Ear Pests and Damage to Organic, Conventional and Bt-Protected Sweet Corn Grown in Central Kentucky[1]

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Abstract Sweet corn (*Zea mays* L. var. *rugosa*) was grown in replicated plots in 2004 and 2006 using organic, conventional, and genetically-engineered (Bt) production practices. Organic plots were treated with Entrust® (Dow AgroSciences LLC, Indianapolis, IN) whereas conventional and Bt sweet corn plots were treated with Warrior® (Syngenta Crop Protection, Inc., Greensboro, NC). All plots were treated once at silk emergence. Organic and conventional plots were treated again 1 wk later. Twenty-five ears were harvested from row centers in each treatment subplot to quantify ear pests and assess ear damage. The highest number of corn earworm, *Helicoverpa zea* (Boddie), larvae were found on organically-grown sweet corn. European corn borer, *Ostrinia nubilalis* (Hübner); southwestern corn borer, *Diatraea grandiosella* Dyar; and fall armyworm, *Spodoptera frugiperda* (J.E. Smith), larvae were not found as frequently. Neither corn earworm nor European corn borer larvae were found on Bt sweet corn ears. Sap beetles, *Carpophilus lugubris* Murray, were found on all 3 types of sweet corn. Organically and conventionally-grown sweet corn had a greater number of tip-damaged ears and numbers of damaged kernels per ear than Bt sweet corn. Ear length and weight were the same for all 3 types of sweet corn. Based on the information generated in this study, growing late-planted sweet corn organically or conventionally on a large commercial scale with a limited spray program and without using other types of ear pest management does not appear to be a practical or profitable option in central Kentucky.

Key Words Bt sweet corn, conventional sweet corn, organic sweet corn, ear pest damage, corn earworm, European corn borer

Sweet corn, (*Zea mays* L. var. *rugosa*) was grown on 810 ha in Kentucky in 2002. Since that time, production increased 39% to 1134 ha with a value of approx. $5 million (Tim Woods, University of Kentucky Extension Service, pers. comm., Woods et al. 2006). Growers sell sweet corn at farmers' markets and roadside stands to local customers but also use Kentucky marketing cooperatives, the Kentucky Produce Auction, and Kentucky Produce Shippers for wholesale marketing. Sweet corn production generally occurs on small farms scattered across the state with harvests from early to late-planted cultivars occurring from late July to early September. Consumer demand for damage-free sweet corn means that growers and vegetable processors have set very low tolerance levels for presence of insects or damage to meet consumer demand for blemish and insect-free food (Pimentel et al. 1977, Bartels and Hutchison 1995, Speece et al. 2005). Growers must develop/adopt the best possible management

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program for insect pests, especially those attacking the ear. Thus, maintaining a good inventory of pest control products and practices and developing more sustainable methods of production are essential for the success of sweet corn growers. Research of this nature is necessary to assist small and limited resource farmers to replace lost income from lower tobacco revenue. It will enable them to ascertain efficacy of modern agricultural production practices on pests and the damage they cause. This, in turn, will enable them to continue operating family farms, the core of rural Kentucky communities.

The primary pests of sweet corn ears in Kentucky are corn earworm, *Heliocoverpa zea* (Boddie); European corn borer, *Ostrinia nubilalis* (Hübner); southwestern corn borer, *Diatraea grandiosella* Dyar; fall armyworm, *Spodoptera frugiperda* (J.E. Smith) and dusky sap beetle, *Carpophilus lugubris* Murray (Sparks 1986, Smith et al. 1989, Wiseman et al. 1999, Maredia and Mihm 1991, Kumar and Mihm 1996, Dowd 2000). Managing the insect pests infesting sweet corn presents serious challenges to small farmers. Concerns about product timing, efficacy, impact on beneficial insects, the environment, social factors, and economics determine which management practices and cropping systems are selected by growers. Methods of control that have little environmental impact, reduce worker exposure to potentially harmful pesticides, leave no residues toxic to nontarget organisms, including beneficial insects, yet are highly effective against pest species resulting in high quality produce are essential for sustainable vegetable production systems. Thus, the objective of this research was to quantify ear pests and assess ear damage of late-planted sweet corn using minimal organic and conventional spray treatments and genetically engineered (Cry1Ab, Bt-11 insect protected) sweet corn production methods.

Materials and Methods

2004 experiment. Organic, conventional and Bt sweet corn was grown in a randomized complete block design with 3 subplots and 3 replicates, each 0.1 ha in area, per cropping type. All plots were conventionally tilled and disked. A preplant treatment of Bicep II Magnum® (Syngenta Crop Protection, Inc., Greensboro, NC) was applied at a rate of 4.9 L per ha to conventional and Bt plots and immediately incorporated for weed control. Organic plots were cultivated once per week for 3 wks after crop emergence for weed control. Soil samples from each field were submitted to International Ag Laboratories, Inc. (Fairmont, MN) and the University of Kentucky Cooperative Extension Service (Franklin Co. KY) for nutrient analyses. Soil fertility recommendations of International Ag Laboratories were followed for the organic plots whereas those of the UK Cooperative Extension Service were followed for conventional and Bt corn plots. Organic plots were fertilized with 560.4 kg soft rock phosphate, 111.2 kg potassium sulfate, 111.2 kg Chilean nitrate, 11.2 kg copper sulfate, 11.2 kg zinc sulfate, 5.6 kg manganese sulfate, and 224.1 kg 10-6-2 fish meal per ha. Conventional and Bt plots were fertilized with 340.8 kg ammonium nitrate, 170.3 kg diammonium sulfate, 282.4 kg muriate of potash and 103.1 kg zinc sulfate per ha before planting. All plots were planted on 6 June 2004 and consisted of 40 rows divided into subplots of 12 rows (2 rows between each subplot of 12 were roto tilled to create drive rows for insecticide application). GSS 0966, a Bt Cry1Ab protected hybrid (Attribute®, Syngenta Seed, Inc., Boise, ID) and its isoline, (Prime Plus®, Syngenta Seed, Inc., Boise, ID) were used. Untreated Prime Plus seed were used to plant organic plots. Plant spacing was 20 cm whereas row spacing was 1 m.

Crop phenology was monitored and when silks began to emerge organic plots were treated with Entrust® (Dow AgroSciences LLC, Indianapolis, IN) at a rate of 106.3 g per ha whereas conventional and Bt plots were treated with 237 ml Warrior® (Syngenta Crop Protection, Inc., Greensboro, NC) per ha for larval control on 5 August. Organic and conventional sweet corn plots were treated again with Entrust and Warrior, respectively, on 12 August. Plots were hand-harvested on 18 August 2004. Twenty-five primary ears from consecutive plants in the center of each subplot were harvested and kept in a cooler at 4°C until analyzed. Ears were individually examined in the laboratory, and corn earworm, European corn borer, southwestern corn borer, fall armyworm, and sap beetles were identified and enumerated. Damaged and missing kernels were quantified, and ear lengths and weights taken.

2006 experiment. Bt, conventional and organic sweet corn plots were established again in 2006 in the same manner and planted on 8 June. Plot size, hybrids, and plant and row spacing were the same as 2004. Organic plots were treated with Entrust at a rate of 106.3 g per ha whereas conventional and Bt plots were treated with 237 ml Warrior per ha for larval control on 2 August. Organic and conventional sweet corn plots were treated again with Entrust and Warrior, respectively, on 9 August. Twenty-five ears were hand-harvested from each subplot on 16 August 2006 and kept in the cooler at 4°C until analyzed. Ears were individually examined in the laboratory for insect pests and damage. Ear lengths and weights also were taken.

Data for each year were transformed with a square-root transformation ($x + 0.5$) and analyzed using ANOVA and Fisher's Protected LSD procedures in CoStat Statistical Software (CoHort Software 2006).

Results and Discussion

In 2004, corn earworm larvae were found on harvested conventionally and organically grown sweet corn ears (Table 1). European corn borer larvae were not found as frequently as corn earworm larvae on organic ears. Neither corn earworm

Table 1. Average number of live pests per ear at harvest ± SE on organic, conventional and Bt sweet corn ears 2004*

Crop	n	Corn earworm	European corn borer	Southwestern corn borer	Sap beetle
GSS 0966 (Bt)	3	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.04 ± 0.02a
Prime Plus (Conventional)	3	0.07 ± 0.03a	0.10 ± 0.08a	0.01 ± 0.01a	0.17 ± 0.13a
Prime Plus (Organic)	3	0.15 ± 0.04a	0.06 ± 0.004a	0.004 ± 0.004a	0.09 ± 0.04a
		d.f. = 2,4	d.f. = 2,4	d.f. = 2, 4	d.f. = 2, 4
		$F = 3.8$	$F = 0.99$	$F = 0.50$	$F = 0.80$
		$P = 0.1190$	$P = 0.4470$	$P = 0.6383$	$P = 0.5104$

* Means followed by different letters are significantly different.

nor European corn borer larvae were found on Bt sweet corn ears. Southwestern corn borer infestation was low overall and occurred only in the organically and conventionally grown plots. Sap beetles were found in ears of all 3 types of sweet corn.

Organically and conventionally grown sweet corn had significantly greater numbers of tip-damaged ears and numbers of damaged kernels per ear than Bt sweet corn. Remarkably, only one kernel on one Bt ear had any detectable damage (Table 2). Organically grown ears were the same length as conventional and Bt ears and all 3 types had similar weights.

In 2006, no corn earworm, European corn borer, or southwestern corn borer larvae were found in any Bt sweet corn ears. However, significantly greater numbers of corn earworm larvae were found in the Entrust-treated organic ears than the Bt or Warrior-treated conventional ears (Table 3). Numbers of corn earworm larvae found were higher than any of the other ear infesting Lepidoptera. Fall armyworm, while not found in 2004, was present only in organically grown ears in 2006 (Table 3). Unlike 2004, sap beetles were not found in harvested Bt sweet corn.

There was minor ear tip damage in Bt sweet corn but substantially less than conventional or organic ears in 2006 (Table 4). Less than one damaged kernel per ear was present on Bt ears. Greater than 9 and 17 kernels per damaged ear were present on conventional and organic ears, respectively. Tip damage and number of kernels damaged per ear in conventional and organic ears were greater in 2006 than 2004. Ear length and weight of each type was the same in 2006 (Table 4). Ears from all 3 cropping types in 2006 weighed less than those in 2004 probably due to extreme heat and drought conditions.

Based on the results reported herein, limited insecticide use for large-scale commercial plantings of late-planted conventional and organic sweet corn production in central Kentucky does not appear to be a practical or profitable option. Large numbers of tip damaged ears (29 - 85%) and large numbers of damaged kernels per ear (4.5 - 17.2) are likely a result of only weekly spraying for ear pests and suggest

Table 2. Damage to and size of organic, conventional and Bt sweet corn ears 2004*

Crop	n	tip damage**	no. kernels damaged**	ear length (cm)**	ear weight (g)**
GSS 0966 (Bt)	3	0.0004 ± 0.0004b	0.01 ± 0.004b	17.9 ± 0.2a	170.7 ± 1.7a
Prime Plus (Conventional)	3	0.29 ± 0.12a	2.16 ± 0.88a	17.7 ± 0.4a	163.1 ± 3.7a
Prime Plus (Organic)	3	0.36 ± 0.02a	4.46 ± 0.28a	18.1 ± 0.1a	160.1 ± 8.3a
		d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4
		$F = 6.85$	$F = 28.2$	$F = 0.74$	$F = 0.72$
		$P = 0.0489$	$P = 0.0044$	$P = 0.5323$	$P = 0.5409$

* Values represent averages per ear ± SE.

** Means followed by different letters are significantly different.

Table 3. Average number of live pests per ear at harvest ± SE on organic, conventional and Bt sweet corn ears 2006*

Crop	n	Corn earworm	European corn borer	Southwestern corn borer	Fall armyworm	Sap beetle
GSS 0966 (Bt)	3	0.00 ± 0.00b	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a
Prime Plus (Conventional)	3	0.07 ± 0.04b	0.01 ± 0.00a	0.001 ± 0.001a	0.00 ± 0.00a	0.02 ± 0.02a
Prime Plus (Organic)	3	0.25 ± 0.02a	0.03 ± 0.02a	0.07 ± 0.05a	0.06 ± 0.02a	0.11 ± 0.09a
		d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4
		$F = 28.65$	$F = 2.15$	$F = 1.81$	$F = 4.27$	$F = 1.10$
		$P = 0.0043$	$P = 0.2326$	$P = 0.2750$	$P = 0.1019$	$P = 0.4166$

* Means followed by different letters are significantly different.

Table 4. Damage to and size of organic, conventional and Bt sweet corn ears 2006*

Crop	n	tip damage**	no. kernels damaged**	ear length (cm)**	ear weight (g)**
GSS 0966 (Bt)	3	0.05 ± 0.03b	0.37 ± 0.03b	17.0 ± 0.03a	129.4 ± 7.0a
Prime Plus (Conventional)	3	0.79 ± 0.09a	9.1 ± 1.3a	17.1 ± 0.22a	131.1 ± 6.9a
Prime Plus (Organic)	3	0.85 ± 0.03a	17.2 ± 3.0a	17.7 ± 0.21a	110.0 ± 4.7a
		d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4	d.f. = 2, 4
		$F = 39.10$	$F = 6.78$	$F = 3.41$	$F = 3.33$
		$P = 0.0024$	$P = 0.0480$	$P = 0.1366$	$P = 0.1408$

* Values represent averages per ear ± SE.
** Means followed by different letters are significantly different.

that without a more frequent spray program, or other means of ear pest management (e.g., vegetable/mineral oils and microbial pathogens, Hazard et al. 2003), growing sweet corn on a large commercial scale would not be profitable. Similarly, high percentages of unmarketable ears were found in lightly treated conventional sweet corn grown in Virginia (Speece et al. 2005) and untreated conventional sweet corn in South Carolina (Hassell and Shepard 2002) and Minnesota (Burkness et al. 2001). Frequently, growers cannot apply intensive applications or other means of ear pest management. Thus, for conventional sweet corn growers, growing Bt sweet corn offers protection against severe ear pest damage. Organic growers would still need to apply multiple crop protection methods to produce an economically viable sweet corn crop.

The Bt based GSS 0966 hybrid provides excellent control of larval lepidopterous ear pests. Using it or other similar Bt hybrids would reduce the use and number of insecticide applications, or eliminate them altogether, so using them could be the basis of more biologically based IPM practices in this commodity (Dively et al. 1998, Lynch et al. 1999, Dowd 2000, Burkness et al. 2001, Musser and Shelton 2003). Nonetheless, there is concern that Bt sweet corn may impact nontarget and beneficial insects. To date, short term field studies conducted in Cry1Ab hybrid sweet corn fields have not found negative effects on beneficial insects (Rose and Dively 2007, Daly and Buntin 2005, Pilcher et al. 2005). However, significant quantities of Cry1Ab endotoxin has been found in several nontarget insect herbivores and in some arthropod predators (i.e., Coccinellidae, Araneae and Nabidae) collected from Bt corn fields (Harwood et al. 2005). This indicates movement of the Cry1Ab endotoxin into higher trophic levels. More recently, several species of Coccinellidae were found to contain detectable levels of Bt endotoxin 2 wks before and up to 10 wks after anthesis (Harwood et al. 2007). Thus, long-term field studies concerning the sustainability of genetically-engineered Bt sweet corn should be performed at the multitrophic level to determine the significance of trophic linkages and whether nontarget arthropods are in any way impacted (O'Callaghan et al. 2005).

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