Selected citations for field-evolved Bt resistance in U.S. corn pests **Updated January 2024**

These publications are the basis for the resistance ratings in the Handy Bt Trait Table. Lepidoptera species are listed first, followed by corn rootworm species.

Insect species	Bt protein	Crop Location(s)	Source/Citation for more information
LEPIDOPTERAN (CATERPILLAR) SPECIES			
corn earworm (CEW) ***Helicoverpa zea***	Cry1Ab	Sweet corn Maryland	• Dively et al. 2016. Field-evolved resistance in corn earworm to Cry proteins expressed by transgenic sweet corn. PLOS ONE 11(12)
	Cry1A.105 x Cry2Ab2	Sweet corn Maryland	• Dively et al. 2016. Field-evolved resistance in corn earworm to Cry proteins expressed by transgenic sweet corn. PLOS ONE 11(12)
	Cry1A.105 Cry2Ab2 Cry1A.105 x Cry2Ab2 pyramids	Field corn Carolinas Louisiana Texas Southeast US	• Bilbo et al. 2019. Susceptibility of Corn Earworm to Cry1A.105 and Cry2Ab2 in North & South Carolina. J. Econ.Ent. 112(4): 1845-1857 • Kaur et al. 2019. Field-evolved resistance of *Helicoverpa zea* (Boddie) to transgenic maize expressing pyramided Cry1A.105/ Cry2Ab2 proteins in NE Louisiana. J. Invert. Pathol. 163: 11-20. • Yang et al. 2019. Occurrence and ear damage of *Helicoverpa zea* on transgenic *Bacillus thuringiensis* maize in the field in Texas, U.S. and its susceptibility to Vip3A protein. Toxins 11(2), 102. doi.org/10.3390/toxins11020102 • Yu et al. 2021. Extended investigation of the field-evolved resistance of the corn earworm to *Bacillus thuringiensis* Cry1A.105 and Cry2Ab2 proteins in the southeastern United States. J. Invert. Pathol. 183. doi: 10.1016/j.jip.2021.107560
European corn borer (ECB) ***Ostrinia nubilalis***	Cry1Fa	Field corn, Potato, Millet Manitoba Nova Scotia Quebec	• Smith et al. 2019. Practical resistance of *Ostrinia nubilalis* to Cry1F *Bacillus thuringiensis* maize discovered in Nova Scotia. Nature Sci Rep 9, Article #18247 • Smith & Farhan. 2023. Monitoring resistance of *Ostrinia nubilalis* in Canada to Cry toxins produced by Bt corn. J. Econ.Ent. https://doi.org/10.1093/jee/toad046 • Farhan et al. 2023. Genetic mutations linked to field-evolved Cry1Fa-resistance in the European corn borer, *Ostrinia nubilalis*. Sci Rep 13, 8081. https://doi.org/10.1038/s41598-023-35252-y
	Cry1Ab	corn Manitoba Nova Scotia	• Smith & Farhan. 2023. Monitoring resistance of *Ostrinia nubilalis* in Canada to Cry toxins produced by Bt corn. J. Econ.Ent. https://doi.org/10.1093/jee/toad046
	Cry1A.105	corn Nova Scotia PEI Quebec	• Smith & Farhan. 2023. Monitoring resistance of *Ostrinia nubilalis* in Canada to Cry toxins produced by Bt corn. J. Econ.Ent. https://doi.org/10.1093/jee/toad046
	Cry2Ab	corn Nova Scotia Quebec	• Smith & Farhan. 2023. Monitoring resistance of *Ostrinia nubilalis* in Canada to Cry toxins produced by Bt corn. J. Econ.Ent. https://doi.org/10.1093/jee/toad046
fall armyworm (FAW) ***Spodoptera frugiperda***	Cry1F	Field corn Florida North Carolina Puerto Rico	• Storer et al. 2010. Discovery and characterization of field resistance to Bt maize: *Spodoptera frugiperda* in Puerto Rico. J. Econ. Entomol. 103: 1031–1038. • Huang et al. 2014. Cry1F Resistance in fall armyworm *Spodoptera frugiperda*: Single gene versus pyramided Bt maize. PLOS ONE 9(11). • Li et al. 2016. Frequency of Cry1F non-recessive resistance alleles in Carolina field populations of *Spodoptera frugiperda*. PLOS ONE 11(4).
Southwestern corn borer ***Diatraea grandiosella***	Cry1F	Field Corn Arizona New Mexico	• Arizona Pest Management Center. Posted 1 Feb 2017. Chlorpyrifos use in Arizona and New Mexico. Public comment submitted to EPA, ID Docket EPA-HQ-OPP-2015-0653-0654.

Insect species	Bt protein	Crop Location(s)	Source/Citation for more information
Western bean cutworm (WBC) *Striacosta albicosta*	Cry1F	Field Corn Western corn belt Great Lakes Ontario	• Ostrem et al. 2016. Monitoring susceptibility of western bean cutworm field populations to *Bacillus thuringiensis* Cry1F protein, J. Econ. Entomol. 109(2) 847–853. • Smith et al. 2017. Evidence for field-evolved resistance of *Striacosta albicosta* to Cry1F *Bacillus thuringiensis* protein and transgenic corn hybrids in Ontario, Canada. J. Econ. Entomol. 110: 2217-2228.
CORN ROOTWORM SPECIES			
Northern corn rootworm (NCR) ***Diabrotica barberi***	Cry3Bb1	Field Corn North Dakota	• Calles-Torrez et al. 2019. Field-evolved resistance of northern and western corn rootworm populations to corn hybrids expressing single and pyramided Cry3Bb1 & Cry34/35Ab1 Bt proteins in North Dakota. J Econ Entomol. 112(4): 1875-1886.
	Cry34/35Ab1 (now Gpp34Ab1/ Tpp35Ab1)	Field Corn North Dakota	• Calles-Torrez et al. 2019. Field-evolved resistance of northern and western corn rootworm populations to corn hybrids expressing single and pyramided Cry3Bb1 & Cry34/35Ab1 Bt proteins in North Dakota. J Econ Entomol. 112(4):1875-1886.
Western corn rootworm (WCR) ***Diabrotica virgifera virgifera***	Cry3Bb1	Field Corn Illinois Iowa Minnesota Nebraska North Dakota	• Gassmann et al. 2011. Field-Evolved Resistance to Bt maize by western corn rootworm. PLOS ONE 6(7). • Gassmann et al. 2012. Western corn rootworm and Bt maize: Challenges of pest resistance in the field. GM Crops & Food: Biotech in Ag and the Food Chain 3(3) 1-10. • Gassmann et al. 2012. Field-evolved resistance to Bt maize by western corn rootworm: Predictions from the laboratory and effects in the field. J. Invert Pathology 110:287-293. • Wangila et al. 2015. Susceptibility of Nebraska western corn rootworm populations to Bt corn events. J. Econ. Entomol. 108: 742-751. • Zukoff et al. 2016. Multiple assays indicate varying levels of cross resistance in Cry3Bb1-selected field populations of the western corn rootworm to mCry3A, eCry3.1Ab, Cry34/35Ab1. J. Econ. Entomol. 109(3): 1387-1398. • Schrader et al. 2017. Evaluation of adult emergence and larval root injury for Cry3Bb1-resistant populations of the western corn rootworm. J. Appl. Entomol. 141: 41-52. • Ludwick et al. 2017. Minnesota field population of western corn rootworm shows incomplete resistance to Cry34Ab1/ Cry35Ab1 and Cry3Bb1. J. Appl. Entomol. 141: 28-40. • Calles-Torrez et al. 2019. Field-evolved resistance of northern and western corn rootworm populations to corn hybrids expressing single and pyramided Cry3Bb1 & Cry34/35Ab1 Bt proteins in North Dakota. J Econ Entomol. 112(4): 1875-1886. • Gassmann et al. 2020. Field evolved resistance by western corn rootworm to Cry34/35Ab1 and other *Bacillus thuringiensis* traits in transgenic maize. Pest Manag Sci 76:268–276. • Reinders et al. 2022. Evidence of western corn rootworm field-evolved resistance to Cry3Bb1 + Cry34/35Ab1 maize in Nebraska. Pest Manag. Sci. 78(4): 1356-1366.
	mCry3A	Field Corn Iowa Minnesota Nebraska Texas	• Gassmann et al. 2014. Field-evolved resistance by western corn rootworm to multiple *Bacillus thuringiensis* toxins in transgenic maize. PNAS 111(14). 5141–5146. • Wangila et al. 2015. Susceptibility of Nebraska western corn rootworm populations to Bt corn events. J. Econ. Entomol. 108: 742-751. • Zukoff et al. 2016. Multiple assays indicate varying levels of cross resistance in Cry3Bb1-selected field populations of the western corn rootworm to mCry3A, eCry3.1Ab & Cry34/35Ab1. J Econ Entomol 109(3): 1387-1398.

Insect species	Bt protein	Crop Location(s)	Source/Citation for more information
western corn rootworm (WCR) **continued**	eCry3.1Ab	Field Corn Iowa Minnesota	• Jakka et al. 2016. Broad-spectrum resistance to *Bacillus thuringiensis* toxins by western corn rootworm. Nature Scientific Reports 6, 27860; doi: 10.1038/srep27860. • Zukoff et al. 2016. Multiple assays indicate varying levels of cross resistance in Cry3Bb1-selected field populations of the western corn rootworm to mCry3A, eCry3.1Ab & Cry34/35Ab1. J Econ Entomol 109(3): 1387-1398.
	Cry34/35Ab1 (now Gpp34Ab1/ Tpp35Ab1)	Field Corn Iowa Minnesota Nebraska	• Zukoff et al. 2016. Multiple assays indicate varying levels of cross resistance in Cry3Bb1-selected field populations of the western corn rootworm to mCry3A, eCry3.1Ab & Cry34/35Ab1. J Econ Entomol 109(3): 1387-1398. • Gassmann et al. 2016. Evidence of resistance to Cry34/35Ab1 corn by western corn rootworm: Root injury in the field and larval survival in plant-based Bioassays. J Econ Entomol 109(4): 1872–1880 • Ludwick et al. 2017. Minnesota field population of western corn rootworm shows incomplete resistance to Cry34Ab1/ Cry35Ab1 and Cry3Bb1. J. Appl. Entomol. 141: 28-40. • Gassmann et al. 2020. Field evolved resistance by western corn rootworm to Cry34/35Ab1 and other *Bacillus thuringiensis* traits in transgenic maize. Pest Manag Sci 76:268–276. • Reinders & Meinke. 2022. Reduced susceptibility of western corn rootworm populations to Cry34/35Ab1-expressing maize in northeast Nebraska. Nature Sci. Rpts. (2022) 12: 19221.
	Cry3 x Cry34/35Ab1 pyramid	Field Corn Iowa Nebraska North Dakota	• Calles-Torrez et al. 2019. Field-evolved resistance of northern and western corn rootworm populations to corn hybrids expressing single and pyramided Cry3Bb1 & Cry34/35Ab1 Bt proteins in North Dakota. J Econ Entomol. 112(4): 1875-1886. • Gassmann et al. 2020. Field evolved resistance by western corn rootworm to Cry34/35Ab1 and other *Bacillus thuringiensis* traits in transgenic maize. Pest Manag Sci 76: 268–276. • Reinders et al. 2022. Evidence of western corn rootworm field-evolved resistance to Cry3Bb1 + Cry34/35Ab1 maize in Nebraska. Pest Manag. Sci. 78(4): 1356-1366.