Looking Below the Surface: Do You Have a Corn Nematode Problem?

Is there a problem with corn nematodes in your crop? Is your use of a nematicide doing any good? Let’s review some guidelines.

Unthrifty corn. Corn not looking so hot? Rather than a herbicide, nutrient, or environmental issue, unexplained yield losses or patchy areas of low productivity or vigor may indicate an established corn nematode population. An extensive survey in 2009–2010 supported by our University of Illinois NIFA–Extension IPM program showed that corn nematode populations are a bigger problem than previously thought.

The survey found, for example, that about half of the cornfields in Illinois have lesion nematode populations with densities at or above the threshold for moderate to severe risk of injury (yield loss). Not only can lesion nematodes injure corn roots, but they frequently act as vectors for the development of root rots. The common belief that corn nematodes are important only in very sandy soils is not accurate. Sandy soil is a risk factor for only a few species (needle, sting, and stubby-root nematodes throughout Illinois, and southern root-knot nematode in southern Illinois). Although needle nematode can kill corn seedlings, most nematodes will not cause injury that severe unless the infestation level is very high.

Corn nematodes include a number of damaging species, such as dagger, lance, lesion, ring, stunt, and occasionally spiral nematode, which may be found in heavy soils. While many companies produce chemicals to manage corn nematode, it is still important to check the product use indications before applying them. Different nematode situations require different types of product application, so it is best that you send in a sample for analysis before attempting nematode control. You have no other way of knowing the identification of your initial population or whether it is being controlled.

Sampling for diagnosis. Consider sampling for nematodes now, especially in cornfields that are at risk. Risk factors include corn-on-corn growing, minimal or no tillage, and the absence of nematode-suppressing soil-applied insecticides. Although the best time to sample for nematode diagnosis is about 4 to 6 weeks after planting, a couple of weeks more or less may not matter very much.
How and where you sample are determined by the reason you’re sampling. Corn nematode management is determined by the species involved and how high their numbers are, so it is very important to get a good sample for a reliable diagnosis. Typically you just want to know whether nematodes are the cause of yield loss in a given field. You can start by examining the physical characteristics of the plants:

- If there are no symptoms, focus sampling on a representative area of the field, perhaps 10 acres or less. Nematodes can reduce yields without causing obvious symptoms. Record the GPS coordinates for the area. Sample in a zigzag or W-shaped pattern, and collect 20 to 25 cores in a bucket.

- If there are symptoms ("hot spots"), sample around the edges of symptomatic areas, collecting a total of 20 to 25 cores. Record the GPS coordinates for the area.

Keep these guidelines in mind as well during sampling:

- Sample as deeply as possible from within the rows when the soil is moist but not wet at least 6 to 8 inches. Use a 1-inch-diameter soil probe if possible.

- Treat the samples gently at all times—do not drop them or break up the cores. Some corn nematodes are very sensitive to manipulation, and you want to avoid killing them before they reach the lab.

- Put the sample in a plastic bag—not paper—to help preserve moisture during transport. Take a cooler along to store the samples and keep the nematodes from being cooked!

- Include the GPS coordinates for the samples along with your contact information when you submit samples.

- Sample around the edges of the hot spots in the field, not in the centers.

**Diagnosis.** Corn injury caused by nematodes cannot be diagnosed from symptoms alone. The symptoms of nematode parasitism look similar to those caused by other production problems, including poor or uneven crop development, yellowing or streaking, and reduced or brushy root systems. The only way to diagnose corn nematodes is to directly examine them under a microscope following an appropriate extraction method. Some private labs analyze soil for corn nematodes, as will the University of Illinois Plant Clinic.

The former nematology testing lab has merged with the Plant Clinic, and nematologist Dr. Alison Colgrove and her staff manage testing and analysis. Services include soil nematode analysis ($40), root analysis ($40), soybean cyst nematode (SCN) egg counts ($20), and pinewood nematode analysis ($20). Send your samples to the Plant Clinic; you can get more information on sample submission at our website (web.extension.illinois.edu/plantclinic). For specialty testing, including SCN Hg typing, variety screening, phytosanitary testing, and other nematode projects and diagnostics, contact Dr. Colgrove before sending any samples: acolgrov@illinois.edu, 217-333-9057.—Suzanne Bissonnette

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**Insects**

**Injury to Bt Corn Observed: Western Corn Rootworm Adults Have Emerged**

The western corn rootworm “season” is underway at a pace earlier than I have experienced since I began studying this versatile insect as a graduate student in the late 1970s. In response to a request by a seed industry representative, I traveled to western Cass County on June 7 to verify a report of severe injury to Bt corn that expresses the Cry3Bb1 protein targeted against corn rootworms.

As readers may recall, last year I observed severe root injury to some producers’ fields in northwestern Illinois (Henry and Whiteside counties; issue 20, August 26, 2011) and north-central Illinois (La Salle County; issue 22, September 23, 2011) that had been planted to Bt hybrids expressing the Cry3Bb1 protein. In 2011, similar reports of injury to Bt hybrids expressing this protein surfaced in some other north-central states, most notably Iowa, where Dr. Aaron Gassmann, an Iowa State University entomologist, published a journal...
article confirming the development of resistance to the Cry3Bb1 protein in some areas of Iowa by western corn rootworms (issue 18, August 5, 2011). Thus far, we have not confirmed resistance to this protein in Illinois. We are cooperating with Dr. Gassmann’s laboratory to determine if the Illinois fields in question in 2011 were infested with a resistant population. Results should be forthcoming in August.

In light of the problems that began to surface last season in Illinois and some other midwestern states, the report concerning performance issues with a Bt hybrid in Cass County warranted attention. On arriving at the first field, I was amazed at the number of western corn rootworm adults in the whorls of plants. The seed industry representatives indicated that beetles had been observed earlier in the week.

This is the earliest that I have observed adult western corn rootworms, nearly one full month ahead of when I typically begin to receive reports—around the 4th of July. The plants were under intense moisture stress, and the leaves were tightly rolled. In addition, beetles were feeding on the epidermis of corn leaves. This type of injury often occurs when beetle emergence is early and plants have not yet begun to shed pollen or produce silks. The plants in the fields that I visited were not at this reproductive stage of development, even though planting had occurred between March 30 and April 2.

After removing roots randomly from the first field, we traveled to a nearby field that also had been planted to a Bt hybrid expressing the Cry3Bb1 protein. Not as many beetles were seen in the second field. Again, we removed roots at random for inspection. Roots from both fields exhibited feeding injury, but the second field had much more injury. Because adults were not as noticeable in the second field, and emergence was just beginning in the first field, I believe more root feeding will continue in both places. Because the plants were short and the soil was hard and dry, there was no lodging. However, as root feeding continues and plants become taller, lodging should be expected, especially if storms with rain and winds materialize.

On June 8, plants that had been dug and evaluated for root injury were checked for the expression of the Cry3Bb1 protein at our University of Illinois laboratory. All plants tested positive for the Cry3Bb1 protein. This does not mean that a resistant western corn rootworm population has been confirmed in Illinois. The registrant of this technology has been notified and will conduct some follow-up investigations in these fields. So, at this point, precise reasons for the continuing performance challenges of some Bt hybrids expressing this protein remain elusive. However, producers should remain vigilant and report any performance issues that surface with their Bt hybrids regarding corn rootworm injury this growing season.

Similar to the affected fields with Bt performance issues last year, the fields in Cass County had been in continuous corn for many years (at least 10 consecutive years). In addition, the same trait (Cry3Bb1) had been used since 2007 (6 growing seasons). Under these conditions, the selection pressure for resistance development is markedly increased. It remains to be seen how the rest of this growing season will play out. For now, it makes sense to monitor this unfolding situation carefully and to pay attention to the performance of your chosen Bt hybrid this season. Longer term, it will be increasingly important to integrate management practices such as rotating corn with other crops, rotating Bt traits from season to season, considering the use of a non-Bt hybrid along with a soil insecticide at planting, and not neglecting the use of a refuge if a Bt hybrid is planted.—Mike Gray
Western Corn Rootworm and Bt Resistance: Resistance Experts Weigh In

In the latest issue of the *Journal of Economic Entomology* (Vol. 105, No. 3, pp. 767–776), titled “Delaying Corn Rootworm Resistance to Bt Corn,” two internationally respected entomologists have provided strong recommendations to the U.S. Environmental Protection Agency about refuge requirements for Bt hybrids that offer corn rootworm protection. Drs. Bruce Tabashnik and Fred Gould, professors of entomology at the University of Arizona and North Carolina State University, respectively, make these specific recommendations (p. 767):

“We conclude that the current refuge requirements are not adequate, because Bt corn hybrids active against corn rootworms do not meet the high-dose standard, and western corn rootworm has rapidly evolved resistance to Cry3Bb1 corn in the laboratory, greenhouse, and field. Accordingly, we recommend increasing the minimum refuge for Bt corn targeting corn rootworms to 50% for plants producing one toxin active against these pests and to 20% for plants producing two toxins active against these pests. Increasing the minimum refuge percentage can help to delay pest resistance, encourage integrated pest management, and promote more sustainable crop production.”

I have extracted some key points from Tabashnik and Gould’s thought-provoking journal article:

- “A primary reason for increasing the refuge percentage for Bt corn producing Cry3Bb1 is that it does not meet the high-dose standard against its key target pest, western corn rootworm.” (p. 768)
- “[S]election experiments have demonstrated rapid evolution of western corn rootworm resistance to Cry3Bb1 corn when adequate refuges are not provided.” (p. 769)
- “Because resistance is expected to evolve faster as the initial resistance allele frequency increases, the higher than expected initial frequency of resistance to Cry3Bb1 also supports increasing refuge percentage to delay resistance.” (p. 769)
- “In local areas where resistance to Cry3Bb1 is detected, more stringent measures will be needed, such as not planting Cry3Bb1 corn until restoration of susceptibility to this toxin is demonstrated.” (p. 770)
- “Also similar to results with Cry3Bb1, western corn rootworm quickly evolved resistance to corn producing either Cry34/35Ab1 or mCry3A in selection experiments.” (p. 770)
- “[T]he similar values of realized heritability for corn rootworm resistance to Cry3Bb1 and Cry34/35Ab1 suggest that it also could readily evolve resistance to these Bt toxins in the field.” (p. 771)
- “Thus, we recommend a 50% refuge for Bt corn plants producing a single toxin that kills corn rootworms, whether the toxin is Cry3Bb1, Cry34/35Ab1, or mCry3A.” (p. 771)
- “[F]or populations of western corn rootworm resistant to Cry3Bb1, plants producing Cry3Bb1 and Cry34/35Ab1 are not effective pyramids because of the reduced efficacy of Cry3Bb1.” (p. 772)
- “Key IPM recommendations for corn rootworms include crop rotation, rotation of Bt corn hybrids producing different toxins (e.g., do not plant Cry3Bb1 corn year after year in the same field), and judicious use of insecticides.” (p. 772)
- “Initial increases in refuge percentage may be limited by the availability of seed for corn that does not produce Bt toxins active against corn rootworms. If so, we propose phased refuge increases beginning in areas where resistance has been detected, resistance is suspected, or resistance is most likely based on historical planting patterns.” (p. 772)
- “We emphasize that these are hypothetical scenarios and, in principle, growers can make such conditions less likely by using IPM to reduce the reproductive output and population density of the pest.” (p. 772)
- “The lag time for increasing refuge seed production has been overlooked in the remedial action plans to address resistance to Bt corn.” (p. 773)
- “The situation with western corn rootworm illustrates that changes in the regulatory framework are needed to achieve faster responses to evidence of field-evolved resistance.” (p. 773)

At this point in the season, it remains unclear whether more reports of greater-than-expected root injury to Bt corn expressing the Cry3Bb1 protein will occur across the Corn Belt. I will share any reports provided to me with readers. It also is very murky what response, if any, the U.S. Environmental Protection Agency will make if additional cases of Bt failures begin to occur. Tabashnik and Gould remind readers of their article that a majority of a 2002 Scientific Advisory Panel recommended a larger refuge (50% minimum) for the initial Bt corn rootworm hybrids expressing the Cry3Bb1 protein that entered the marketplace in 2003. This recommendation was not implemented; instead, a 20% structured refuge was put in place matching that for Bt hybrids in the Corn Belt targeted at lepidopteran pests such as the European corn borer.

But there is a critical difference: hybrids used for lepidopterans are high dose. Some will say, All this is water under the bridge—now what? To prolong the effectiveness of this tremendous technology as we move forward, growers must take more seriously than ever before the importance of integrating management tactics for corn rootworms. Thinking longer term is imperative. Technological transgenic advances beyond Bt proteins for corn rootworm control will not be available commercially until, most likely, the end of this current decade.—Mike Gray
Crop Development

Crops and Water

Illinois cornfields in areas that have had some rain continue to look good, but crop ratings are still sliding as corn shows visible symptoms of drought stress in the areas that have received little rain over the past six weeks. As of June 10, National Agricultural Statistics Service reports that the average height of the corn crop is a record 29 inches, but it is rated at only 56% good to excellent, and the soybean crop at only 50% G–E.

With few other problems such as hail, nutrient deficiency (except those related to dry soil), disease, or insects, most of the perceived deterioration in crop condition is due to the ongoing lack of rainfall and the crop stress symptoms that accompany it. According to data from the Midwest Regional Climate Center, rainfall between May 1 and June 12 ranged from 2 to 5 inches in Illinois, with deficits from normal ranging from 1 to 2 inches along and south of I-80 to 5 inches or more in extreme southern Illinois. Some rainfall on June 12 in some of the driest areas of southern Illinois moved these totals up a little, but dryness persists through much of the state.

While we all sense when we’re in a drought, there are ways to look at dryness from the crop’s perspective, which often differs from the human perspective. One way is through an indication reported weekly by NASS about how much of the surface and subsurface soil is dry. On June 10, 26% of topsoil was listed as being “very short” on moisture, 52% was “short,” and 22% was adequate. Subsurface numbers were similar, with a little more (28%) listed as adequate in moisture.

Another way to look at severity of drought is through the Palmer Drought Index, a complex measurement taking into account both rainfall (as compared with normal) and anticipated effects on agriculture. As of June 5, most of Illinois, with the exception of the northeastern part of the state, was “abnormally dry,” which is the mildest form of drought. A small part of extreme southern Illinois was categorized in “severe drought,” which would be expected to reduce crop yields considerably if it persisted much longer. Parts of that area that received some rainfall this week will drop out of the severe-drought category by the time the next Palmer map appears. An area north of the severe-drought area and another in central–west central Illinois were in “moderate drought.”

How are crops faring in this ongoing period of less-than-normal rainfall? As we’ve said before, water use and photosynthetic rates are closely linked, so a decrease in water availability means a decrease in the crop’s daily dry matter production. So while cooler weather in recent weeks has decreased water use rates, and the corn crop can have its leaves out and active longer in the day before they roll up when the roots can no longer provide water fast enough, lower temperatures also mean slower rates of photosynthesis.

As the corn crop grows and expands its leaf area, water loss rates increase as photosynthetic rates increase. Figuring out how much water the crop uses as it grows is a little complicated, but it starts with knowing how much “demand” the atmosphere has for water each day, then using a factor called the “crop coefficient” to estimate how much of this demand the crop provides—that is, how much water the crop loses through the process of transpiration. Transpiration is the loss of water vapor from leaves, and it’s linked to the rate of intake of CO₂ during photosynthesis, hence the close tie between the two processes.

The amount of water that evaporates from an open pan is used to estimate demand on a daily basis. This amount increases with wind speed, temperature, sunshine, and low humidity, and under central Illinois conditions it ranges up to about 0.3 inches per day. According to the Illinois Climate Network (part of the Illinois State Water Survey), open-pan evaporation was estimated at 6.84 inches at Champaign last month. This is a very high value for May—evaporation was only 3.91 inches in May 2011. Rainfall during May 2012 was 3.55 inches.

The larger the crop plant, the more water the crop uses; the crop coefficient ranges from 0 to 1 and is the percentage of open-pan evaporation that the crop uses at each stage of development. The crop coefficient for corn rises from around 0.1 at VE or V1 to about 0.2 by V3, 0.4 by V6, 0.6 by V11, 0.7 by V15, and 0.9 by the time pollination has ended and the canopy is full. So the corn crop planted in mid-April and growing from stage V1 to V7 with the 500 GDD received in May this year would have transpired about 30% of potential evaporation in May, or about 2 inches of water. Evaporation from the soil surface would have used a little more, but total use would not have exceeded the 3.55 inches of rain in Champaign during May. Such a crop is now at about V10, with a crop coefficient of above 0.5, and so is using about 1 inch of water per week. By mid-June, such a crop has used a total of about 5 inches of water.

In areas with less rain, soils that can hold 2 to 3 inches of plant-available water per foot of depth would easily have had enough water to keep the crop growing through mid-vegetative stages. The reason this did not happen in some areas, where plant leaves are rolling on a daily basis, is that the root system has not been able to tap the water that is available in the soil. “Rootless” or “flop-py” corn with poorly developed nodal roots represents one reason for this. In some fields that were planted later or into drier soils, roots were unable to get into more moist soil zones early, and once soils dried between these zones and the ends of the roots, the ability of roots to reach these zones was lost. Insect or disease problems of roots are contributing in some cases as well.
Soybean water use follows a pattern similar to that of corn, with the crop coefficient increasing steadily from about V2 through R3 or so, reaching a maximum of about 0.8, so a little lower than corn’s maximum use rate. Soybeans planted in April here at Urbana have reached V6 and are about 16 inches tall; their crop coefficient of around 0.45 would mean a daily water use rate of perhaps 1/8 of an inch, and water use up to now totaling perhaps 3 to 3.5 inches. Most of the May-planted crop is only at V3 or so and is using water less rapidly.

Some soybean fields planted into dry soils have poor stands in places, and others have roots that have not yet reached soil moisture. So the soybean crop is showing symptoms of lack of water in many fields as well. Leaves don’t roll in soybean as they do in corn; instead they tend to lose turgor and droop, in some cases dropping to vertical orientation. This reduces the intensity of sunlight on the leaf and the heating that comes with it when there’s not enough water to keep photosynthesis going, but it also means leaves are doing no photosynthesis and so will not show any growth for the time they are in this condition. Note that soybean leaves tend to drop to vertical during the night as a natural phenomenon—this helps protect them from radiational cooling and can be a benefit on cool nights. They normally reorient to horizontal as the sunlight increases in the morning.

Though we tend to worry a lot when the weather is dry, the best indication of how the plant perceives dry weather—that is, how much water it’s able to extract from the soil despite lack of rainfall—is visible in how the plant grows. Many have commented on how well the corn crop is increasing its plant height even in dry weather. In drier areas or with the crop farther behind and lacking good roots, though, the current dry period will result in decreases in plant size. If this persists, those cells that make up kernels, silks, leaves, and seeds may also be restricted in size, with direct effects on yield.

Plant height and leaf area expansion occur when water moves into cells to push out cell walls. Cell walls harden after this expansion, after which no further size increase is possible. Cells have to attract water from the rest of the plant in order to expand, so this process is quite sensitive to water availability. This is why most cell expansion—what we see as visible “growth”—takes place at night, when there is no transpiration.

True growth is an increase in plant dry weight; this happens only during photosynthesis (so in daylight hours) and is often not visible to the eye. It of course powers, through sugar formation, processes that result in cell expansion, but taking water into cells is not really “growth.” Still, the ability to photosynthesize and to form grain is affected by cell expansion, so having enough water that cells can expand fully is critical.—Emerson Nafziger

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