n/a	n/a	n/a	n/a	n/a	n/a	n/a	YGRW
Root damage rating[1]								0.12
Consistency of performance (%)[4]								94
Technical information								
Registered for use at cultivation	N	Y	N	N	Y	N	n/a	n/a
Registered for popcorn/seed corn/sweet corn	PES	E	PES	PES	PES	E	PS	n/a
Human hazard (signal word)								
Granular formulation	D	C	W	n/a	C	n/a	n/a	n/a
Liquid formulation	n/a	W	n/a	W	n/a	W	n/a	n/a
Restricted-use pesticide	Y	N	Y	Y	Y	Y	N	N
Labeled for control of other soil pests at the rootworm rate[3]								
billbugs	N	Y	N	N	N	Y	N	N
cutworms	Y	Y	Y	Y	Y	N	Y	N
nematodes	N	N	N	N	N	N	N	N
seedcorn beetle	N	Y	Y	Y	Y	Y	N	N
seedcorn maggot	Y	Y	Y	Y	Y	Y	Y	N
white grubs	Y	Y	Y	Y	Y	Y	Y	N
wireworms	Y	Y	Y	Y	Y	Y	Y	N

*Key to symbols: n/a = not applicable, D = danger, W = warning, C = caution, Y = yes, N = no, P = popcorn, E = seed corn, S = sweet corn.

[1]Average root damage rating (Node Injury Scale 0-3) where damage in the untreated plots exceeded 0.25 or greater that will likely predisposed plants to significant yield losses. The untreated plots averaged 1.44.

[2]Percentage of root masses where damage rating was less than or equal to 0.25 when the untreated equaled or exceeded 0.25. Tests from 2003-2007.

[3]Insecticide not included if label states “for suppression,” “reduction of,” “aids in control,” or “control of light to moderate infestations only.”

[4]2004-2007 Data only.

with one of the liquid rootworm insecticides. Read the label for use restrictions and mixing information. Compatibility checks should be made before tank mixing. Weather is probably the biggest limiting factor in using postemergence treatments effectively. Wet fields during late May to early June could prevent timely application, thus leaving the corn vulnerable to attack by rootworms. Reduced tillage may limit the use of a rootworm insecticide as a postemergence treatment because cultivation to incorporate the insecticide would not be possible. In this case, crop rotation or application of an insecticide at planting are the only alternatives.

Soil moisture is probably the key non-biological factor affecting the ultimate level of control with a soil insecticide. Too much or too little soil moisture can adversely affect insecticides in different ways. Under dry soil conditions, the insecticide may not be distributed adequately in the soil solution and profile, which is necessary to effect control. On the other hand, under extremely wet conditions, the insecticide may be leached out of the soil profile or carried away with surface runoff.

Soil microorganisms play an important role in decreasing the effective life of some, if not all, soil-applied insecticides. Soil-applied insecticides used today are broken down biologically by soil microorganisms such as bacteria, fungi, and actinomycetes. In some soils, this biodegradation has apparently been enhanced over time. When applied at planting, the rate of breakdown of these insecticides have been accelerated to the point where the level in the soil was insufficient at the time when protection from rootworm larvae was needed.

One strategy to help avoid, or perhaps merely postpone, the development of widespread problems with enhanced biodegradation resulting in control failures is to rotate insecticides. The basis for this is that the insecticides currently available are structurally different, even if they belong to the same chemical class (Table 3). To date, it has not been demonstrated that a soil able to rapidly degrade one insecticide is necessarily predisposed to degrade others. Consequently, producers who have used any insecticide for more than two consecutive years should consider switching to another product, but not necessarily one belonging to a different insecticidal class.

Transgenic Bt Corn

Hybrids that have been genetically engineered to provide root protection against attack by rootworm larvae were on the market for the first time in Indiana in 2003. These genetically modified corn hybrids contain a gene derived from a naturally occurring soil bacterium, *Bacillus thuringiensis* (Bt), which produces a specific protein that is toxic to both species of the western and northern rootworm larvae (Bt-RW). Beetles of these species are not adversely affected when they feed on leaves, pollen, or silks of these transgenic corn plants.

Bt-RW is produced by genetically altering the corn plant's DNA to include a gene that produces a toxic protein specific to rootworms. Although death is not immediate, the insect slows or stops feeding and little movement occurs. This gene can be expressed throughout the plant or in specific structures depending on the technique used to place the gene in the plant. As in most Bt hybrids, the gene is expressed in multiple plant parts.

Below ground insects, other than corn rootworm, may be present during the season and Bt-RW corn provides no protection against these. All Bt-RW hybrids will be pre-treated with a low rate of a seed-applied insecticide to protect against these other below ground insect pests.

Resistance developing within the rootworm population with this technology is a potential problem. To reduce this possibility, non-Bt-RW corn should be grown in the same or adjoining field of Bt-RW corn. This refuge will allow the diverse gene pool in the rootworm population to be spread among the beetle population within an area. However, if this technology is widely adopted and refuge is ignored or poorly devised, this will limit the gene pool and could result in the widespread development of resistance in the rootworm population. Non-Bt corn, treated with a soil insecticide, will act as a refuge for some of the rootworm, thus preserving the genetic diversity that is now in the population. To accomplish this, producers must plant at least 20% of their corn acreage in non-Bt-RW corn within the same or adjoining field. If these refuges are not provided, this technology may be short lived.

Extended Diapause in Northern Corn Rootworm

Rootworms have adapted to temperate conditions by producing eggs that require exposure to cold temperatures before hatching. This condition prevents eggs from hatching in the fall and allows the insect to survive winters in North America when its host is not available. This dormant period is called diapause. Extended diapause describes a condition that exists when an insect's normal dormant period is prolonged beyond what is expected. A small percentage of NCR eggs are capable of remaining dormant in the soil through two winters and one growing season before hatching in the second season. First-year corn in areas of Minnesota, Iowa, and South Dakota have been damaged by NCR with the extended diapause trait. The dominant species in Indiana is WCR, which continues to have an insignificant percentage of eggs with the extended diapause trait.

Western Corn Rootworm: *Diabrotica virgifera virgifera* LeConte
Northern Corn Rootworm: *Diabrotica barberi* Smith & Lawrence
Southern Corn Rootworm: *Diabrotica undecimpunctata howardi* Barber

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