Direct Silk Applications of Corn Oil and *Bacillus thuringiensis* as a Barrier to Corn Earworm Larvae in Sweet Corn

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ADDITIONAL INDEX WORDS. *Bt*, *Helicoverpa zea*, integrated pest management, organic pesticides, *Zea mays*, Zea-later

SUMMARY. **Field studies were conducted in 2000 and 2001 to rate the efficacy and longevity of four pesticide treatments against corn earworm (*Helicoverpa zea*) larvae (CEW) in sweet corn (*Zea mays*). The four treatments used were 1) corn oil, 2) *Bacillus thuringiensis* ssp. *kurstaki* (*Bt*), 3) oil + *Bt*, and 4) an untreated plot. All treatments were applied on silk day 5. Silk day 1 was the first day that more than 50% of the ears had 2.5 cm (1 inch) or more silks emerging from the husk using a hand-held pump applicator. Two first-instar CEW larvae were placed directly into silk channel of selected ears on 6 different days (days 3, 6, 9, 12, 15, and 18 after first silk). The same six ears were then harvested 4 days later. Untreated ears had more live CEW and higher levels of feeding damage than the other three treatments ears for all harvest days in both years. The number of CEW found per ear was lower when *Bt* was included in the treatment. The use of corn oil gave the lowest damage ratings on almost all harvest days in both years. Treatments which contained oil had the highest number of marketable ears in both years, but also the highest percentage of underdeveloped kernels at the tip of the ear (6% to 9%). The oil and *Bt* treatments appeared to control CEW for at least 17 days, from silking through maturity. This treatment regime appears to be a promising alternative for growers to conventional pest management methods.**

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Sweet corn is grown on over 8,094 ha (20,000 acres) of farmland in New England (New England Agricultural Statistics Service, 2003). Corn earworm and european corn borer (*Ostrinia nubilalis*) are the two most critical pests of sweet corn in this area, especially for organic growers because of the lack of effective pesticides against these pests. *Bacillus thuringiensis*, while effective as a foliar spray (Hazzard and Mazzola, 1997), does not control CEW larvae once they enter the silk channel of the ear. Feeding damage and frass make the ears unmarketable to consumers.

Early studies showed that mineral oil (sometimes mixed with a second toxic compound), added directly to the silk channel of the ear, reduced the number of CEW and the degree of damage they caused (Barber 1938, 1940, 1944; Carruth, 1942; Pepper and Barber, 1940). Though effective, this method was not widely adopted due to lack of an economically viable means of applying the treatment. A hand-held pump applicator, called the Zea-later (Conlet Plastics, New Milford, Conn.) was recently patented and is now commercially available (Johnny's Select Seed, Albion, Maine), which may improve application efficiency.

In 1996 (Siedlecki et al.), initial trials suggested that several types of mineral, vegetable, and petroleum oils lowered the number of CEW larvae found, resulting in more insect-free ears. Other studies examined different oils in varying amounts, the timing of oil application, and the integration of direct silk oil treatments with foliar *Bt* applications (Hazzard, 1994, 1997; Hazzard and Mazzola, 1997; Ngollo et al., 1995) and suggested that corn oil, combined with *Bt* and applied on day 5 after first silk, gave the highest level of control.

Corn earworm moths prefer to deposit eggs on fresh silks, but may lay eggs on silks throughout the silking period, which typically lasts for 21 d. Eggs hatch in 3 to 7 d at field temperatures. Thus, there can be newly hatched CEW larvae entering the silk channel from silk initiation through harvest at milk stage. Also, growers have indicated that it takes about 8 h to apply the oil to 0.4 ha (1 acre) of corn. Therefore, in order for the oil application to be cost effective, a single application would have to control CEW from first silk through maturity. The longevity of the oil and *Bt* in the silk channel has not been studied. The objective of this experiment was to compare oil and *Bt*, alone and in combination, to determine their effectiveness against the CEW over time.

A negative effect of the oil treatment is inhibited kernel development on ear tips, especially if the treatment was applied in the first few days after silking. This effect on kernel development has been called cone tip or tip stunting (Carruth, 1942; Siedlecki et al., 1996). In one study, canola oil reduced total ear length by 1.8 cm (0.71 inch) and the proportion of the ear with fully developed kernels by 6% (Hazzard and Gault, 1993). This effect does not appear to affect direct sales at farm stands because the consumer appears satisfied that it is a side effect of an organic treatment (Hazzard, 1994). However, wholesale brokers have rejected corn if the cone tip is too severe (Hazzard et al., 2000). Therefore, the second objective of this study was to determine which of the treatments effects cone tip.

Materials and methods

Raising corn earworm. This experiment was started early in the growing season to avoid wild populations of CEW in the field; hence, laboratory-raised larvae were used. Sixty-four pupal stage insects were shipped to the University of Massachusetts from the USDA Southern Insect Management Research Laboratory collection (Stoneville, Miss.) on 5 Apr. 2000 and 7 May 2001.

The pupae were placed in containers [473-mL (16-fl oz) cup #116MR with plastic lid #624-P (Solo, Inc., Chicago)] and kept in a rearing room at a constant temperature of 25 °C (77.0 °F). Male and female pupae were separated and kept in the cups until the moths emerged.

As the moths emerged from the pupal casings, they were transferred into new cups to mate, along with a strip of dental wicking (Richardson Dental, Charlotte, N.C.) immersed in a sugar water solution (10% sucrose solution, wt:vol) for feeding.

Each cup with breeding moths was covered by a mesh metal screen (with 1 mm squares) that provided a structure for the females to hold when they laid eggs. Eggs were collected by removing the screen, then placing it into another cup [148 mL (5.0 fl oz) #TS-5 with lid #662-P (Solo, Inc.)] filled with a commercially purchased CEW diet to hatch [Southland Co., Lake Village, Ark.;163 mL (5.5 fl oz) of dry diet mixed with 900 mL (30.4 fl oz) water and 7 mL (0.2 fl oz) raw linseed oil)]. The cups were numbered with the date that the eggs were laid.

Larval emergence is temperature dependent, as are other stages of the CEW life cycle (Butler, 1976). In a room at 21 °C (69.8 °F), the eggs took about 2 to 3 d to hatch. To manipulate hatching time, eggs were placed in a refrigerator at 13 °C (55.4 °F), then moved to 21 °C (69.8 °F) to progress them towards hatching. Adjustments were made to rearing temperatures to slow or speed the development of the colony. The goal was to have a minimum of 400 first-instars available to use in the field experiment every 3 d over a 15 d period.

YEAR 1 FIELD WORK. A 100.6 × 36.6-m (330 × 120 ft) portion of a grower's cornfield in Deerfield, Mass. was rented for this research. The grower took responsibility for all fieldwork until it was about 10 d away from first silk. After that time, he did not enter the plots nor spray any pesticides within 7.6 m (25 ft) of the experimental area.

The soil type in the first year was a Limerick silt loam (coarse silty, mixed, mesic). The corn cultivar Temptation (Sieger's Seed Co., Zeeland, Mich.) was planted on 20 Apr. 2000. A granular application of 17N–0P–23.2K was broadcast at 55.1 kg·ha^{-1} (300 lb/acre) during the week of 20 Apr. 2000. A side-dress of urea (46N–0P–0K) at 21.1 kg·ha^{-1} (115 lb/acre) was applied on 1 July 2000. No pesticides were used. The field was irrigated as deemed necessary by the farmer.

Plots were four rows wide on 1.2-m (4-ft) centers with two outer rows as guard rows. This was a split-plot design with eight replications. Each main plot was 11.0 m (36 ft) long and each subplot was 1.8 m (6 ft) long. The main plot was the four pesticide treatments: 1) an untreated plot (no oil and no *Bt*); 2) Stop N' Shop brand (Amherst, Mass.) corn oil; 3) *Bt* (Dipel DF; Valent Agricultural Products, Richardson, Texas); and 4) oil + *Bt*. Pesticide treatments were applied on silk day 5 (18 July 2000). Silk day 1 (13 July 2000) was designated as the day that a minimum of 50% of the corn ears (only the primary ear was used on each stalk) within the experimental area had about 2.5 cm of silk protruding from the ear (Adams and Clark, 1996).

Within each main plot were six subplots delineating larvae application days (silk days 3, 6, 9, 12, 15, and 18. Six ears were chosen randomly in each sub-plot and labeled. Two first-instar larvae were laid near the opening of the silk channel with a soft-tipped paintbrush at 1000 HR on the appropriate day. Preliminary data showed that four days was sufficient time for larvae to move into the silk channel and feed.

The pesticide treatments were applied at 1030 HR on silk day 5. To prepare the oil and *Bt* mixture, 900 mL (30.4 fl oz) of oil plus a spreader [(10% Atlox (Uniqema, New Castle, Del.) by volume was added] were combined with 28.4 g (1.0 oz) of Dipel DF that had been previously mixed with 100 mL (3.4 fl oz) of distilled water. The Zea-later was used to deliver 0.5 mL (0.017 fl oz) [*Bt* rate: 0.56 kg·ha^{-1} in 20 L·ha^{-1} (0.5 lb/acre in 5.3 gal/acre) of corn oil assuming 96,368 ears/ha (39,000 ears/acre)] of suspension directly into the silk channel of each corn ear. All liquids were agitated manually and regularly during application to keep materials in suspension.

The same six ears from each plot were harvested 4 d after each larvae application (silk days 7, 10, 13, 16, 19, and 22). Day 22 also represented the day a grower would normally harvest ears for market (milk stage). The ears were placed in bags, then immediately taken to the laboratory for evaluation. The ears were inspected for signs of damage caused by larval feeding, and for the number of live CEW. Damage was assessed by a numeric rating system similar to damage scales used in past studies (Hazzard, 1994; Siedlecki et al., 1996). The ratings ranged on a scale from 0 to 5, and indicated the specific location of damage: 0 = no damage, 1 = damage to silk only, 2 = damage on ear from tip to 2.5 cm (1 inch), 3 = damage to ear from 2.5 to 5.1 cm (2 inches) below the tip, 4 = damage to ear from 5.1 to 7.6 cm (3 inches) below the tip, and 5 = damage to ear 7.6 cm or more below the tip. Total ear and cone tip length (area of undeveloped kernels) was measured. Cone tip was expressed as a percent of total ear length. The number of marketable ears was based on a percentage of ears receiving a damage rating of 0. Cone tip was not used as a criteria for marketability.

YEAR 2 FIELD WORK. A different piece of land in Deerfield, Mass. was rented from the same grower as in 2000. In year 2, 'Peto 6803' (Peto-Seed Co., Inc. Saticoy, Calif.) was planted into a Hadley loam (coarse-silty, mixed, mesic) on 1 May 2001. A granular application of 17N–0P–31.5K was broadcast at 55.1 kg·ha^{-1} (300 lb/acre) during the week of 1 May 2001. The corn received a side-dressing of 15N–7.9P–2.5K [21.1 kg·ha^{-1} (115 lb/acre)] on 10 June 2001. Lamda-cyhalothrin (Warrior; Zeneca Agrochemical Products, Wilmington, Del.) was applied on 20 June and 29 June 2001 at a rate of 30 mL·ha^{-1} (0.24 lb/acre a.i.) to combat high numbers of european corn borers in the tassel prior to silk initiation.

In year 2, silk day 1 was 8 July 2001. The four pesticide treatments were applied on 12 July. Larval application (days 3, 6, 9, 12, 15, and 18) and harvest (7, 10, 13, 16, 19, and 22) took place on the same silk days as the first year. All other aspects of the fieldwork in 2001 were conducted in the same manner as noted above in 2000.

The data from six ears in each split-plot for the four treatments and eight replications for this factorial experiment (treatment x time) were analyzed using the general linear model (GLM) of SAS (SAS version 8.2 for Windows; SAS Institute, Cary, N.C.).

Results

Because weather and cultivar affected the time of silking and, coordinating the time of silking with the time of larval development was difficult, the cultivar used for the experiments could not be controlled. Thus, two different corn cultivars were used in

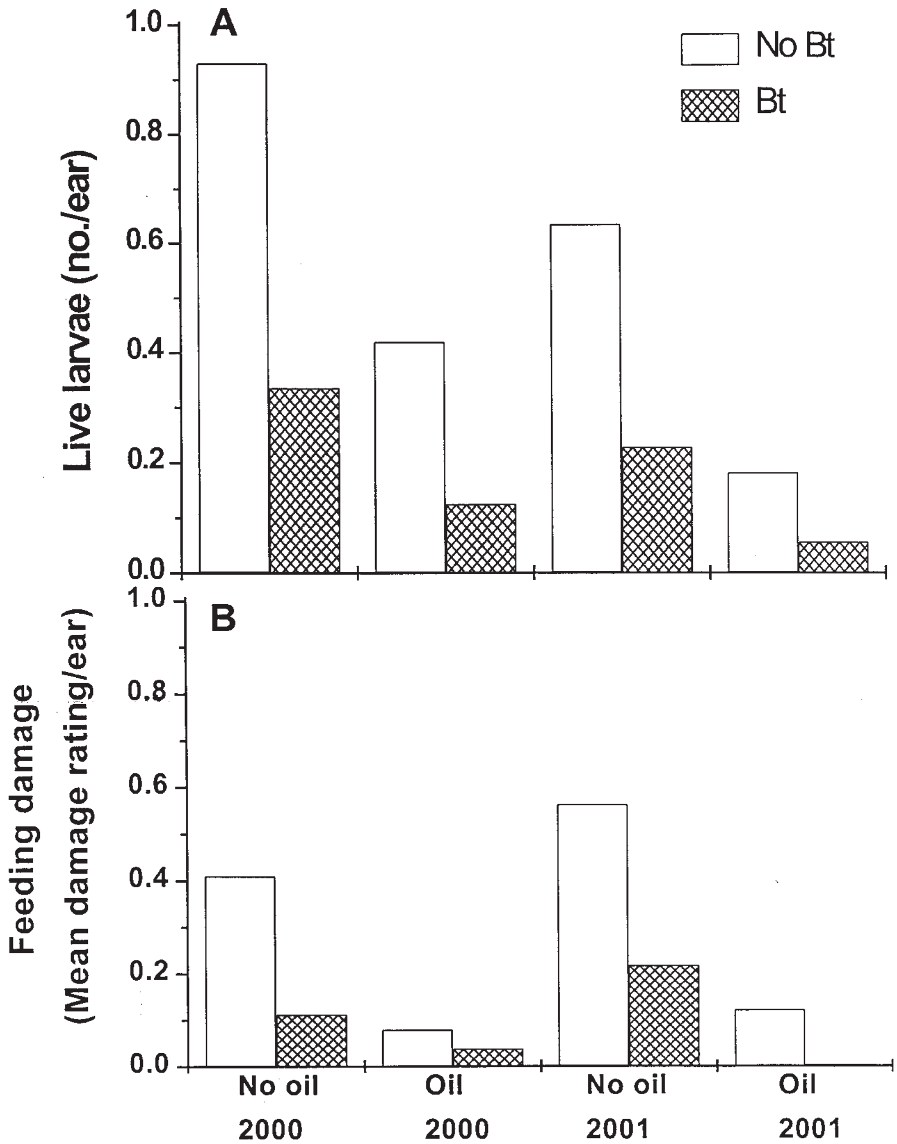

Fig. 1. Number of live corn earworm larvae per ear (A) and the level of damage caused by corn earworm feeding (B) averaged over all treatments and the six larval application days in 2000 and 2001. Both corn oil (oil) and *Bacillus thuringiensis* ssp. *kurstaki* (*Bt*) were significant at the $P \leq 0.01$. The combination of oil + *Bt* was also significant at $P \leq 0.01$, but the effects were not additive (n = 278). Oil = food grade corn oil at 0.5 mL (0.017 fl oz) per ear; *Bt* = Dipel DF (Valent Agricultural Products, Richardson, Texas) at 0.56 $kg \cdot ha^{-1}$ (0.5 lb/acre) in 20 $L \cdot ha^{-1}$ (5.3 gal/acre) of oil. The Zea-lator (Conlet Plastics, New Milford, Conn.) delivered 0.5 mL of the treatment directly into the silk channel of each ear.

2000 and 2001. Due to the differences in temperature, rainfall, soil types, and cultivars between year 1 and year 2 of this experiment, the data for each year were analyzed separately. The general treatment effects averaged over the six larval placement dates, are shown in Fig. 1 for the number of live larvae found per ear (Fig. 1A) and the level of damage per ear caused by larval feeding (Fig. 1B). Overall, the use any treatment decreased the number of live larvae found and the degree of feeding damage compared with the untreated control (no oil, no *Bt*). Though not additive, the oil + *Bt* combination resulted in the highest level of control overall and the least amount of feeding damage.

Corn earworm. The main effects of time, oil, and *Bt* were significant in 2000 and 2001 (Table 1). Time did not interact with oil to significantly affect the number of CEW so this data was not presented, but time did interact significantly with *Bt* and a separation of means was performed for this effect (Fig. 2). Results of the comparison of means showed that the use of *Bt* was significant on 4 of the 6 harvest days in 2000. The number of live CEW found on ears without *Bt* applications were almost four times as high as the number of live CEW found on ears treated with *Bt*.

In 2001, the use of *Bt* was significant on 5 of the 6 harvest days. Differences were nonsignificant only on the first harvest day (silk day 3) perhaps due to the fact that larvae had been exposed to treatments for only 2 days when these ears were analyzed. For larval placement dates 6, 9, 12, 15, and 18, there was about a 5-fold greater number of live CEW in treatments without *Bt* than in those with *Bt*. Thus, the use of *Bt* as a treatment provided significantly improved protection against corn earworm larvae compared to treatments without *Bt*.

Damage. Recorded damage ratings ranged between 0 and 2, meaning that until the last 2 harvest dates, larvae were rarely found further down than 2.5 cm from the tip of the ear. Most of the CEW were found in the silk above the ear. Part of this is due to that fact that in the early stages of ear growth, the ear is still elongating. Since larvae find ample silks to feed on, larvae tend not to move towards the developing ear.

The three main effects, time, oil, and *Bt* were significant (Table 1). Oil interacted with time to affect the damage rating per ear (Fig. 3) while *Bt* and time did not interact significantly in either 2000 or 2001 (data from this mean separation is thus not shown). The oil treatment was more effective in suppressing larval damage on days 9, 12, 15, and 18 in both years. In 2001, the level of damage increased over time in the untreated ears compared to the oil treated ears.

Cone tip. Air temperatures were several degrees below normal in 2000 during early growth and silking. There was also above average rainfall up to the time of first silk. Many of the ears within and outside the experimental area showed a flattened shape at the tip of the ear, which was attributed to abnormal weather conditions. It was difficult to distinguish between cone tip and other physiological abnormalities in the ear. Thus cone tip was not measured in the first year. However, in 2001, cone tip was observed and recorded (Table 2). Cone tip length measured in this year was longer in

Table 1. Statistical analysis for the number of live corn earworm and the level of damage in sweet corn treated with corn oil (oil), *Bacillus thuringiensis* ssp. *kurstaki* (*Bt*), oil + *Bt*, and an untreated control, averaged over the 6 d that larvae were applied in 2000 and 2001. Oil = food grade corn oil at 0.5 mL (0.017 fl oz) per ear, *Bt* = Dipel DF (Valent Agricultural Products, Richardson, Texas) at 0.56 kg·ha^{-1} (0.5 lb/acre) in 20 L·ha^{-1} (5.3 gal/acre) of oil. Treatment was delivered 5 d after first silk; Exactly 0.5 mL was delivered directly into the silk channel using a Zea-lator (Conlet Plastics, New Milford, Conn.).

	Live corn earworms (no.) (n = 288)		Damage level (n = 288)	
Treatment analysis	2000	2001	2000	2001
Oil	**	**	**	**
Bt	**	**	**	**
Time	**	**	*	*
Oil × *Bt*	*	*	**	**
Oil × time (n = 48)	NS	NS	*	*
Day 3	---	---	NS	NS
Day 6	---	---	NS	NS
Day 9	---	---	*	*
Day 12	---	---	*	*
Day 15	---	---	*	*
Day 18	---	---	*	*
Bt × time (n = 48)	*	**	NS	NS
Day 3	NS	NS	---	---
Day 6	NS	*	---	---
Day 9	*	*	---	---
Day 12	*	*	---	---
Day 15	*	*	---	---
Day 18	*	*	---	---
Oil × *Bt* × time	NS	NS	NS	NS

NS,*,**Nonsignificant or significant by F test at P = 0.05 or 0.01, respectively.

all treated ears compared to untreated ears. Ears receiving only *Bt* as a treatment had a mean cone tip length of 0.06 cm (0.02 inches) or 0.3% of the entire ear length. The oil treatment had a mean cone tip length of 1.24 cm (0.5 inch) or 6.5% of the ear, but the oil and *Bt* mixture recorded the highest reading of 1.69 cm (0.7 inches) or 9.1% of the ear. Clearly, oil had a greater effect on kernel development than *Bt*.

MARKETABLE EARS. Marketable ears were those that received a rating of 0 based on the damage scale used in this experiment. Cone tip was not used as a criteria for marketability. For both years, the number of marketable ears was highest in the plots treated with oil and oil plus *Bt* (Table 2). In comparison, *Bt* alone provided 88% and 83% marketable ears, while only 73% and 46% of the untreated ears were marketable in 2000 and 2001, respectively.

Discussion

Although the actual number of live CEW found varied between the 2 years, the effects were similar. Though there were more live larvae found in year 1 than in year 2, the untreated ears always had greater numbers of larvae than either of the treatments. Carruth (1942) and Hazzard (1997) found similar results, though only a single harvest was made at the milk stage of the ear in these experiments. Most CEW or their damage were found in the silks during the first three harvest days after treatment. The ears are short in the early stages of development. Because CEW feeds on silks as well as kernels, there is little reason for CEW to continue to move towards the developing ear. The level of damage increased over time as the ear grew and became more accessible to the larvae.

It appears that *Bt* is more effective at killing CEW than oil. One study in a petri dish showed that CEW was more likely to avoid areas with oil, but pass through areas with *Bt* (P. Westgate, personal communication). It is not known whether this type of avoidance can occur within the silk channel or not. Visual observation of the silks treated with oil indicates that all silks are coated equally with oil throughout the husk, whereas when *Bt* is used alone (mixed with only water), it sometimes beads up at the entrance to the silk channel. Since the mode of action of oil (we believe by asphyxiation) and *Bt* (stomach poison) are different, it should not be surprising that their effectiveness as treatments are somewhat different.

The oil appeared to have greater damage deterrence and for a longer period of time than *Bt*. As most corn takes 20 d or more to reach maturity

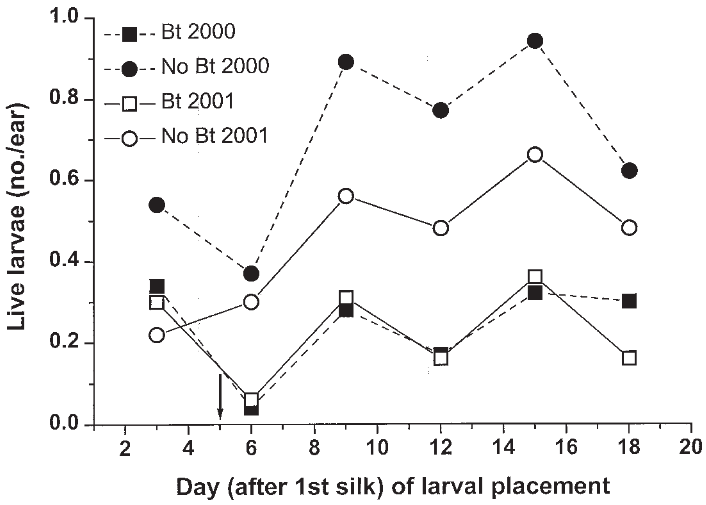

Fig. 2. Number of live corn earworm per ear. Graph depicts the separation of means for the *Bacillus thuringiensis* ssp. *kurstaki* (*Bt*) × day of larval placement (Time) interaction. The corn oil (Oil) × time interaction was not significant so the separations of these means are not presented. The treatments were significant at $P \leq 0.05$ in 2000 on larval placement dates 9, 12, 15, and 18 and at $P \leq 0.01$ in 2001 on larval placement days 6, 9, 12, 15, and 18. The arrow depicts the day that the treatments were applied in the silk channel. Oil = food grade corn oil at 0.5 mL (0.017 fl oz) per ear *Bt* = Dipel DF (Valent Agricultural Products, Richardson, Texas) at 0.56 kg·ha^{-1} (0.5 lb/acre) in 20 L·ha^{-1} (5.3 gal/acre) of oil. The Zea-lator (Conlet Plastics, New Milford, Conn.) delivered 0.5 mL of the treatment directly into the silk channel of each ear.

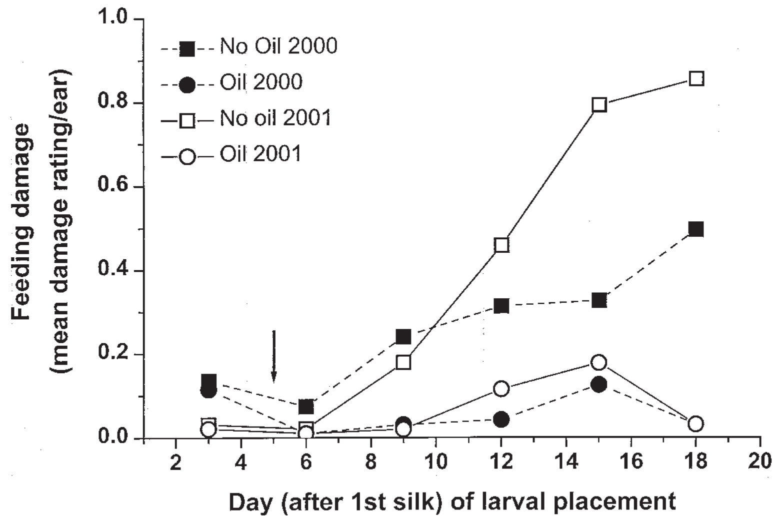

Fig. 3. Level of damage per ear caused by corn ear worm feeding. Graph depicts the separation of means for the corn oil (oil) × day of larval placement (Time) interaction. The *Bacillus thuringiensis* ssp. *kurstaki* (*Bt*) × Time interaction was not significant so the separations of these means are not presented. The treatments were significant at $P \leq 0.05$ in 2000 and 2001 on larval placement dates 9, 12, 15, and 18. The arrow depicts the day the treatments were applied in the silk channel. Oil = food grade corn oil at 0.5 mL (0.017 fl oz) per ear; *Bt* = Dipel DF (Valent Agricultural Products, Richardson, Texas) at 0.56 kg·ha^{-1} (0.5 lb/acre) in 20 L·ha^{-1} (5.3 gal/acre) of oil. The Zea-lator (Conlet Plastics, New Milford, Conn.) delivered 0.5 mL of the treatment directly into the silk channel of each ear.

once silks emerge, the longevity of treatment is an important factor. One farmer estimated that it took about 8 h to oil one acre of corn (D. Kaplan, personal communication). Organic growers, with few other options for controlling CEW in the silks, indicated that a single application is cost effective because the increase in the number of marketable ears compensates for the cost of the labor (S. Mong and J. Mannix, personal communication).

Cone tip lengths were impacted in year 1 by the unusual cold and wet weather occurring in that growing season. In year 2, cone tip among the different treatments was more typical of what was observed in other studies (Carruth, 1942; Hazzard, 1994; Hazzard and Gault, 1993). Oiled ears had the highest percentage of cone tip on each ear. The silks at the tip of the ear (about the last 10 rings of kernels from the tip) are the last to emerge and the tips are often still inside the silk channel when the oil is applied. The silks at the tip usually did not detach from the kernels as they did further down the ear. This lack of detachment suggests that fertilization does not take place. We theorize that oil coats the trichomes on the silks, thus affecting either the ability of the trichomes to capture pollen or the ability of the pollen tube to penetrate and/or grow through the silk to the egg (A. Carter, personal communication). The oil itself could be phytotoxic to the silk tissue, though no abnormal dessication, wilting, or discoloration was observed in the silks. The silks felt only very slightly oily to the touch.

Typically, some portion of the tip is unfilled, even in untreated ears. Carruth (1942) suggested that 1.3 cm (0.5 inch) of cone tip was normal in an untreated ear. Modern varieties are expected to have complete fill all the way to the ear. Cone tip was not used as a criteria to determine marketability because consumer reaction to cone tip is variable (R.V. Hazzard, personal communication). Growers who sell through direct markets such as farm stands and farmers' markets in New England are able to explain cone tip to their customers. The explanation seems acceptable to consumers, especially those who prefer organically grown corn. Contact with consumers through the wholesale market, however, is not possible. Growers or retail packers who pre-package partially husked ears simply cut the tip off prior to packaging. However, further research to find ways to prevent the cone tip is worthwhile.

The data from this experiment appears to support the current recommendations from the University of Massachusetts for CEW control using direct silk application of oil and/or *Bt* (Hazzard, 1998, 2002). It also appears that the treatment is effective from silk day five through maturity and thus is a promising method for CEW control, especially for organic growers.

Literature cited

Adams, R.G. and J.C. Clark. 1996. Northeast sweet corn production and integrated pest management manual. Univ. Conn. Coop. Ext. System, Storrs.

Table 2. Percent cone tip and the percent of marketable ears in sweet corn treated with corn oil (oil), *Bacillus thuringiensis* ssp. *kurstaki* (*Bt*), oil + *Bt*, and an untreated control in 2000 and 2001. Treatment was delivered on 5 d after first silk. Treatments were applied directly into the silk channel using a Zea-lator (Conlet Plastics, New Milford, Conn.). Ears were harvested on d 22 after first silk when they were at the milk stage. Cone tip was not used as a criteria for marketability. Oil = food grade corn oil at 0.5 mL (0.017 fl oz) per ear, *Bt* = Dipel DF (Valent Agricultural Products, Richardson, Texas) at 0.56 kg·ha^{-1} (0.5 lb/acre) in 20 L·ha^{-1} (5.3 gal/acre) of oil.

	Cone tip (%) (n = 48)		Marketable (%) (n = 48)	
Treatment	2000[z]	2001	2000	2001
Untreated	---	0.01 b	73 b	43c
Oil	---	6.49 a	96 a	98 a
Bt	---	0.32 b	88 a	83 b
Oil + *Bt*	---	9.1 a	96 a	100 a
Analysis				
Oil	---	**	*	*
Bt	---	NS	*	*
Time	---	---	---	---
Oil × *Bt*	---	*	*	*

[z]All ears showed some physiological abnormality at the tip in 2000 which we believe was due to cold, wet conditions during silking.

[NS,*,**]Nonsignificant or significant by F test at $P = 0.05$ or 0.01, respectively. All other interactions not shown did not pertain to this test. Mean separation by Duncan's multiple range test at $P \leq 0.05$.

Barber, G.W. 1938. New control methods for the corn earworm. J. Econ. Entomol. 31(3):459.

Barber, G.W. 1940. Dichloroethyl ether in mineral oil for corn earworm control in sweet corn. J. Econ. Entomol. 33(3): 384.

Barber, G.W. 1944. Mineral oils, alone or combined with insecticides, for the control of earworms in sweet corn. USDA Tech. Bul. 880.

Butler, W. 1976. Bollworm development. J. Environ. Entomol. 6: 520–521.

Carruth, L.A. 1942. An investigation of the mineral oil treatment for corn earworm control. J. Econ. Entomol. 35(2):227–233.

Hazzard R.V. 1994. *Bt*, p. 18. In: R. Hazzard (ed.). Proc. N.E. Farmer to Farmer Info. Exchange, N.E. Organic Farming Assn. Univ. Mass. Ext. System, Amherst.

Hazzard, R.V. 1997. Integrated microbial insecticides and oils into sweet corn IPM in Massachusetts. Sust. Agr. Res. Educ.–Agr. in Concert with the Enivron. Final Rpt. (ANE 95-26).

Hazzard, R.V. 1998. Biointensive insect management in sweet corn. Univ. Mass. Ext. Factsheet Veg SF1-99:1–4.

Hazzard, R.V. 2002. Corn earworm threshold. Univ. Mass. Veg. IPM Nswlt. 13(10):6.

Hazzard, R.V. and J. Gault. 1993. Microbial control of second generation european corn borer and fall armyworm in 1992. Insecticide Acaricide Tests 18:122–123.

Hazzard, R.V. and M. Mazzola. 1997. Foliar sprays of *Bacillus thuringiensis* in early corn. 1996. Arthropod Mgt. Test 22:122–123.

Hazzard, R.V., A. Carter, P. Westgate, and R. Cook. 2000. Sweet corn, p. 28–29. In: R. Hazzard (ed.). Univ. Mass. (Amherst) Ext. Agroecol. Veg. Prog. 2000 Annu. Rpt..

New England Agriculture Statistic Service. 2003. New England Agriculture Statistics 2002. New England Agr. Stat. Serv., Concord, N.H.

Ngollo, D., R.V. Hazzard, and E. Groden. 1995. Direct silk applications for control of sweet corn insects in Massachusetts and Maine. Entomol. Soc. Amer. Eastern Branch, 66th Annu. Mtg., Harrisburg Pa. (abstr.).

Pepper, B. and G.W. Barber. 1940. Dichloroethyl ether in mineral oil for corn earworm control in sweet corn. J. Econ. Entomol. 33(3):584–585.

Siedlecki, E., B. Schultz, D. Gorlin, and R.V. Hazzard. 1996. Managing *Helicoperpa zea* in sweet corn: Organic and IPM as alternatives to conventional tactics. Div. III thesis. Hampshire College, Amherst, Mass.