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Adult Corn Rootworm Management

Western corn rootworm, *Diabrotica virgifera virgifera LeConte*

Northern corn rootworm, *D. barberi Smith and Lawrence*

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Western corn rootworm beetle, *Diabrotica virgifera virgifera LeConte*, photo by J.A. Kalisch.
Northern corn rootworm beetle, *D. barberi Smith and Lawrence*, photo by M.E. Rice.

Adult Corn Rootworm Management

Lance J. Meinke - Associate Professor

The western corn rootworm (WCR), *Diabrotica virgifera virgifera* LeConte, and the northern corn rootworm (NCR), *D. barberi* Smith and Lawrence, are among the most economically important insect pests of field corn in the United States. Crop losses and control expenses attributed to corn rootworms annually cost producers millions of dollars. Corn rootworm larvae can cause substantial injury to corn plants by feeding on corn roots. Larval tunneling interrupts the integrity of root systems and may destroy individual roots or root nodes (i.e. root pruning). Root feeding by larvae can adversely affect plant growth and development and reduce plant stability and grain yield. If extensive root injury coincides with heavy rains and strong winds, plants may lodge (lean over), reducing light interception by plants and resulting in mechanical harvest losses.

Several corn rootworm management options are available to producers. Rotating corn with nonhost crops will effectively prevent larval corn rootworm damage in most fields. If corn is planted in a field for two or more successive years (continuous corn), a corn rootworm beetle scouting program can be used to determine if insecticide applications are needed (Stamm et al. 1985). When necessary, insecticide applications can be directed toward corn rootworm larval or adult stages. One commonly used strategy is to apply a soil insecticide at planting time or first cultivation to reduce larval feeding damage (Mayo and Peters 1978). An alternative strategy targets the beetle or adult stage. Insecticide applications are used to suppress beetle populations and reduce egg-laying so that larval populations the following year will not cause economic loss (Pruess et al. 1974). This publication focuses on the latter strategy.

In areas of the western Corn Belt, adult corn rootworm control programs have been used for over 30 years to manage corn rootworm populations in continuous corn. In Nebraska, when western corn rootworm resistance to organochlorine insecticides became apparent in 1961, producers in the south central area started using aerial applications of insecticides to suppress beetle populations and subsequently manage larval damage the following season (Beardmore 1975, Mayo 1976). Various studies demonstrated that aerial applications could greatly reduce adult corn rootworm populations (Hill et al. 1948, Musick 1971, Mayo 1976, Union Carbide 1977), and Pruess et al (1974) documented that the adult corn rootworm management strategy could be used to prevent economic damage the following season. This practice, used in conjunction with field scouting to determine beetle densities and to identify fields exceeding thresholds, is used and/or recommended by a growing number of professional crop consultants in Nebraska and other Corn Belt states.

Adult corn rootworm control is also used to prevent silk clipping and subsequent reductions in grain yield and seed quality of inbred corn grown for production of hybrid seed. Insecticide applications often are applied to seed-corn fields during pollination when beetle densities exceed threshold levels, but are not intended to manage corn rootworm egg populations and larval damage the following year. Low numbers of western corn rootworm beetles per ear can cause significant damage to seed corn during pollination (Culy et al. 1992). The impact of beetle injury can be reduced or magnified because of environmental conditions present during pollination. Commercial hybrid corn appears to be much more tolerant to beetle silk feeding than inbred corn lines. Capinera et al. (1986) reported that densities of up to 20 beetles per ear did not significantly reduce commercial hybrid corn yields. Use of adult corn rootworm control strictly to prevent silk clipping is rarely justified in commercial hybrid corn fields.

Most insecticides used for beetle control are applied aerially, although some applications in the western Corn Belt are delivered through sprinkler irrigation systems (chemigation). Most of these insecticide formulations are "contact kill" products — beetles are killed if directly hit by spray droplets during application or by walking on a sprayed surface. Refer to Cooperative Extension insecticide recommendations for current information on specific products approved for corn rootworm control.

Adult corn rootworm management is very knowledge and labor intensive. A good understanding of beetle biology and factors that affect beetle population dynamics and movement in agroecosystems is needed to effectively use an adult management strategy.

Adult Corn Rootworm Population Dynamics

Many factors can interact to determine beetle population levels in a corn field at different times during the season. The number of beetles emerging from within a

continuous cornfield is often a primary contributor to the total population level in a field. Even if an adult management strategy was successfully used the previous year, or a soil insecticide was applied at planting-time or in conjunction with cultivation, some larvae will be present (few to many depending on the situation) which will eventually emerge as adults.

Planting date significantly affects when emergence begins. In late planted fields, as compared to early planted fields, initial emergence is often delayed, and total emergence reduced (Bergman and Turpin 1984; *Table I*). Initial beetle emergence can occur as early as late June in some areas of the Corn Belt. Peak beetle densities usually occur during July to mid-August in many areas, with most eggs laid from late July through early September.

Beetle movement also can contribute to the population level in a field during a specific time period. Both western corn rootworm and northern corn rootworm beetles are very mobile, and short-range trivial movement within fields or into neighboring fields occurs during the entire time beetles are present. The relative proximity of a cornfield to other continuous cornfields will influence the size of the immigrant pool of beetles. The western corn rootworm has been shown to have a true migratory phase in which a certain proportion of a population will move long distances. Migrating females often are mated, but have not yet developed mature eggs (Coats et al. 1986; Grant and Seevers, 1989). Many migration events occur during or just after peak emergence, but long range movement has been observed throughout the adult activity period. The mobility of corn rootworm beetles also enables them to colonize first year cornfields. Because a high percentage of migrant western corn rootworm beetles are usually female, more female western corn rootworms are often found in first year cornfields than males (Godfrey and Turpin 1983).

Western corn rootworms and northern corn rootworms prefer pollen (especially corn pollen/silks) as a food source so pollinating fields attract beetles. The corn growth stage in an individual field relative to surrounding cornfields can greatly influence whether the field will be a "donor field", a "receiver field", or a "neutral field". If corn in a field pollinates later than corn in the surrounding fields, the field will be attractive to beetles and some beetles may move into the field (receiver field) from fields that have finished pollination (donor fields). If corn in all fields within a local area pollinates about the same time, then each field in relation to surrounding fields would be similar in attractiveness to beetles (neutral fields) thereby lessening the chance that mass movement of beetles into one or more fields will oc-

Table I. Corn rootworm emergence profiles from a continuous cornfield, Saunders County, Nebraska, 1994[1].

	Cumulative Percentage Emergence			
	Western Corn Rootworm		*Northern Corn Rootworm*	
Date	*Males*	*Females*	*Males*	*Females*
		Planted: May 3, 1994[2]		
5 July	17.9	6.3	0.0	0.0
8 July	39.3	12.5	30.8	0.0
12 July	71.4	31.3	46.2	12.5
18 July	85.7	59.4	61.5	37.5
26 July	89.3	75.0	100.0	100.0
2 August	100.0	84.4		
11 August	100.0	96.9		
18 August	100.0	100.0		
		Planted: May 24, 1994[3]		
5 July	0.0	0.0	0.0	0.0
8 July	0.0	0.0	0.0	0.0
12 July	0.0	7.7	0.0	0.0
18 July	40.0	61.5	54.5	0.0
26 July	40.0	84.6	100.0	100.0
2 August	80.0	84.6		
11 August	100.0	84.6		
18 August	100.0	100.0		

[1]A sixteen-row strip of late-planted corn was placed in the center of an early-planted 30-acre field. Beetles were collected over time from single plant emergence cages (Hein et al. 1985) placed in the early and late-planted part of the field (12 cages per planting date). Cages were arranged in side by side transects that ran the length of the field.

[2]May 3, 1994 planting date: initial corn rootworm egg hatch was detected June 2, 1994; initial WCR emergence: June 27, 1994; total beetles collected from 12 cages: 60 WCR, 21 NCR; final sex ratios; WCR: 0.88 ♂: 1 ♀, NCR: 1.63 ♂: 1 ♀; beetle whole plant counts reached the economic threshold by July 12, 1994; initial egg-laying WCR females observed July 20, 1994.

[3]May 24, 1994 planting date: total beetles collected in 12 cages: 18 WCR, 12 NCR; final sex ratios: WCR: 0.38 ♂: 1 ♀, NCR: 11 ♂: 1 ♀.

cur. Receiver fields also may act as trap crops, (i.e. an increase in female beetle density over time results in more eggs being laid in these fields than in surrounding fields), which can influence the amount of larval damage that will occur in receiver and donor fields the next season.

Weather patterns can greatly influence immature and adult corn rootworm survival, the beetle emergence pattern, and the length of beetle activity/egg laying periods. Very wet soil conditions (i.e. waterlogged soils) during the larval/pupal period can reduce larval establishment on plants or kill larvae and pupae, thus reducing the number of adults emerging in a field. A cool summer can slow larval and plant development, which will influence initial beetle emergence dates. Cool weather also can lengthen the beetle emergence, beetle activity (increase survival/longevity), and egg-laying periods. Conversely, hot weather can speed up immature rootworm development, greatly compress the emergence period, and shorten beetle activity and egg-laying periods (greater mortality/shorter life span due to heat stress).

Management Considerations

When using an adult corn rootworm management strategy in continuous corn, it is important to scout cornfields starting in late June to identify when initial beetle emergence occurs, to identify which corn rootworm species are present, and to determine if beetle densities reach the established economic threshold. Whole plant beetle counts, ear zone beetle counts, and sticky traps are sampling methods that can be used to estimate corn rootworm population levels (Hein and Tollefson 1984, 1985). Economic thresholds used in Corn Belt states are based on pooled western corn rootworm and northern corn rootworm counts obtained from sampling programs. In many states, whole plant count thresholds are set values independent of plant population, while in other states thresholds are placed on a sliding scale dependent on field plant population *(Table 2)*. Because the female to male corn rootworm ratio is usually greater in first year cornfields than continuous cornfields, thresholds are lower in first year cornfields *(Table 2)*. Consult your local Cooperative Extension Office for more information on adult economic thresholds.

Several factors related to beetle emergence patterns should be considered to target the optimal time for initial insecticide applications. In some years, when western corn rootworms emerge before corn pollen is available (i.e. before tasseling), beetles will feed on lower leaves and then move to silks and tassels as they become available. Female beetles on the average need to feed on high quality food (i.e. pollen, silks, ear tips) for at least 10-14 days before they can lay eggs (Branson and Johnson 1973). When corn leaves are the primary food source, egg development is delayed (Elliott et al. 1990). Also, more males than females emerge during the early emergence period *(Table I)*. Males and females without fully developed eggs will be present at this time, so few eggs will be laid. When scouting fields, it is important to estimate beetle population levels (in relation to the threshold) as well as record when initial gravid females are observed to appropriately time insecticide applications.

The beetle sex ratio, female reproductive status, and emergence rate during the early emergence period usually make it advantageous not to spray during the first three weeks of the emergence period even if beetle densities exceed threshold levels. In most years, a large proportion of the total beetle emergence from a given field will occur during the first three to four weeks of the emergence period. Delaying the initial insecticide application for three weeks after first beetle emergence will allow applicators to target more effectively the egg-laying proportion of the beetle population; more females will emerge before application and the pool of emerging beetles that can contribute to population resurgence after the insecticide application will be reduced. (See *Table I* for an example of emergence profile/economic threshold/female reproductive status interactions that can affect adult management decision-making.)

After an initial insecticide application, it is important to continue monitoring beetle population levels and to consider the biological variables and weather trends that affect population resurgence when evaluating product performance and the potential need for another application. The resurgence level will be determined primarily by: 1) the number of beetles surviving the initial application (dependent on inherent properties of the product, product residual, and pre-application beetle population level);

Table II. Nebraska adult corn rootworm economic thresholds adjusted for plant population.[1]

Average no. plants per acre	*Average no. of rootworm beetles per plant*	
	continuous corn[2]	*first year corn[3]*
18,000	1.00	0.75
20,000	0.90	0.68
22,000	0.81	0.61
24,000	0.75	0.56
26,000	0.69	0.52
28,000	0.64	0.48
30,000	0.60	0.45

[1]Beetle population densities ≥ the threshold may produce an economically damaging larval population in corn the following season.
[2]Based on 0.75 beetle per plant equivalents @ 24,000 plants per acre and a 50:50 ratio of females to males using the formula (Stamm et al. 1985):

$$\text{Adjusted beetles per plant} = (0.75 \text{ beetle per plant}) \times \frac{24{,}000 \text{ plants per acre}}{\text{field plant population per acre}}$$

[3]Based on 70:30 ratio of females to males; 75% of continuous corn threshold.

2) beetle emergence after the application; and 3) beetle movement into the field minus beetle movement out of the field. Retreatment thresholds often are lower than the economic thresholds used to trigger initial applications because females usually become a larger proportion of beetle populations as the season progresses. Unless there is good evidence that the initial application failed (i.e. few dead beetles observed, many gravid females present), it is usually advantageous to delay a second application until later in the egg-laying period when emergence is near completion. Rarely, can more than two applications be economically justified for corn rootworm management. In addition, usually it is not economical (or environmentally sound) to use a beetle control program followed by a soil insecticide application the next season in continuous corn.

When beetle emergence and egg-laying periods are relatively short in duration (i.e. hot, dry year), it is usually easier to manage corn rootworm populations with only one well timed insecticide application because the critical period when the insecticide must lower beetle densities will be shorter and there is less chance of prolonged population resurgence after application. In a cool wet year, with prolonged beetle emergence and egg-laying periods and potentially shorter product residual due to washoff, a situation may be created where overall control is poor and population resurgence may be fairly rapid. It is also more difficult to successfully manage corn rootworm populations using an adult-based strategy in receiver or trap crop fields than in donor or neutral fields because there is a greater chance for population resurgence in receiver fields after insecticide application.

In summary, when making adult management decisions it is important to consider each management situation separately, taking into account how the previously discussed factors interact. This is especially important when selecting the product to be used for beetle control, when determining the appropriate application time(s), and when evaluating product efficacy.

Adult corn rootworm management advantages. Many planting-time soil insecticides are applied prophylactically without knowledge of pest density as "insurance treatments" for corn rootworm control. Adult corn rootworm management is based on scouting, thresholds, and knowledge of insect biology. It is geared toward the Integrated Pest Management concept of treating only when necessary. Proper use of an adult management strategy provides greater corn rootworm population management than when a soil insecticide is used. Soil insecticides provide some measure of root protection, but many beetles emerge annually from soil insecticide-treated fields, contributing to future egg and larval populations (Gray et al. 1992). Use of custom aerial application also restricts pesticide handling, calibration, storage, and application to a few individuals (in contrast to soil insecticides) which reduces annual grower exposure to pesticides. Depending on the product and application timing, other corn pests (i.e. western bean cutworm, European corn borer) may be managed with adult corn rootworm applications, decreasing total pest management cost.

Adult corn rootworm management disadvantages. Adult corn rootworm management is more labor and knowledge intensive than other management alternatives (e.g. crop rotation, larval control) so it is recommended that a well trained individual (i.e. professional crop consultant) be consulted to evaluate each situation and properly time insecticide applications when needed. Some broadcast applications of conventional products can kill nontarget insects (e.g. bees, predatory insects) and contribute to spider mite outbreaks. Because corn rootworm population suppression is the goal of the adult management strategy, widespread use of this strategy could place enough selection pressure on local rootworm populations that future generations might become resistant to selected insecticides. Finally, in some locations, especially where crop land is near urban areas, the general public may not always respond favorably to aerial application of pesticides.

Research/Emerging Technologies

Behavior-based adult corn rootworm management concept. An adult corn rootworm management concept has been developed in which semiochemicals (beetle behavior modifying chemicals) are used to facilitate beetle location and feeding on formulations that contain small amounts of insecticide. This "bait-type" concept relies on beetles coming to and eating the insecticide while, as previously mentioned, most insecticides currently used for beetle control are "contact kill" products. Currently, the key ingredients found in behavior-based formulations are cucurbitacins which are bitter compounds found in most cucurbits. Curcurbitacins are not sufficiently volatile to act as attractants, but corn rootworm beetles stop and feed compulsively when they touch substrates that contain the compounds. Cucurbitacins also have been shown to be antifeedants for selected nontarget insects found in corn fields (Weissling et al. 1991).

Research and development of cucurbitacin-based baits has been conducted for more than a decade. Laboratory bioassays and small-scale field studies have documented that efficacy of bait particles containing small amounts (typically < 1%) of insecticide was greatly enhanced when minute amounts of cucurbitacins were added to formulations (Metcalf et al. 1987, Lance and Sutter 1990, Weissling and Meinke 1991). Several sprayable semiochemical-based baits are available commercially. These baits have been successfully used for beetle control in commercial cornfields and show potential for use in corn rootworm management programs (Sutter and Hesler 1993, Meinke 1994).

Potential benefits from utilizing the behavior-based approach include: 1) effective beetle control can be obtained with low amounts of insecticide per acre,
2) adverse effects on nontarget organisms are reduced because formulations are fairly pest specific and must be eaten, 3) human exposure to insecticides and potential environmental contamination are reduced.

Areawide Corn Rootworm Management. Currently, the adult corn rootworm management strategy described here is applied to single continuous cornfields or groups of fields in local areas. Because of the mobility of corn rootworm beetles and the challenge to adequately reduce egg laying to acceptable levels in some fields under certain conditions (i.e. receiver fields surrounded by continuous corn, high population levels, etc.), managing adult corn rootworm populations on an areawide basis has been proposed as an alternative to managing single fields. This idea was initially studied by Pruess et al. (1974) who conducted an experiment to suppress adult corn rootworm densities in a 16-square-mile area of Nebraska. The USDA recently has been conducting similar research within a 16-square-mile management area in South Dakota where semiochemical-based baits have been used as the adulticide (Sutter and Hesler 1993). Cooperation would be required of growers, consultants and various state/federal agencies to enable an areawide management program to be successful. Mandatory compliance within large areas could be required, however, this would differ greatly politically and logistically from the way adult management strategies are now used. Currently the areawide management concept is being discussed at federal and state levels (see Gray 1995 for current developments/debate) to determine if pilot programs should be conducted.

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