## Mitigation Measures to Manage Bt Resistant Corn Rootworm in Ontario
***Recommendations from OMAFRA and the Canadian Corn Pest Coalition***

**Current Resistance Status:** Extensive injury by corn rootworm (CRW) to pyramid Bt rootworm (Bt-RW) hybrids was observed in several Ontario counties in 2020. This level of injury suggests that CRW populations have developed resistance to multiple Bt-RW proteins under continuous corn production practices. Bt corn resistance in CRW is widespread in the United States due to long-term use of Bt-RW hybrids. Until recently, there have only been isolated CRW resistance cases in Ontario. CRW injury observed in 2020 in Ontario is very similar to what US growers experienced before widespread resistance was reported. Taking action now is the best chance to manage resistant populations before they become widespread in Ontario.

Due to possible cross resistance to all available Bt-RW proteins, simply rotating to a different Bt-RW hybrid may not provide control of Bt resistant CRW. Very few new Bt-RW proteins are coming to market in the near future, so mitigation efforts targeting resistant CRW populations must be taken immediately to prevent substantial yield loss and feed shortages in the coming years.

**High Risk Fields and Regions:** High risk fields include those in continuous corn production (3+ years) with a history of repeated Bt-RW hybrid use. These fields have likely experienced high CRW beetle populations in recent years. Fine-textured soils are typically at greater risk of CRW than coarse textured soils, however all soil types may be at risk. Measurable yield loss and reduced tonnage due to CRW root feeding can occur before fields exhibit secondary symptoms such as goosenecking or lodging.

Several fields in Huron, Perth and Durham counties have been identified with injury to Bt-RW proteins though all continuous corn production fields are at risk. Areas with three or more years of continuous corn are shown in this map: **Continuous Corn (3+ years) in Ontario, Quebec, Manitoba and Saskatchewan**

**Recognizing Rootworm Damage:** CRW is a serious pest of corn, causing significant yield or tonnage reduction, especially in dry years when the crop is already stressed. Both northern (green) and western (black and yellow striped) corn rootworm undergo one generation per year (Fig.1). Adult beetle emergence begins in early June and continues through the month of August. Beetles can live for four to six weeks and each female may lay up to 1000 eggs in the soil. Eggs overwinter in the soil and hatch in the following spring. Larval feeding begins in early June until early August. Larvae feed almost exclusively on corn roots, pruning and tunneling through roots, inhibiting root growth, interfering with nutrient and water uptake, and

compromising standability (Fig. 2a). Significant root pruning can cause goosenecking (Fig. 2b) and lodging which may not be noticed until wind or weather events occur (Fig. 2c).

After pupation, beetles emerge, mate and lay eggs within the field they emerged from; however, as pollen and silk resources dry up, beetles may fly short distances to later planted corn fields to find fresher food. Some beetles may fly up to 40 km away or be carried by windstorms. Beetles prefer to feed on corn pollen and silk but may also feed on leaves or pollen of soybeans and other crops and weeds.

**Figure 1. Adult northern corn rootworm (left) and western corn rootworm (right). Photo credit: Jocelyn Smith, UGRC**

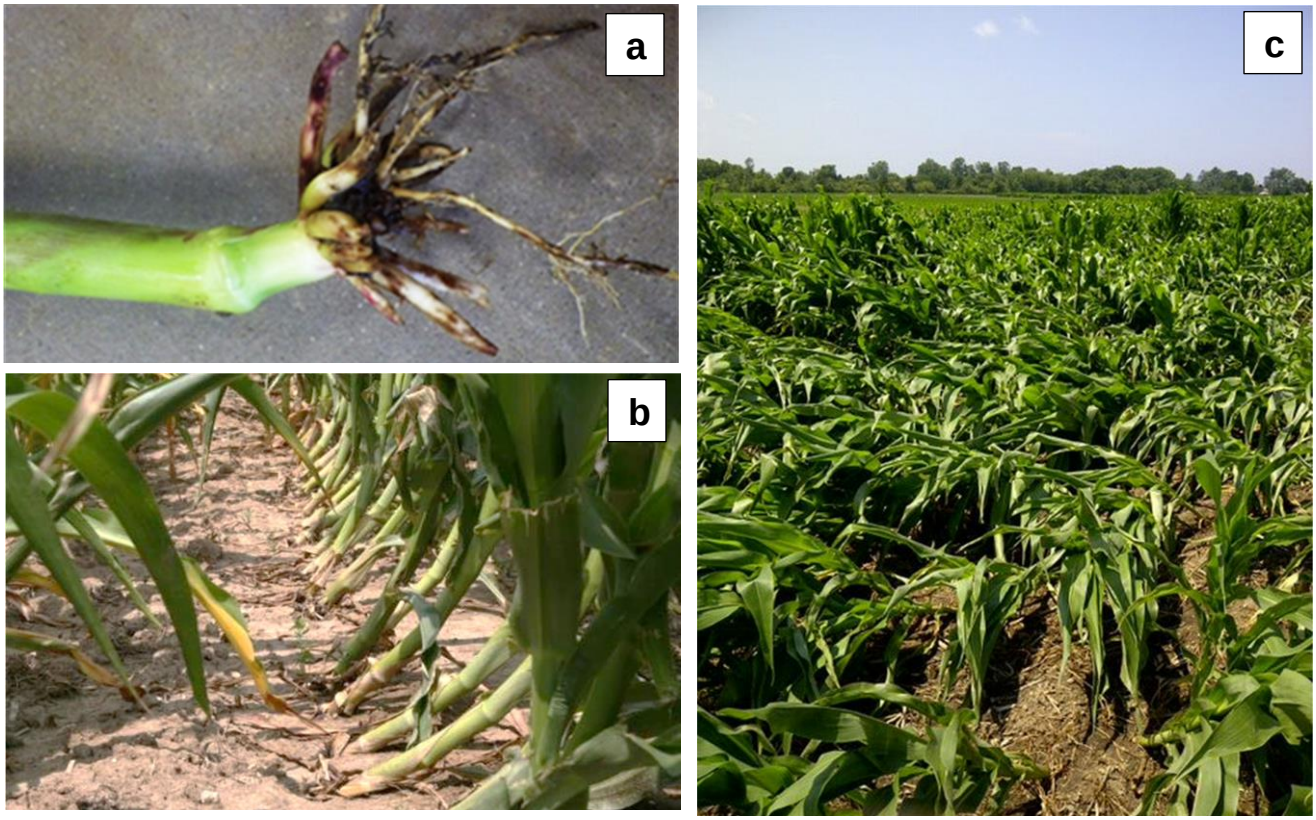


**Figure 2. Signs of feeding injury from rootworm larvae. Roots are clipped back or absent and feeding scars are evident (a). Reduced root systems lead to plant instability and goosenecking (b). After wind events, plants may lodge making harvest difficult (c). Photo credits: Jocelyn Smith, UGRC (a and c); Chris Difonzo, MSU (b).**

**Recommended Mitigation Measures:** Based on the current resistance status, mitigation efforts must be taken over the next few years to reduce resistant CRW populations, in the hope of restoring the durability of current Bt-RW hybrids. Bt-RW hybrids only express moderately toxic proteins against CRW; therefore, the risk of resistance development is high and will remain within the populations. These products should not be considered the primary solution for continuous corn production going forward. CRW management requires a long-term strategy that does not solely rely on Bt-RW corn hybrids. See **Long-Term Responsible Use of Bt Hybrids for Rootworm Management** for more information.

1) **Crop Rotation -** The best approach to manage CRW populations is to rotate out of corn as CRW larvae must feed on corn roots to survive. This includes **controlling volunteer corn plants** in the rotated fields which could support their survival. If fields in high-risk areas are rotated out of corn for at least one year (preferably two), Bt resistant CRW populations would be significantly reduced.

   In some regions of the US that are dominated by a corn-soybean rotation, CRW have adapted to lay eggs in soybean fields (rotation-resistant CRW). When rotated to corn the following year, these fields experience CRW injury. Ontario is suspected to have low levels of this rotation-resistant CRW. In these cases, rotating to a non-corn crop for more than one year is recommended, especially if the surrounding crop landscape is predominantly corn and soybean fields. Fields that have experienced pyramid Bt-RW failures are encouraged to rotate out of corn for two years to mitigate resistant CRW populations.

   Livestock producers should consider purchasing corn for feed instead of growing it in 2021 and 2022 or consider one of the alternative feed crop options below:

   a. **Silage Alternatives** - winter cereals + sorghum: Silage options in Field Crop News
   b. **Grain Feed Alternatives** – barley, wheat and other options specific for each livestock species are here: Non-corn options for livestock producers
   c. **Cash Crop Alternatives** – any non-corn crop including soybeans, cereals and others are beneficial, as rootworm larvae can only survive on corn.

   Significant benefits of rotating out of corn go beyond rootworm management. Research from long-term tillage and rotation trials in Ontario have shown soil health improvements and significant yield benefit to a good rotation in both dry and wet growing seasons.

   **Consider land swapping -** Turn to local producers who do not grow continuous corn. If a field(s) did not have corn the previous year, corn can be planted with little to no risk of CRW injury; therefore, CRW protection is not needed. Bt-RW hybrids are not recommended to be used in first year corn fields.

**If Rotation Away from Corn is Not Possible in 2021 (options a & b will not mitigate the resistant population unless used with option c):**

a. **Use a pyramid Bt-RW.** If planting a Bt-RW hybrid, ensure it is a pyramid hybrid expressing multiple Bt-RW proteins. This option will support the survival of Bt resistant populations and but may continue to experience CRW injury. Report CRW injury to your seed supplier, agronomist or the CCPC. Make efforts to rotate out of corn for 2022 to mitigate resistant CRW populations. Use of high rate neonicotinoid insecticide seed treatments or soil applied insecticides on Bt-RW hybrids is not recommended as these products together can lead to further resistance issues.

b. **Plant a non-rootworm Bt hybrid with root protection tools via seed treatment or soil insecticide**. Bt hybrids expressing proteins that only control above ground pests such as western bean cutworm (WBC), European corn borer (ECB) will remove further exposure of CRW to Bt-RW proteins, reducing selection pressure for resistance. If using non-rootworm Bt hybrids, root protection tools such as high rate neonicotinoid seed treatment or soil insecticides are needed.

   Refer to the **Canadian Bt Corn Trait Tables** for more information on which Bt proteins target CRW or above ground pests (i.e. WBC, ECB etc).

**c.** **Biocontrol nematodes:** Promising results from Cornell University (NY) show that soil-applied biocontrol nematodes kill CRW larvae and can mitigate Bt resistant CRW populations, restoring silage and grain corn yields within 2-3 years. Control is persistent; therefore, application is required only once. Research trials will be implemented in Ontario in 2021. If you are interested in participating in an on-farm research trial, please contact Tracey Baute (tracey.baute@ontario.ca) or Jocelyn Smith (jocelyn.smith@uoguelph.ca).

**Root Protection Tools for Non-Rootworm Bt hybrids:** Soil-applied or insecticide seed treatments only protect roots from CRW injury within their application zone, resulting in a large proportion surviving outside of that zone. When used on Bt-RW corn hybrids, these products mask existing Bt resistance issues. Both Bt and insecticides cause delayed adult emergence, leaving only surviving CRW to mate with each other, furthering resistance development. CRW has also developed resistance through overuse of these products in the US. Refer to the **Field Crop Protection Guide, Publication 812** for more information on soil insecticide and seed treatment options. **Granular soil applied insecticides** will have additional costs to purchase and install insecticide boxes on the planters. Access to **high rate neonicotinoid seed treatments** will require a pest assessment report as part of the Class E pesticide restrictions: **https://www.ontario.ca/page/neonicotinoid-rules-growers**. **Foliar insecticides** for adult control have not been found to manage resistant CRW populations due to the extended period of adult emergence and egg laying, as well as migration of adults from nearby fields.