Agricultural Innovations
Practical applications for sustainable agriculture
Fact Sheet
Sustainable Agriculture Research & Education

Organic Insect Management in Sweet Corn

Scouting, thresholds and management methods for key caterpillar pests

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Inside this fact sheet:

SARE Agricultural Innovations are based on knowledge gained from SARE-funded projects. Written for farmers and agricultural educators, these peer reviewed fact sheets provide practical, hands-on information to integrate well-researched sustainable strategies into farming and ranching systems. The articles are written by project coordinators and published by SARE.

Geographic Range:

Northeastern U.S. The methods presented in this fact sheet were developed in the Northeastern U.S.; however, they can be used anywhere in North America where these pests are a problem. The mix of caterpillar pests and the timing of their infestation in corn depend upon geographic location, requiring the use of localized IPM scouting for each pest. This method has not been extensively tested in southern regions where corn earworm over-winters and pressure may be greater than in the Northeast.

Introduction

When customers flock to markets in search of sweet corn, they want it to be of the highest quality -- sweet, fresh and worm-free. Yet, in ecological or organic production of sweet corn, achieving worm-free corn is one of the most difficult challenges. In the Northeast, three major caterpillar pests -- corn earworm, European corn borer, and fall armyworm -- invade ears and cause ugly feeding damage. Without effective controls, it is impossible to produce high quality corn throughout the season.

This fact sheet discusses an integrated strategy for controlling these three caterpillar species using methods that meet current organic certification standards. Any grower interested in methods that are safe for the applicator and the environment may be interested in this approach. The components of this strategy are 1) monitoring to determine pest pressure and need for treatment and, if necessary, 2) a direct treatment of each ear with a microbial or botanical insecticide carried in vegetable oil to control corn earworm, 3) *Trichogramma* releases and/or foliar applications of *Bacillus thuringiensis* (*Bt*) or spinosad to control European corn borer and/or 4) foliar applications of *Bt* or spinosad for fall armyworm control.

Corn Earworm *(Helicoverpa zea)*

The corn earworm is a widespread pest, which is also known as tomato fruitworm, and cotton bollworm. In southern areas of the U.S., corn earworm over-winters and infests sweet corn throughout the season. Corn earworm moths reach northern states through annual migrations, invading late-season corn from mid-July through September. In New England, large numbers of moths can arrive suddenly on storm fronts that move up the coastline and river valleys. The heaviest numbers are found in coastal areas, but corn earworm can be a devastating pest in late-season corn anywhere in the Northeast.

Photo A. Caterpillar pests in sweet corn: corn earworm

Photo B. *Heliothis* net trap with corn earworm (CEW) lure in silking sweet corn for monitoring arrival and population of CEW. Note that the base of the trap, where the lure hangs, is at the level of the corn silks. Because of the very heavy moth pressure at this site (>50 moths per week), counting was made easier by covering top with plastic bag and inserting a vapor strip.

Adult moths have light tan scales and are about 1 ¼ inches in length. Distinctive features are a dark spot on the forewing, a dark band near the margin of the hind wing and, in live moths, bright green eyes. Female moths lay single cream-colored, globe-shaped eggs on the silk as well as other parts of the plant. They are attracted to the odor of corn silk; dried silks are less attractive than fresh silk as egg-laying sites. They lay an average of five eggs per day over their seven- to14-day life span. Eggs hatch in three to seven days, depending on temperature, and newly hatched larvae move directly down the silk and into the ears to feed at the tip of the ear. Unlike European corn borer and fall armyworm, earworm larvae do not tunnel through the husk to reach the ear. Corn earworm caterpillars reach 1 ½ to 2 inches when full grown and have small bumps and hairs that give the body a rough texture. They can be brown, tan, green, or pink, with light and dark longitudinal stripes (photo A). Their head capsule is always golden brown.

Monitoring and thresholds

Trapping moths is a critical IPM tool for monitoring corn earworm flight activity. Either blacklight or pheromone traps baited with corn earworm lures can be used. Blacklight traps can be placed near corn fields, but not necessarily in them, and give a reasonable estimate of populations up to one mile away from fields. Traps should be checked daily, and capture of any corn earworm moths should trigger treatment [1]. The pheromone trap should be placed in freshly silking corn with the lure at ear height (photo B). Lures are suspended in an opening at the base of the trap and replaced every two weeks. Two traps per field, at least 50 feet apart, are recommended. When the silk dries, move the traps to a new block of corn in fresh silk. Count the moths captured in each trap twice weekly. Trap captures totaling two moths per week per trap indicate that a damaging population of corn earworm is present. Damage will increase as trap captures rise [1, 9].

Monitoring on your own farm provides the most accurate and timely information on corn earworm flights; however, regional data also can be used. Cooperative Extension systems in many states maintain *Helicoverpa zea* trapping networks and report captures regularly throughout the season. Contact your county or state Extension system to determine what information is available in your area.

Control: foliar spray applications

Foliar sprays of *Bacillus thuringiensis* (*Bt*) will not control corn earworm. Recent research suggests that spinosad, which became available in an organic formulation (Entrust™) in 2003, can suppress corn earworm if used on a three- to four-day spray schedule, as in the same manner that broad-spectrum insecticides are used in conventional production. Further work is needed to evaluate the effec-

Photo C. Zea-later oil applicator being used to apply oil/*Bt* treatment to corn silk.

tiveness of this material under a range of corn earworm pressures and spray intervals. Growers who would like to use this method should refer to existing publications on sprayer design and spray coverage for effective control of corn earworm [1, 9].

Control: direct silk applications

An effective way to control corn earworm infestation in corn ears, which is especially suited for small to medium growers, is to apply a small amount of organically approved insecticide in oil directly to the silks of developing corn ears. A mixture of insecticide in oil applied directly to the silks at the neck of the ear penetrates the silk channel and acts as a barrier and a toxin. Caterpillars that eat the insecticide or contact the oil-coated silks die before they cause damage inside the ear. A similar technique, using mineral oil mixed with various toxins, was widely used by sweet corn growers in the 1940s before the development of synthetic insecticides. Research conducted from 1992-2002 at the University of Massachusetts, Hampshire College, and on farms throughout New England has re-examined and improved this technique. Evaluation of other toxins, such as spinosad and neem, as well as other carriers has followed, and suggests that other materials used in the same way may be as effective. The following recommendations are based on this work.

Application method

This method involves walking through the stand of corn and treating the top ear of each plant. Only one application per ear is recommended. Treat each block when most ears are close to the ideal stage. It is cost-effective to treat only one ear per stalk. If silk emergence is very uneven throughout the field, it may be necessary to go through the stand a second time to treat late-emerging silks and achieve optimal control without tip fill problems. Apply 0.5 ml per ear (equivalent to five drops from an eyedropper) directly to the silk at the tip of the ear so that it will coat the silk channel. Higher quantities do not appear to give better control and may cause slightly oily ears at harvest.

Tools: A hand-held applicator is needed to deliver oil to each ear. Oil sprays are phytotoxic and result in sticky brown husks. There is no way to avoid taking time to apply the oil to each ear. Eye droppers and converted oil cans can be made to work, but for commercial corn acreage durability, consistency, and ease of use are critical. The Zea-later™ (photo C), a hand-held applicator designed at the University of Massachusetts and Hampshire College expressly for this purpose, is being distributed by Johnny's Selected Seeds (207-861-3902). This device is durable, comfortable to hold and use, and delivers 0.5 ml of oil with each squeeze of the trigger. Tubing connects the device with a two liter bottle for the oil that can be strapped around your waist.

Cost: The cost of this method including labor and materials is approximately $100 to $120 per acre. To treat one acre requires about eight to ten hours of labor. Typical materials include about 0.5 lb dry *Bt* product, two gallons of corn or soy oil, and 1.6 cups of lecithin per acre. The price may change if other materials are used.

Timing of application: Proper timing of the oil application is one of the most important factors in the successful use of this method. The best time to apply oil is when the tips of the silks have begun to wilt and turn brown, and pollination is nearly complete (Photo C). In western Massachusetts this generally happens five to seven days after silk growth starts- three to four days after the silk is fully grown, and about 14 to 21 days before harvest. Although caterpillars that are already in the ear may be killed by the Bt/oil application, the best control is achieved when it is present prior to larval entry. The Bt/oil barrier persists after application and continues to kill newly entering larvae [2].

Within a field, plants grow at different rates and begin silking at different times. In a relatively even stand, silk emergence is concentrated in a three- to four-day period. To determine the best time for oil applications, note the day on which 50% of the corn has begun to show silk, and count from that date.

Photo D. Sample of corn ears at harvest. Ear on right has cone-tip from oil application. The other two were not treated with oil; the tip fill of the center ear is incomplete, a condition that occurs in some varieties or under certain environmental conditions. Oil application does not always result in cone-tip.

Applications made *earlier* than five days after silk do not appear to give better control and may result in a higher rate of "cone" tips (photo D). Cone tip develops when oil interferes with pollination of the silks that are attached to the tip of the ear, which are the last silks to develop. This results in unfilled kernels in the last half-inch of the tip. While partially-filled tips are a relatively common occurrence in sweet corn, the lack of kernel growth caused by oil is more pronounced.

Oil applied *later* than eight to nine days after silk initiation can result in more feeding damage to the kernels caused by caterpillars that entered the ear prior to the application. There is a window between five and eight days after silk initiation that provides the best combination of corn earworm control and ear fill [3, 11].

This provides some flexibility in treating blocks of corn as they become ready. Since the development of corn varies greatly depending upon the temperature, one way to determine if the corn is ready to be treated is to carefully open some representative ears from the field. If the silks are all still attached to the kernels (photo E-1) then the corn is too young. The silks will be detached from the developing kernels if pollination of the kernel has taken place. If the silks are mostly detached, and connected only at the top 0.5" to 1.0" of the tip, then the ear is ready to be treated (photo E-2).

Materials

Regulatory issues: Any material applied to your commercial sweet corn for caterpillar control must conform to two separate federal laws; three if you are organically certified.

1) The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) regulates pesticides: all materials applied as a insecticide must be registered by EPA and have a pesticide label that includes sweet corn, or it must be exempt from labeling (FIFRA, Section 25b). **Note: each state has its own labeling regulations, which may be more restrictive than FIFRA; some states do not allow the exemptions.** Contact your state agency in charge of pesticides for instructions on the legal use of FIFRA exempt materials in your state (see National Pesticide Information Center website for a list of state agencies in charge of pesticides).

2) The Federal Food, Drugs and Cosmetics Act (FFDCA), regulates all materials applied to food crops; accordingly, the material applied to the corn ear must have a residue tolerance or have a tolerance exemption (section 408).

3) A third federal law applies to organic farmers: the National Organic Rule. This law requires that materials used be allowed by the National Organic Program or the Organic Materials Review Institute (OMRI).

The materials discussed below satisfy all of these criteria.

Insecticides: *Bacillus thuringiensis subsp.* Kurstaki. Corn earworm larvae feed on silks as they move down the silk channel, then feed on the tip of the ear. Early in ear devel-

Photo E. De-husked corn ears during early silk. 1) Kernels have not been fertilized, ear is too young for oil treatment. 2) Only kernels at tip have not been fertilized. Oil should be applied at this stage.

opment the silk channel is several inches long (at harvest it ranges from 0.1 to 2 inches). Oil carries Bt down the silk channel where larvae ingest a toxic dose, cease feeding, and die before reaching the ear. Bt mixed with oil is more effective than Bt in water [4].Use a microbial Bt product that is registered and labeled for use in sweet corn, and use the lowest labeled rate for corn earworm or European corn borer. In trials using Dipel DFTM it was found that using a concentration of Bt that delivers Bt at the lowest labeled rate of 0.5 lb/acre produced better control than lower rates and as good control as higher rates [5]. This translates to approximately 3 tablespoons per liter of oil, for a plant population of 16,000/acre.

If you are farming in accordance with organic certification standards, check with your certifier, the National Organic Program or the Organic Materials Review Institute to be sure that the Bt product you want to use is allowed. As of January 2005 there were no organically certified liquid Bt suspensions. For dry formulations the Bt must be dissolved in water first, and then added to the oil. To achieve a stable suspension of dissolved Bt in the oil an emulsifier can be added to the oil (see Emulsifiers, below). Because of the safety and regulatory status of Bt products and the long interval before harvest, use of Bt products in this manner is in accordance with pesticide and food safety regulations.

Neem. Neem products also can be used as the insecticide in this method. The University of Massachusetts Amherst has conducted a trial using one product (Aza-directTM), at three concentrations of neem in oil: 1:1, 1:10 and 1:20, neem:oil (volume to volume ratio). All concentrations resulted in reduced ear damage compared to oil alone and there was no significant difference between concentrations [5]. Be sure that the label of the product indicates it is appropriate for use on sweet corn.

Spinosad. Recent trials have shown that spinosad works well as an insecticide in the direct silk method. Entrust™, the organic formulation of spinosad, is currently labeled for use in sweet corn and can be legally applied to corn silks using this method. Use a rate in the range recommended on the label (1-2 oz/acre; 1 oz = 6.3 Tablespoons). Since Entrust™ is a dry formulation, suspension in oil is best achieved when used with an emulsifier (see Emulsifiers, below).

Other. Other insecticides may be appropriate and effective; however, we have not tested their effectiveness nor determined the legality of applying them directly to the corn ears in this manner. If you want to try other materials, review the label and check with the manufacturer, the EPA or your state agency responsible for pesticide regulations (see Regulatory Issues, above).

Oils:

Corn and soybean oils. Vegetable oil alone reduces the amount of caterpillar feeding damage in the tips of corn ears; however, it is most effective when used as a carrier for *Bt* [4]. The oil coats the silk channel and reaches the ear tip, increasing the effectiveness of the *Bt*. Water is not a good carrier because it beads up on the silk and does not fill the space within the channel. Both corn and soybean oils conform to all of the regulations listed above. It requires about 2.1 gallons of oil to treat one acre, applied at 0.5 ml per ear of corn (estimating 16,000 ears/acre). Corn or soy oil may be available in certain formulations as a registered pesticide (see emulsifier/oil combos, below), or may be purchased in food grade form from grocery stores. Before using corn or soy oil check with your state agency in charge of pesticides to determine any legal restrictions on its use in your state.

Petroleum-based oils. Highly refined petroleum oils, also known as narrow range mineral oils, have been shown to be effective as an oil carrier, but they have not been tested as extensively because their organic status has been inconsistent over the years. These oils must meet the regulatory requirements described at the beginning of this section.

Emulsifiers: If you are using a dry insecticide formulation it is recommended that you use an emulsifier to insure a stable suspension in the oil.

Lecithin. Add 5% volume of liquid lecithin to the oil before adding the dry material mixed in water (e.g. add 5 ml lecithin to 95 ml oil). Liquid lecithin is the consistency of molasses; we strongly recommend that you add it directly to the oil instead of measuring into a separate container first. Lecithin will mix readily with oil but will not mix directly with water, making cleanup difficult.

Liquid Bt's with emulsifiers. If you are NOT certified organic you may be able to use a liquid *Bt* product and avoid the need for an added emulsifier. Liquid *Bt* products allowed for organic production may become available in the future. Check with OMRI for updates.

Oil/Emulsifier combinations: Although more expensive than buying them separately, some organic crop oils come with an emulsifier already mixed into them, and are labeled for caterpillar control in corn. These can be either vegetable based or narrow range mineral oils. If you are organically certified use a product that has been reviewed by OMRI and is allowed in organic production (www.omri.org). Before applying any of these products, make sure that the product is labeled for use on corn and is registered in your state.

Photo F. Caterpillar pests in sweet corn: european corn borer.

Carrageenan as an alternative carrier: The need for an emulsifier can be avoided with the use of carrageenan instead of oil. Carrageenan, derived from seaweed and exempt from FIFRA and food tolerance, can be used as an alternative carrier. Since it is water based, dry formulations of insecticides will mix readily, eliminating the need for an emulsifier; however, because of the water base it does not penetrate the silk channel like oil and must be injected well into the silk channel. Also, on its own carrageenan has little effectiveness against corn earworm, acting primarily as a carrier of the toxins. Further work is needed to evaluate carrageenan as part of this method, but it does appear to reduce or eliminate the cone-tip affect.

Other factors

Sweet corn cultivars: Good husk coverage at the tip of the ear enhances the effectiveness of this technique. This is especially important where corn earworm pressure is extremely high. Look for cultivars that suit your climate and your market and also have a tight husk with a long extension above the ear throughout maturity. A tight husk protects the ears by holding the oil in a narrow channel, forcing caterpillars to encounter the oil and *Bt* to reach the ear. Another trait that contributes to success with the oil method is consistent plant development and ear maturity.

Available sweet corn varieties change rapidly. Variety trials conducted in Maine in 1999, 2000 and 2001 [6] and in Maryland in 2003 [7] have identified some varieties that have good husk coverage. Of the varieties tested in Maine, Sweet Chorus, Sweet Symphony, Wizard (variable maturity), Bon Appetite, Delectable, Providence, Serendipity, Twilight, and War Dance (all se), and Jumpstart and SS#6082 BC (sh2) all had good tip coverage. Of those tested in Maryland, Temptation, Argent, and Frosty (se) and Punchline (sh2) had good tip coverage and a tight husk.

Weed control: Since this method involves walking through a corn field and treating every corn ear, it is important that you have good weed control in your corn field. Tall weeds at the time of application interfere with access to each ear, thereby reducing the effectiveness of the control method.

Weather: One advantage of this method is that oil can be applied in windy or even wet weather. If it rains after the oil application, it is *not* necessary to re-apply the oil. We have found that the oil method works best in healthy, well-nourished, actively growing, sweet corn . Long periods of cold, wet weather or periods of drought that cause plant and eargrowth to slow sometimes result in poor control or may increase the cone tip effect.

European Corn Borer *(Ostrinia nubilalis)*

European corn borer is an introduced pest that has spread across much of eastern and central North America. The number of generations of European corn borer ranges from one per year in the extreme north to four per year in the Southeastern U.S. Most of the range within the U.S. has two generations per year; sometimes these co-exist with a strain that has one generation per year. There are two strains of European corn borer: the Iowa (E) and New York (Z) strain, which are present in different ratios in different regions.

In northern areas, larvae over-winter in stalks of corn and other host plants, and pupate in the spring. In New England, adult moths emerge in late May or early June and mate in weedy or grassy areas. Fields that have been in field corn, sweet corn, or peppers for a long time will have higher pressure from European corn borer than other fields.

About one week after flight begins, females start to lay flat, white egg masses on the underside of leaves in early corn. Eggs hatch in about one week, depending on temperature. Larvae feed in the whorl and in the succulent emerging tassel. As the tassel opens up, these larvae move downward, bore into the stalk and tunnel into ears through the side, base or tip. When moths are active during silking, they lay eggs on leaves near the ear and the larvae move directly into the ear after hatching. These larvae may tunnel through the husk or move directly down the silk channel at the tip of the ear.

The moths are about ¾" long and light tan or brown in color with yellow bands, and the male has darker coloring than the female. Larvae are either light colored or brown, with dark spots on each segment. The head capsule is dark brown and flattened in shape. Full-grown larvae are ¾" to 1" long and move fast when disturbed (photo F).

Monitoring and thresholds

Monitoring networks for European corn borer are maintained by Extension systems in many states and can be used to determine when flight begins in your region for each generation. European corn borer flight also can be monitored on-farm using blacklight or pheromone net traps. Consult your state Extension program to determine what type of traps are recommended in your area. Trap captures will tell you exactly when flight begins, when it peaks, and how high the population is [1, 9].

If you are using pheromone traps, consult your state Extension program to determine whether one or both E and Z strains are present. If both strains are present, use two traps: one baited with an E(II) lure, the other with Z(I), placed at least 50 feet apart in weedy borders of corn fields. Make sure the bottom of the trap stays close to the top of the weeds [1, 9].

Once flight is detected, blocks of sweet corn with newly emerging tassels should be scouted weekly by inspecting the tassels of 50 to 100 plants, in groups of 10, for the presence of European corn borer larvae and fresh feeding damage. This can be done in whorl stage corn by pulling the developing tassel out of the plant and inspecting it for frass and small larvae. Corn with emerged green tassels corn can be inspected for damage without removing the tassel. If more than 15% of the plants have one or more larvae present, then a spray should be applied because ear damage will be greater than 5% at harvest if European corn borer is not controlled.

Control

European corn borer can be controlled through releases of parasitic wasps that attack the egg stage, or with foliar sprays of *Bt* or spinosad that target larvae. During silking, oil applied to the silks for corn earworm control also will control European corn borer larvae that enter the ear through the silk channel, but may not give complete control of those entering from the side.

Trichogramma releases

Trichogramma are small parasitic wasps that lay their eggs in the egg masses of host insects. *Trichogramma* larvae feed and pupate inside the egg, killing the egg and preventing hatch. *Trichogramma ostriniae* lays its eggs in European corn borer egg masses, and is the species that has shown the highest level of European corn borer control in field trials, reducing larval infestations enough to avoid the need for sprays. A closely related species, *Trichogramma brassicae,* is commercially available and also will suppress European corn borer.

Since *Trichogramma* control European corn borer by parasitizing egg masses, they should be released just as the moths start to lay eggs, when the corn is in the four- to six-leaf stage. Knowing when European corn borer flight begins, reaches a peak, and ends in a given field is key to the proper timing of *Trichogramma* releases. You can use regional information about flight activity from your state or county Extension program and target your releases to that; however, to coordinate timing on your farm you should monitor flight activity in your own fields.

Release rates and number of release locations within the field vary depending upon the species. Consult a supplier of beneficial organisms for more details; orders should be placed in advance of the growing season. We recommend releasing the species *Trichogramma ostriniae*, which is available through IPM Laboratories (www.ipmlabs.com; 315-497-2063).

Foliar sprays: European corn borers can be adequately controlled with one to three sprays per block of corn. If, when you scout, you find that 15% (or more) of the ears have live larvae or fresh feeding damage, spray once with *Bt* or spinosad. The ideal time is just before or during tassel emergence but before silking and before larvae move into the ear or stalk. Use a spreader-sticker for better control. Scout again in five to seven days, looking for live larvae, and use a second spray if the infestation is still over 15%. Shorter spray intervals should not be necessary, but

be sure to scout again within a week after the first spray. With *Bt* use at least two-thirds the maximum label rate as low rates can result in lower levels of control.

If European corn borer moths are active (e.g., pheromone trap captures >7 per week) and laying eggs during the period when ears are forming, an additional spray during silking can help reduce the number of small borers that move directly into the ear after hatching. If possible, this spray should be applied at ear height.

Photo G. Caterpillar pests in sweet corn: fall armyworm.

Sprayer design and needs depend on how much sweet corn acreage you grow and how important spraying is in your operation. For growers with small acreage, it may be practical to use a backpack mist blower, walk through the corn and cover two or three rows in each direction with a concentrated solution. Tractor-mounted boom sprayers that can be lifted as corn grows are well suited for moderate to large acreage and should be configured for over-the-top coverage of the tassel as well as coverage of the foliage and ear zones. Drop nozzles are recommended.[9] *Bt* and spinosad products can be used whenever European corn borer or fall armyworm are the target pests, regardless of the time of season or stage of crop growth.

Fall Armyworm *(Spodoptera frugiperda)*

Like corn earworm, the fall armyworm is a summer migrant to the colder regions, over-wintering in Florida and other southern states. Fall armyworm moths, which are about ¾"to 1" long with clear hindwings and mottled brown forewings, migrate into New England and other northern areas in mid to late summer. The females lay scale-covered eggs on many types of plants, with a preference for whorl-stage corn. Eggs hatch in two to 10 days and larvae feed deep in the whorl as well as in tassels and ears. Like European corn borer they eat through the side of the corn ear; however, unlike European corn borer, fall armyworm leave behind a large, messy opening. Larvae are smooth, brown or dark green with lengthwise stripes, and the head capsule is dark with a distinctive light-colored marking in the form of an inverted Y. Full-grown larvae reach 1 ½ inches. (photo G).

Monitoring and thresholds

Watch whorl-stage corn for signs of ragged feeding damage and scout for larvae in the whorl and the emerging tassel. Feeding damage from fall armyworm is more obviously destructive than that of European corn borer; however, if you find only feeding damage and no larvae, it is likely that the infestation is over and larvae have pupated. The scouting method and threshold for fall armyworm are the same as for European corn borer: if 15% of plants are infested with either larvae, controls are needed.

Control

Foliar sprays are the only effective means of control for fall armyworm at this time. *Bt* products that contain *Bt aizawi* or *Bt kurstaki* and have fall armyworm listed on the label may be used. Spinosad is also a good alternative. Spray to control fall armyworm during whorl stage if they are above threshold. For tassel stage, see thresholds and methods described for European corn borer, above.

Table 1. Recommended treatments for each caterpillar pest.

Pest	Oil Treatment	Foliar Spray	Trichogramma release
Corn earworm(CEW)	X	X**	
European corn borer (ECB)	X*	X	X
Fall armyworm (FAW)		X	

*Oil reduces damage that results from any caterpillars that enter through the ear tip, including ECB; other methods are needed to achieve integrated control of ECB.
**Spinosad only; not Bt; suppresses CEW only if used in intensive spray program.

Putting it all Together

Depending upon location and the time of the season, it is possible to have one, two or three of the key caterpillar pests in a single planting of sweet corn. European corn borer and fall armyworm may be feeding at the whorl or tassel stage and can move into ears during silking. Some enter ears through the tips and some through the side. Corn earworm enters only through the tip, and only during silking. An integrated strategy is needed to address each pest, at the appropriate growth stage of the corn.

The following approach has provided effective control of all of these pests in experimental trials in Massachusetts (see table 1):

Whorl stage: Scout for fall armyworm. If infestation is greater than 15%, spray with *Bt* or spinosad. If using *Trichogramma,* start releases at this stage.

Pretassel/tassel stage: Scout for European corn borer and fall armyworm. If infestation is greater than 15%, make a foliar application of *Bt* or spinosad; scout and make a second application, if needed, five to seven days later.

Early silk stage: If corn earworm moths are present, use the oil method to control all caterpillars that enter through the tip. If European corn borer flight is high during silking, apply *Bt* or spinosad.

Conservation of Natural Enemies

Sweet corn is a favored habitat for beneficial insects that feed on caterpillar eggs and small larvae, corn leaf aphids, and sweet corn pollen and help suppress pest populations. These natural enemies include ladybeetles, insidious flower bugs, lacewing larvae, parasitic wasps, and indigenous *Trichogramma* species. The methods described here conserve these natural enemies. Studies conducted to evaluate the effects of *Bt* and spinosad on a range of beneficial insects and non-target organisms have shown that both have low toxicity, although spinosad shows somewhat more negative effects than *Bt* [10].

SARE Research Synopsis

With funding from SARE and from the Organic Farming Research Foundation (Santa Cruz, CA) the organic caterpillar control methods outlined in this article were tested on eight commercial vegetable farms throughout New England from 1999 to 2001. During the project, grower

Table 2. Data for each of the participating farms.

Farm	Location	Total Veg. Acres	Acres of Sweet-Corn	Markets	3 Years; Average Flight / Night		% Clean Ears All 3 Years	
					ECB	**CEW**	**No Oil**	**Oil Treated**
1	Maine	36	2	Wholesale	1.6	4.9	67.1	82.7
2	Rhode Island	16	2.5	Wholesale Farmstand CSA	4.7	11.7	9.1	38.8
3	Southern VT CT River Valley	50	12	Wholesale Farmstand	12.3	1.0	65.8	76.7
4	Southern VT CT River Valley	30	10	Farmstand	4.7	1.3	77.8	92.2
5	Western MA CT River Valley	18	4	CSA	2.7	2.3	63.0	87.0
6	Central MA	30	6	Farmstand	4.4	9.0	50.1	73.4
7	Western MA CT River Valley	38	4.5	Wholesale	5.7	0.4	60.2	84.9
8	Central CT CT River Valley	22	1	Farmstand Farmer's Markets	1.4	1.2	22.5	47.5

The average nightly moth captures, during the corn's susceptible period, over the 3 year project for European corn borer (ECB) and corn earworm (CEW) are included, as well as the average percent of corn ears that had no caterpillar damage in the oil treated and control corn plantings.

interest and input guided the development of the Zea-later™ applicator device and further studies on the timing and longevity of the oil treatments. Of the eight farms that participated in the project, six continue to grow sweet corn; all of these farms have continued to use the control methods outlined above.

For three growing seasons (1999-2001), three blocks of corn per year were planted on each farm to test the effectiveness of the *Bt* foliar sprays for European corn borer (ECB) and fall armyworm (FAW), combined with oil treatments to the silks for corn earworm control (CEW). All of the ears in one half of each planting were oiled for CEW control while the other half was not, regardless of the pest pressure. When foliar applications were applied, all corn in the planting was treated. All corn plantings were scouted for ECB and FAW damage and traps were monitored for ECB, FAW and CEW pressure. At harvest, 100 oiled corn ears and 100 non-oiled ears were scored for damage and caterpillars. Any caterpillar damage to the kernels, however slight, rendered the ear non-marketable for the purposes of this study.

All farms showed significant improvement in the quality of the ears between the oiled and the non-oiled ears of corn. Four out of the eight farms were able to achieve a three-year average of over 80% clean ears with the oil method (table 2), with improvements each year of the project (figure 1). A significant portion of damage on some of the farms was due to poor control of the ECB pest with the foliar spray due to poor timing, too few sprays, or lack of spray when called for [11]. Other farms, such as Farm # 2, struggled with very high CEW pressure and poor weed control (table 2). See the full report for more detailed results and individual farm profiles.

The timing of the oil/*Bt* application can be critical to the success of this method and the development of the corn ears. In one timing experiment conducted over two growing seasons, different plots received one oil application on day 3 to 11 after 50% of the field showed first silk. The percent cone tip at harvest decreased linearly with the day of treatment application in both years. The best combination of effective insect control resulting in the highest rates of marketable ears with the least degree of cone tip was achieved by application on days 5 to 7 after 50% of the field showed silk. This window is likely to vary by a day or two depending upon the temperature.
In another timing experiment, we examined the effectiveness of the oil treatment relative to when the CEW larvae

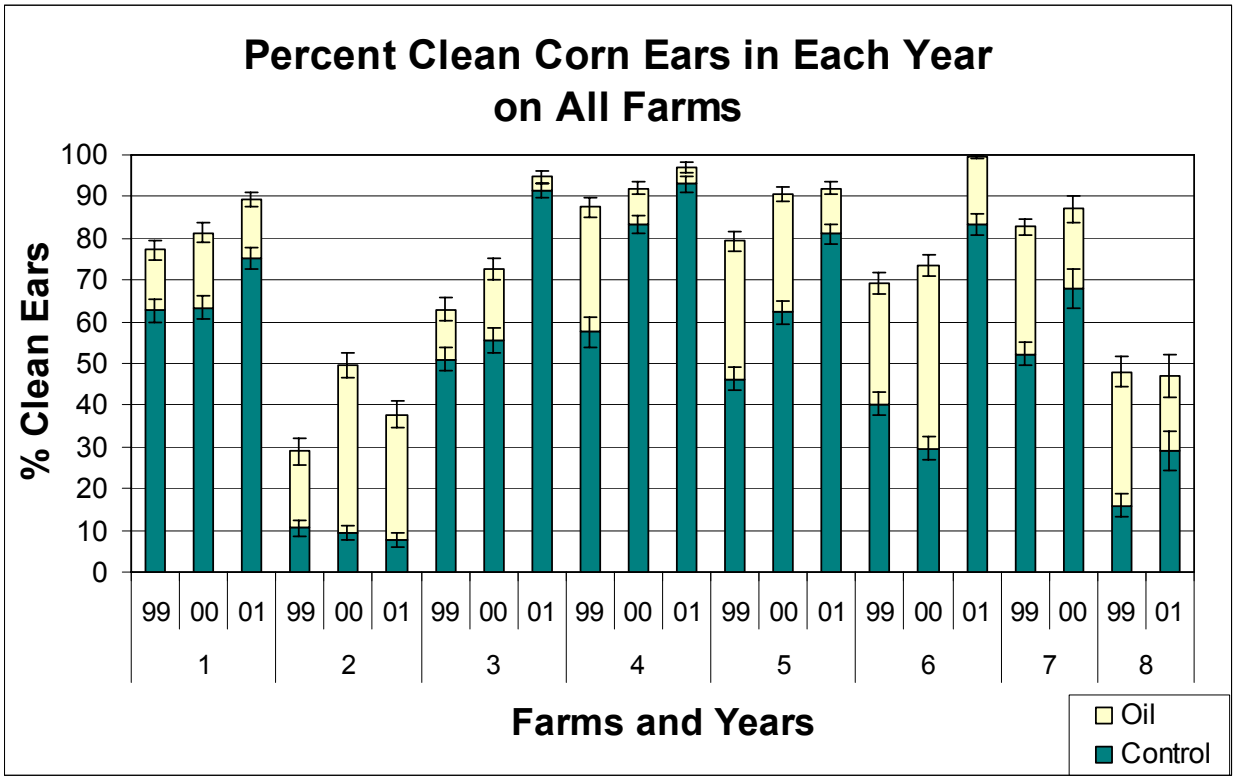

Figure 1. Average percent of harvested ears that were clean (no damage to kernels) on each farm in each year of the project in control (green) and oiled (yellow) ears.

entered the silk channel. In two seasons, oil, *Bt* or oil+*Bt* was applied on day 5 after 50% silk. Newly hatched CEW larvae were then applied to those oiled ears and to non-oiled ears on day 3, 6, 9, 12, 15, or 18. Ears were picked and examined four days after each larvae application. Both oil and *Bt*-treated ears had fewer larvae and less feeding damage than the non-treated ears. Oil and *Bt*, alone or together, provided protection to the ears up through the end of the experiment at 22 days after 50% silk. When the larvae were applied to the silk two days before the oil treatment, damage was not significantly less in treated ears compared to untreated ears.

This fact sheet is based on a SARE-funded project.
For more information, please visit www.sare.org > Project Reports > Search the Database for project # LNE99-118

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