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Rotation resistant rootworms 2007
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Introduction
Corn rootworms have been, and in many cases still can be, managed with crop rotations. However, some populations of both northern and western corn rootworms (CRWs) have adapted to the corn-soybean rotation. Regular, annual rotations between corn and soybeans have selected for a variant of the northern CRW that has a two-year life cycle, referred to as extended diapause. Female northern CRWs deposit eggs in the soil within cornfields. When the field is rotated to soybean the next year, most eggs hatch and the larvae starve. However, a portion of the eggs remain dormant in the soil for a second winter and do not hatch until the following spring when corn is planted back into the field resulting in damage to the rotated corn. Extended-diapause northern CRWs originally caused severe injury to rotated corn in NW Iowa, SW Minnesota, SE South Dakota, and NE Nebraska during the late 1980s. Since then their range has expanded until it is now found throughout most of Iowa. South Dakota has estimated that nearly 50% of their northern CRWs are the extended-diapause variant. Data from the 2005 & 2006 monitoring program has concluded that extended diapause is present throughout eastern Iowa. This information, in combination with previous surveys, confirms that extended diapause is present at some level in all parts of that state. Although its presence has been confirmed throughout the state, its relative abundance may be changing.

The western CRW that has adapted to the rotation is referred to as the “variant western CRW” or the “eastern variant of the western CRW.” It can most properly be called the “rotation-resistant western CRW.” The western CRW adapted to crop rotation through a change in its egg-laying behavior. The female deposits eggs in the soil of both corn and soybean fields. The following year, crops are rotated; soybeans planted to corn and corn planted to soybeans. Larvae from those eggs that were laid in corn starve because their only food source is soybeans. Larvae from those eggs that were laid in soybeans are able to survive because corn has been planted after beans; causing injury and yield loss to the rotated corn. The rotation-resistant western CRW first caused severe damage to rotated corn in east-central Illinois during 1995. Since then its range has been expanding into western Ohio, southern Michigan and Wisconsin, and west to Iowa. The presence of rotation-resistant western CRWs in eastern Iowa (eastern most 2–3 counties) has been documented by our monitoring projects in 2005 and 2006. However, the extent of his westward movement is unknown.

There has also been some concern about the presence of high numbers of northern CRWs in soybeans fields and whether they are exhibiting similar behavior to the rotation-resistant western CRW. Are northern CRWs laying eggs in soybean?

Research in 2006 and 2007 was designed to address these questions. The objectives of the research were to:

• detect the westward extent of the variant western CRW
• examine the distribution of extended diapause in eastern Iowa
• determine if northern CRWs are laying eggs in soybeans

Methods
Field locations 2006
Soil sampling for egg laying by northern CRWs was conducted in a soybean field (corn in 2005) at each of the following nine counties: Boone, Story, Wright, Butler, Chickasaw, Webster, Buchanan (North), Buchanan (South), and Cass (Fig. 1).

![Figure 1. Field locations 2006 (soil sampling).](image)

Field locations 2007
Monitoring for the westward extent of the variant western CRW and the abundance of extended diapause northern CRW was conducted at 18 locations, [Country (location within country) Fig. 2]: Howard, Chickasaw (North), Chickasaw (South), Floyd, Butler, Bremer, Buchanan (North), Buchanan (South), Tama, Benton (North), Benton (South), Iowa (East), Iowa (West), Keokuk, Mahaska, Monroe, Jefferson, and Davis. At each location a corn field (soybeans the previous year) and a soybean field (corn the previous year) were sampled.
Northern CRW activity in soybean (2006 & 2007)

Soil sampling (2006): In the soybean field (corn in 2005) at each location, 15 half-liter soil samples were collected with a 10 cm diameter golf-cup cutter from each field using the “normal core method” described by Foster et al. 1979. Eggs were extracted from the soil by washing and floating methods (Shaw et al. 1976). Eggs were counted and identified to species (Krysan 1986). The 15 sample locations were spread out in a stratified random, U-shaped pattern covering as much of the field as possible. Samples were collected at three times: 1) early May, before egg hatch, to quantify eggs laid in corn in 2005, 2) late June, after “normal” egg hatch, to estimate extended diapause, and 3) late September, after 2006 eggs laid, to determine if eggs were laid in the soybeans.

Egg traps (2007): To try and detect egg laying in soybean by northern CRWs, 18 egg traps were placed into each soybean field at the following 2007 locations: Buchanan (North), Buchanan (South), Chickasaw (North), Chickasaw (South), and a field in Story country at the Johnson Farm. Egg traps consisted of a 24oz plastic drink cup filled with a clay particle substrate called Turface™ ProLeague (Profile Products LLC, Buffalo Grove, IL; Fig. 3). Small drainage holes were burned into the cup 3cm from the top to allow excess water to drain out. These cups were sunk into the ground within the soybean row (until the top was flush with ground level) using a golf-cup cutter and saturated with water. They were put out during the last week of June and the first week of July and left in the field until the last week of August. At this time, the cups were returned to the lab and eggs were washed out of the Turface using water and standardized sieves (# 20, 35, and 60). The eggs that were recovered were identified to species by examining the chorion pattern.

Figure 2. Field locations 2007 (variant monitoring and egg traps). Egg traps were only located at Buchanan North and South, Chickasaw North and South, and one additional field in Story County, near Ames – not shown above.
Figure 3. Egg trap, 24 oz drink cup filled with a clay particle substrate called Turface™ ProLeague and with drainage holes burned into the cup 3cm from the top.

Rotation resistant monitoring (2007)

Emergence traps: At each location, 12 emergence cages were placed in each cornfield prior to adult emergence (first week in July). Traps were monitored weekly for adult emergence. The mean number of beetles captured per cage was calculated for each field.

Sticky Traps: Following the University of Illinois protocol (Cook et al. 2005), 12 Pherocon-AM sticky traps were placed in each soybean field. Traps were changed weekly from the last week in July to the third week in August. The average number of beetles caught per trap per day was calculated.

Results

Northern CRW activity in soybean (2006 & 2007)

Soil samples: The results from all three sampling times (May, June, and September) are shown in Fig. 4. Based on the comparison of May and June samples, extended diapause in northern CRW populations varied from 12.5–62.5% (Fig. 5). For 4 of the fields, their proportion of extended diapause was higher than expected (> 33%) in central and western Iowa. The ratio of northern to western CRW eggs in soybeans following corn was dramatically skewed toward northern (53–99% were northern depending on the field). The species that dominates in this ratio varies over years and the cycling is probably related to the impact of the environment on survival of the eggs and larvae in the soil. Comparison of the June and September samples show no evidence of egg laying is soybeans for 7 of the 9 fields, and only a small increase in mean eggs per 0.5 liter of soil for two of the fields (Buchanan County, North and South fields; Fig. 6). Paired comparisons showed this change to be significant but it should be kept in mind that this was an increase from an average of 1 egg per 0.5 liter of soil to 2 eggs per 0.5 liter of soil. Previous research has shown that 7–10 CRW eggs per half liter of soil may result in an economic infestation so these levels are well below what would be expected to cause injury.
Figure 4. Mean number of rootworm eggs per half liter of soil from soybean fields sampled in May, June, and September 2006.

Figure 5. Percentage of northern CRW eggs in nine Iowa soybean fields that were determined to be extended diapause, 2006.
Figure 6. Comparison of the mean number of rootworm eggs in per half liter of soil from soybean fields sampled in June and September, 2006

Egg traps: Egg trap samples are still being processed but preliminary data shows very low numbers of eggs being recovered. It is possible that these types of traps may not be that attractive to northern CRWs.

Rotation resistant monitoring (2007)

Emergence traps: Western CRWs were captured in 14 of the 18 fields (Fig. 7); however, numbers caught were extremely low in 12 of these 14 fields (mean < 1 beetle/cage) and the other two fields also had very low numbers (mean < 3.5 beetles emerging/cage). Capture of less than one beetle/cage on average could be due to incidental invasion of the cage by adults and consequently it may not be fair to consider the variant “present” or endemic in these locations. The two fields with slightly higher capture (≥ 3 beetles/cage, Butler and Buchanan counties, south field only in Buchanan) were monitored in the 2006 survey as well. No western CRWs were captured in those counties in 2006 so this represents a slight westward movement of the variant in that area.

Northern CRWs were captured in all 18 corn fields; however, numbers were very low (0.1 beetles/cage) in two of the fields (Monroe and Davis counties). In the other 16 fields, numbers caught varied from 3.5–36.2 beetles/cage. There is no predetermined threshold for emergence data; however, economic loss would probably be expected when emergence numbers exceed 20 beetles/cage (6 of the 16 fields).
**Figure 7.** Mean number of CRW adults captured from rotated corn fields at 18 Iowa locations, 2007.

**Sticky traps:** Western CRWs were captured on sticky traps in only 2 of the 18 soybean fields and the capture rates were less than half a beetle/trap/day (well below the threshold of 3–5 beetles/trap/day; Fig. 8). Northern CRWs were captured on sticky traps in 16 of the 18 fields. Their capture rates varied from 0.1–2.6 beetles/trap/day. However, it is important to note that the threshold developed for western CRWs (3–5 beetles/trap/day) does not necessarily hold true for northern CRWs.
Figure 8. Number of CRW adults captured/trap/day using Pherocon AM yellow sticky cards in 18 Iowa soybean fields, 2007.

Conclusions

Northern CRW activity in soybean (2006 & 2007)
- The proportion of northern CRW eggs that were extended diapause appears to be slightly higher than expected (4 fields with > 33%)
- An increase in egg numbers late in the season was seen in 2 soybean fields (Buchanan County, North and South fields); however, the total number of eggs was small and far below levels where we might expect injury the next year (7–10 eggs/half liter of soil).
- The results of the egg trap are still pending. This may be a useful tool for monitoring egg laying for the variant western CRW as well.
- So far we have very little evidence of northern CRWs laying eggs in soybean; however, further study may be needed.

Rotation resistant monitoring (2007)
- In 2005 and 2006, rotation-resistant western CRW were found throughout the eastern part of the state (eastern 2–3 counties of the state).
- In the more western counties surveyed in 2007, there was very few or no variant CRWs detected. The variant western CRW maybe be present at low levels in these areas but they are far below economic levels at this point.
**Recommendations**

- Soybean fields in the eastern 2–3 counties of Iowa should be monitored for the western CRWs using 12 Pherocon AM sticky traps/field, changed weekly from late July–mid August.

- If the number of beetles caught in soybeans exceeds 3–5 beetles/trap/day and corn is planted in the field the following year, CRW protection should be applied.

- Soybean fields west of this area (the area we surveyed in 2007) could monitor for the presence of the variant using 6 Pherocon AM sticky traps per field. This level of monitoring will detect the presence or absence of the variant but data collected with only 6 traps/field cannot be used reliably with the threshold.

- Northern CRW emergence from all fields documents that the extended-diapause northern CRW is present throughout eastern Iowa. We are not able to predict economic numbers of northerns, but if corn lodged in 2006 and there was root injury, corn should be protected from rootworms in 2008 when it is rotated back into the field.

**References**


