First-Year Corn Rootworm Injury: East-Central Illinois Research Progress to Date and Recommendations for 1996

Eli Levine and Michael Gray

Background

Western and northern corn rootworms are the most serious insect pests of non rotated corn in the midwest (Levine and Oloumi-Sadeghi 1991). Adult female beetles lay the vast majority of their eggs in the soil of cornfields during August and early September, and the eggs lie dormant until hatching in the spring. Generally, very few eggs are laid in other crops. Because rootworm larvae cannot survive on roots of crops such as soybeans, alfalfa, or wheat, crop rotation is recommended to manage these pests. In fields where corn is grown year after year, soil insecticides are typically applied to protect roots from rootworm feeding.

In Illinois, the percentage of corn acres treated annually with soil insecticides has decreased from 65 percent in 1978 to 33 percent in 1990 (Pike et al. 1991). This reduction has been achieved largely through educational programs of the Cooperative Extension Service that encourage producers not to treat "first-year corn" (rotated corn) with a soil insecticide. However, the practice of prophylactically treating continuous corn with a soil insecticide still occurs on 88 percent of 2.8 million acres of continuous corn grown annually in Illinois at a price tag of approximately $37 million each spring. The importance of crop rotation from agronomic and pest management vantages has been capitalized on for many years by most corn growers in Illinois and in other parts of the Corn Belt. If corn rootworms become adapted (preliminary evidence suggests this may be occurring throughout east-central Illinois) to a corn and soybean rotation, and soil insecticides become a mainstay for profitable corn production in Illinois, the economic and environmental consequences would be staggering. Successes achieved regarding insecticide use reductions since the late 1970s could quickly become reversed. In light of

escalating environmental and human health and safety concerns relative to pesticide use, reversing previous gains is not acceptable.

Genesis of the Problem

In June 1987, severe corn rootworm larval injury to corn grown for seed production (inbred corn) was reported within a 1-square mile area near Piper City in Ford County, Illinois. The injury to corn roots occurred in six fields that had been planted to soybeans grown for seed production the previous year. All fields were free of volunteer corn or heavy weed infestations in 1986. Since that time, we have been trying to find the cause for this damage. The severe corn rootworm problem reoccurred in the same area in 1988 and in the years since.

We determined that the damage was caused by the western corn rootworm, not the northern corn rootworm. This was unexpected because prolonged diapause or dormancy is well known in the northern corn rootworm (Levine et al. 1992b, Steffey et al. 1992) and only recently has it been reported in the western corn rootworm, but at very low levels (less than 0.2% of *any* eggs observed, Levine et al. 1992a). Prolonged diapause allows eggs to pass through two or more winters before hatching rather than the normal one winter pattern. Larvae from such eggs could potentially cause damage to corn after a one-year rotation with another crop if resulting larval densities were sufficiently high. However, eggs from the Piper City population of western corn rootworms did not show*any* evidence of prolonged diapause (Levine 1993).

Although egg laying by Piper City western corn rootworms was taking place in soybean fields, a large 1989 field study less than 60 miles away in Urbana with different soybean plantings (giving different plant maturities) confirmed earlier published studies (Shaw et al. 1978) that neither western nor northern corn rootworms lay enough eggs in weed-free soybean fields to cause economic damage to a subsequent crop of corn (Levine 1993). Because western

corn rootworm adults are quite mobile and considerable genetic mixing is thought to occur, we expected that Urbana and Piper City populations to show similar egg-laying behavior.

We also investigated the possibility that western corn rootworms may have laid eggs in the Piper City soybean fields because pyrethroid insecticides used on neighboring seed corn may have repelled rootworm females into the nearby soybean fields (Levine 1995). Pyrethroid insecticides are routinely used for corn earworm control in seed corn and are typically applied during the first two weeks of August, the period of initial corn rootworm egg-laying. In several laboratory bioassays, we demonstrated that permethrin, a pyrethroid insecticide, could repel western corn rootworms from treated corn and cause them to lay eggs in untreated soybeans. We concluded that the situation at Piper City could very well have been caused by pyrethroid insecticide use.

1993 Problems and Follow-up

During the summer of 1993 we received a few reports of rootworm larval injury to first-year seed (inbred) and commercial (hybrid) corn following soybeans outside the Piper City area (but still in east-central Illinois). One of the fields was a seed cornfield in Flatville where pyrethroid insecticides were routinely used for corn earworm control. The remaining fields were in the Homer area and involved commercial corn with no history of pyrethroid use in the immediate area. Corn rootworm larval injury was severe in the Flatville field and moderate in the Homer fields. The western corn rootworm was overwhelmingly the predominant species in both areas. Western corn rootworm eggs obtained from female beetles collected in soybean fields in the Homer area were subjected to natural soil temperature conditions in the laboratory. By the end of June 1994, 83% percent of the eggs hatched and 11% remained unhatched, but appeared to be in good condition. These eggs were subjected to another overwintering cycle. None of these eggs hatched in the spring and summer of 1995 (75% died and 25% remained

unhatched). Based on these observations, prolonged diapause in the western corn rootworm did not appear to be the cause of the root injury problem in the Homer fields.

1994 Problems and Follow-up

During the summer of 1994, a number of new reports of rootworm larval injury to first-year commercial corn following soybeans were received, again all in east-central Illinois. One field near Dewey, several fields near Crescent City, and a couple of fields near Sibley sustained severe larval rootworm injury. The predominant species was the western corn rootworm in the fields near Dewey and Crescent City. The fields near Sibley also contained high densities of northern corn rootworm adults, so prolonged diapause in the northern corn rootworm could not be ruled out as the cause for rootworm injury in the Sibley fields. Pyrethroid use in the vicinity of all these fields was minimal.

Prolonged Diapause

To check for the prolonged diapause trait, eggs were obtained from western corn rootworm females reared from larvae collected at Crescent City and Dewey in June 1994 and from adults collected in August 1994 at Crescent City and Sibley. These eggs were then subjected to conditions they would normally experience in the field. By September 1995, none of the eggs obtained from female beetles reared from larvae collected at Crescent City (47.1% of the eggs hatched normally and the remaining 52.9% died) and only 9.8% of the eggs obtained from female beetles reared from larvae collected at Dewey remained unhatched, but appeared to be in good condition (the remaining 37.7% hatched normally and 52.5% died). In addition, by September 1995, only 5.6% of the eggs obtained from female beetles collected at Crescent City

and 3.1% of the eggs obtained from female beetles collected at Sibley remained unhatched but appeared to be in good condition (the remaining eggs either hatched normally or died). These potentially viable eggs are being subjected to another overwintering cycle. If they hatch in June 1996, we will know that they have the prolonged diapause trait. As mentioned earlier, the percentage of *any* western corn rootworm eggs with the trait has been less than 0.2%. If most of the potentially viable Crescent City and Sibley eggs hatch in 1996, this could be cause for concern and point the finger at prolonged diapause as a cause for some of the problems. As it stands now, factors other than pyrethroid insecticide use and prolonged diapause seem to be involved in the problems producers have been experiencing with rootworms in first-year corn following soybeans.

Rootworm Beetles in Soybean Fields

Rootworm beetles are very frequently found in crops such as soybeans and alfalfa during the growing season. However, that does not necessarily mean that they are depositing their eggs in these locations. For example, historical data from Urbana shows that between the years 1979 and 1982, western corn rootworm beetle counts in soybeans in mid-August ranged from 5.8 per 100 sweeps (with a sweep net) in 1980 to 15.8 per 100 sweeps in 1979 (corn-soybean rotation; Helm, unpublished data). Although we did not find significant western corn rootworm oviposition in our 1989 soybean planting time study at Urbana, we decided to sample western corn rootworm beetle densities in soybean fields adjacent to problem cornfields. For comparison, soybean fields in the Champaign-Urbana area, where no reports of problems had been received (prior to 1995), were also sampled. Western corn rootworm beetle counts never exceeded 16 beetles per 100 sweeps in Champaign-Urbana soybean fields in mid-August 1994 (Table 1), the peak period for rootworm oviposition. In contrast, beetle counts in soybean fields near problem cornfields ranged between 23 and 100 western corn rootworm beetles per 100

sweeps. However, despite having relatively low beetle counts in soybean fields, all of the Champaign-Urbana fields that were planted to corn in 1995 and evaluated for rootworm larval injury sustained moderate to fairly severe damage (Table 1). This is the first time that we have observed such injury by rootworms to first-year corn in this part of the state. Between the time of our soybean planting study in 1989 at Urbana and 1994 there may have been a change in the behavior of this insect.

1995 Problems

June and July of 1995 brought about an explosion of first-year corn injury reports. Calls came from many counties in east-central Illinois. Only extremely isolated cases of first-year corn larval injury were reported outside this area. In addition to east-central Illinois, some producers in north-western and west-central Indiana have reported similar rootworm problems in corn following soybeans. Injury has been intense in many of these fields and yield losses have been catastrophic for many corn growers. Many of the producers are unfamiliar with corn rootworm problems in a corn-soybean rotation. High densities of adult beetles in these areas also escalated the number of insecticide applications aimed at protecting the pollination process (adult beetles clip silks). Delayed planting (corn plants did not have much of a head start before rootworm eggs began to hatch), good winter survival of rootworm eggs (mild winter), late egg hatch (mid-June), and very prolonged hot and dry conditions in July (did not encourage root regrowth) made a bad situation much worse. Even with these factors, rootworm injury to first-year corn should not have taken place.

Questionnaire

In an effort to learn as much as we could about the phenomenon of damage to first-year corn following soybeans, we designed a questionnaire that was mailed to growers who called with problems and also was included in the July 14th issue (no. 17) of the *Pest Management & Crop Development Bulletin*. We received 75 completed questionnaires. A summary of the results are as follows:

1. County in which the problem cornfield was located (n = 75; percent of total reports):

Champaign	28.0%
Livingston	25.3
Vermilion	16.0
Iroquois	14.7
Ford	5.3
Grundy	4.0
Christian	1.3
Edgar	1.3
Fayette	1.3
Kankakee	1.3
Moultrie	1.3

The single report for Fayette County (far southern part of the county) deserves special mention. This field was well removed from the concentration of first-year corn injury cases in east-central Illinois. Larvae were collected in this field and reared out in the laboratory. The adults turned out to be the southern corn rootworm. This species is generally not a serious pest of corn in Illinois. Adults migrate northward each spring (they typically cannot successfully overwinter in Illinois) and lay eggs in the ground around the bases of plants. The larvae soon emerge and injure corn roots, much like northern and western corn rootworm species. Our best

guess is that the mild winter of 1994-1995 allowed many adults to overwinter and get a head start on laying eggs near corn plants.

2. Soybean maturity group, 1994 (n = 54):

Group II	33.3%
Group II and III	13.0
Group III	53.7

3. Soybean planting date, 1994 (n = 55):

May 1-15	45.5%
May 16-31	52.7
June 1-15	0.0
June 16-30	1.8

4. Soybean row spacing, 1994 (n = 63):

7-8 inches	33.3%
10 inches	3.2
15 inches	4.8
20 inches	1.6
30 inches	50.7
36-38 inches	6.3

5. Was the soybean field relatively free of grasses and volunteer corn in 1994? (n = 62):

yes	96.8%
no	3.2

6. Were no-till techniques used to plant soybeans into corn stubble in 1994? (n = 49):

yes	40.8%
no	59.2

7. Was seed corn grown nearby this soybean field in 1994? (n = 33):

yes	18.2%
no	81.8

In summary, the majority of first-year cornfields with rootworm damage in 1995 did not have infestations of volunteer corn or grassy weeds in soybeans in 1994, conditions known to lead to egg laying in such fields. In addition, damage did not seem to be related to any particular tillage system, corn stalk residue level, row width, soybean maturity group, soybean planting date, or seed corn production activity in the area (seed corn production usually involves the use of pyrethroid insecticides, shown to repel corn rootworm beetles; Levine 1995).

Several producers' comments were enlightening. One producer mentioned that he had problems with corn rootworms even with a three year rotation of wheat, soybeans, and corn. Another experienced rootworm damage to a cornfield that included an area that had been planted in soybeans for the previous 3 years. These two observations suggest that prolonged diapause was not a factor.

Larval Rearing

Larvae were collected on July 6, 1995 from four first-year cornfields with severe corn rootworm larval damage in east-central Illinois (Loda, Saunemin, Strawn, and Gifford). The larvae were brought back to the laboratory where they were transferred to new corn plants. All 85 adults that emerged were the western corn rootworm, confirmation that the damage was being caused by the western species. Few northern corn rootworms were seen in any damaged fields this summer.

Emergence cages

Emergence cages were erected over corn plants cut 4 inches above the soil surface on July 24, 1995 at both Loda and Saunemin. Twelve cages were installed at each location and monitored through August 10. All 94 adults captured in the cages were the western species.

Root ratings

On July 17 to 19, 1995 we evaluated corn rootworm larval injury in a number of first-year cornfields belonging to growers who suspected serious rootworm damage had occurred. Ten roots from each of 16 fields in a five county area were rated for injury using the Iowa State University 1 to 6 scale. The root ratings are provided in Table 2. Averages for several of the first-year cornfields were near or above a root rating of 4.0 (one node of roots destroyed) suggesting that a potential economic loss is possible. Plants with root ratings of 4.0 are often susceptible to lodging (leaning) which leads to physiological and harvesting losses.

Rootworm Beetles in Soybean Fields

As in 1994, we sampled soybean fields in east-central Illinois from late July to early September 1995 for corn rootworm adults. By far, the predominant species of corn rootworm was the western corn rootworm. Female beetles constituted over 70% of the collections. Numbers of western corn rootworms per 100 sweeps in soybean fields are presented in Table 3. Counts in the Urbana locations were generally higher than in 1994 (Table 1). Densities tended to peak early in August and fall rapidly toward the end of the month. All female beetles sampled on July 25 and August 2, 1995 were mated and dissections indicated that many had or were about to begin laying eggs. It is possible that we may have missed some population peaks in 1994 at some of the Champaign-Urbana locations; that is, sampling may not have been started soon enough or may have been spread over too long a period of time.

Steve Roberts of the Illinois Natural History Survey sampled soybean fields on a transect southwest of Decatur to just east of St. Louis. Six to seven sites were sampled with a sweep net (100 sweeps per field) on August 10 and 23, 1995. All fields except for one were adjacent to cornfields. Interestingly, no western corn rootworm beetles were found in any of these samples.

Presently, we do not have economic thresholds for western corn rootworm beetles in soybeans to base soil insecticide decisions upon for the following season. Based upon sweep net sampling in soybean fields in 1994, and followed up with root ratings in first-year corn this season, numbers of beetles per sweep didn't always correlate very well with root injury the following season. This shouldn't be a surprise to those familiar with corn rootworms.

Food Preference Study

Food choice tests were conducted in the laboratory to determine if western corn rootworm beetles have developed a taste for soybean plants. Gravid (laden with eggs) female western corn rootworm beetles collected in a soybean field at Saunemin, Illinois were compared to those collected from a cornfield at Mead, Nebraska. Beetles from the Mead, Nebraska site were used because of the heavy concentration of continuous corn in that area. If differences in food preferences were to be evident, we reasoned that these two population extremes were good choices for this test. Regardless of the population source, all adults completely devoured corn foliage before they would even begin to feed on soybean foliage. When given no choice, both populations fed equally on soybean foliage, but only after 24 hours of starvation. On the other hand, both populations of beetles devoured soybean flowers, but this appears to be a rather limited food supply. It is very possible that western corn rootworm beetles are moving into soybean fields for a reason other than food; they may specifically be coming into these fields to lay eggs.

Other Studies in Progress

We are continuing to look at the hatch patterns of western corn rootworm eggs obtained from different populations of western corn rootworm beetles so that we can be more confident that prolonged diapause is not causing the problem producers are now experiencing. Large greenhouse cage studies were also conducted this past summer to compare the egg laying behavior of populations of beetles from problem (Saunemin, Illinois) and non problem (Mead, Nebraska) areas on both corn and soybeans. At this writing, eggs have yet to be recovered from the soil of these plants. Soil samples were to be taken in October 1995 from problem fields in Loda, Saunemin, and Urbana, Illinois. Egg densities will be compared with those from samples taken in July 1995 (after egg hatch but before new egg laying began). Species will be

determined by looking at the egg shells under a microscope. Data from these studies will be presented in January 1996.

Suspected Cause of First-Year Corn Injury

Because of the intense crop rotation in east-central Illinois and west-central Indiana, producers may have selected inadvertently for a strain of western corn rootworm that lays eggs in soybean fields. If this hypothesis is proven true, corn production throughout the Corn Belt could be affected significantly. Rapid dispersal of the western corn rootworm has occurred previously. This species was of little concern to U.S. corn production prior to the 1950s because it remained along the western edge (Colorado, Nebraska, and Kansas) of the major U.S. corn production area. As irrigation increased, western corn rootworms began to lay eggs in irrigated soil, much of which was treated with chlorinated hydrocarbon insecticides. In a few years, western corn rootworms developed a 1,000-fold resistance to these insecticides (aldrin and heptachlor). The resistant strain spread rapidly from a single location in southeastern Nebraska in 1961 until, by 1973, the entire Corn Belt was enveloped. Corn producers in neighboring states are watching with apprehension as the situation in Illinois unfolds. Research is underway to keep crop rotation a viable option for corn rootworm management. If crop rotation fails as a management tool for corn rootworms, the economic impact could exceed $100,000,000 for Illinois corn producers.

Another possible explanation for escalating first-year corn problems may involve a hypothesis suggested by entomologists at Purdue University. This hypothesis suggests that asynchrony has developed between peak densities of egg-laying beetles and the flowering of corn plants. This asynchrony is the result of planting full-season corn hybrids earlier and earlier along with the trend of delayed egg hatch of corn rootworms. Because of this asynchrony,

beetles may simply be laying eggs in greener, less mature soybean fields versus rapidly drying cornfields.

Western Corn Rootworm Larval Injury to First-Year Corn: Recommendations for 1996

The use of crop rotation has and continues to be the main pest management strategy for corn rootworms in Illinois and across the Corn Belt. Since 1993, the incidence and severity of corn rootworm larval injury in first-year cornfields throughout much of east-central Illinois has increased. Producers in the following counties have been most significantly affected: Champaign, Ford, Iroquois, Kankakee, Livingston, McLean (eastern half), Vermilion, and Will. Only very isolated cases of first-year corn larval injury have been reported outside this cluster of counties. In addition to east-central Illinois, some producers in western Indiana have reported similar rootworm problems in corn following soybeans. Thus far, no other states have indicated that they are experiencing western corn rootworm larval injury in first-year cornfields, suggesting the problem is very isolated.

Research being conducted at the University of Illinois and the Illinois Natural History Survey has led investigators to the following conclusions. Western corn rootworms are responsible for the intensity of the root injury throughout many east-central Illinois first-year cornfields in 1995. In the 1980s, first-year corn larval injury was largely attributed to the ability of some northern corn rootworm eggs to prolong their diapause for more than a single winter. Research conducted in the late 1980s revealed that only about 2 percent of first-year cornfields in Illinois were likely to suffer economic injury because of the prolonged diapause phenomenon. Although a small percentage of western corn rootworm eggs have been shown to prolong their diapause for more than a single winter under laboratory conditions, this mechanism does not account for the 1995 episode of first-year corn injury in east-central Illinois. To date, all evidence suggests that some western corn rootworm adults are laying eggs in certain soybean fields. The eggs overwinter in the soil for a single season and after hatch occurs, the larvae

begin to feed on corn roots in early June. Answers have not been determined regarding why this egg laying is occurring.

During 1995, if a producer in east-central Illinois experienced first-year corn larval injury and found western corn rootworm adults in adjacent soybean fields, they should consider the use of a soil insecticide in corn following soybean in 1996. This recommendation will remain in effect until more complete explanations and economic thresholds can be determined. Growers outside of east-central Illinois are strongly encouraged not to use a soil insecticide on first-year corn for rootworm control as a standard practice.

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Table 1. Number of western corn rootworm beetles per 100 sweeps with a sweep net in soybean fields in 1994 and subsequent root injury ratings to corn in 1995[1]

	1994 Sampling Date				1995 Root
Location	7/18-19	8/4-5	8/18-19	9/1-2	Rating
Champaign[2]	11	8	3	5	ns
Urbana #1[2]	18	19	13	4	2.95
Urbana #2[2]	ns	ns	1	0	2.95
Urbana #3[2]	ns	ns	16	1	3.90
Urbana #4[2]	ns	ns	9	4	3.70
Crescent City[2]	116	161	100	98	not planted
Dewey[2]	28	51	23	10	ns
Flatville[3]	23	103	52	ns	seed corn
Piper City[3]	ns	71	45	10	seed corn
Sibley[2,4]	ns	76	87	23	no check

1 ns = not sampled on these dates.

2 Nearby fields devoted to commercial corn production with no pyrethroid use in 1993.

3 Nearby fields devoted to seed corn production with pyrethroid use in 1993.

4 Large populations of northern corn rootworm beetles also present.

Table 2. Results of first-year corn survey of rootworm injury in east-central Illinois

County	Location	Root Rating[1]
Champaign	Dewey - Field 1	4.50
Champaign	Dewey - Field 2	3.85
Champaign	Dewey - Field 3	3.40
Champaign	Gifford	3.85
Iroquois	Loda	4.55
Iroquois	Wellington - Field 1	3.80
Iroquois	Wellington - Field 2	3.50
Kankakee	Grant Park	3.95
Livingston	Dwight	3.05
Livingston	Emmington	2.90
Livingston	Forrest	3.30
Livingston	Pontiac	4.20
Livingston	Saunemin - Field 1	2.70
Livingston	Saunemin - Field 2	4.90
Livingston	Saunemin - Field 3	3.45
Vermilion	Rossville	3.60
Average	---------	3.72

1 The root rating system used was the Iowa State University root-rating scale: 1 - no visible damage or only a few minor feeding scars; 2 - Some roots with feeding scars but none eaten off to within 1.5 inches of the plant; 3 - Several roots eaten off to within 1.5 inches of the plant but never the equivalent of an entire node of roots destroyed; 4 - One node of roots

destroyed or the equivalent; 5 - Two nodes of roots destroyed or the equivalent; and 6 - Three or more nodes of roots destroyed.

Table 3. Number of western corn rootworm beetles per 100 sweeps with a sweep net in soybean fields in Illinois, 1995

	1995 Soybean Sampling Date[1]					
Location	7/25	8/2	8/9-10	8/17-18	8/28-29	9/6-7
Urbana #1	21	85	31	18	1	0
Urbana #2	ns	21	26	2	1	0
Urbana #3	ns	42	29	32	14	5
Wellington	ns	128	143	32	22	11
Loda	ns	49	56	33	35	9
Dewey	ns	39	118	7	1	4
Saunemin	ns	108	66	50	34	12

[1] ns = not sampled on this date.