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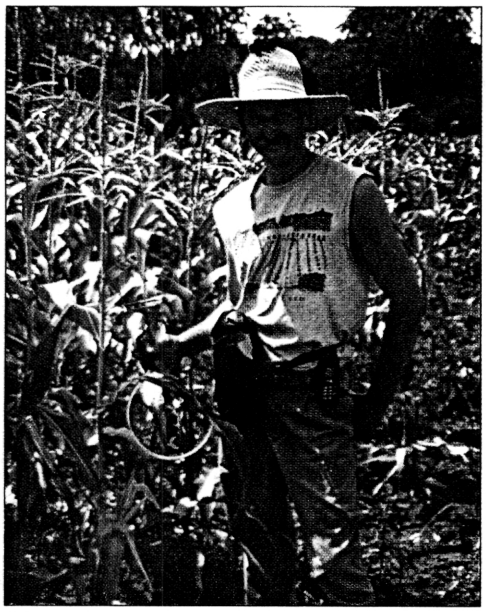

Figure 3

Caterpillar control in organic sweet corn

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Every sweet corn grower knows the frustration of opening ears of succulent corn, ready to harvest, and finding them loaded with well-fed caterpillars and their nasty mess. "The fat ones that wave at you when you open the ear," one grower calls them–and they drive customers away in a hurry. Most often, these are corn earworms, which enter the ear though the silk channel and feed in the tip (Figure 1). This pest has been the major obstacle to production of organic sweet corn throughout the US. Conventional control of this pest relies on repeated applications of synthetic insecticides, which are prohibited in organic standards. A method that uses small quantities of vegetable oil mixed with *Bacillus thuringiensis*, applied directly to the silks to create a barrier inside the silk channel, gives organic growers a means to control this corn pest throughout the season. The Zea-Later oil applicator, now commercially available, makes this method physically and economically feasible.

Larval behavior on corn ears. Corn earworm (*Helicoverpa zea*) moths lay their single, globe-shaped white eggs on the silks, preferring fresh silk over dried silk. Newly hatched caterpillars move rapidly into the silk channel, which is enclosed by the top of the husk. They feed very little on the exposed silk, which explains why sprays of *Bacillus thuringiensis* (Bt) are not highly effective against this pest. Once inside the husk, larvae feed on silks and kernels, well protected from predators and pesticides.

Two other species of caterpillars also infest corn ears. European corn borer (*Ostrinia nubilalis*) may move into ears from previous feeding sites up in the tassel, or from egg masses laid on the underside of leaves near the ear. Some will tunnel through the husk and feed on the side of the ear. Others crawl down the silk channel, similar to corn earworm. Likewise, fall armyworm (*Spodoptora frugiperda*) may tunnel through the side of the husk, or may move down the silk channel. Depending on the geographic location and the time of the season, corn may be infested with one, two or all three of these kinds of larvae.

Direct silk applications of oil. Vegetable oil that is applied directly to the tip of each ear coats all the silks down inside the silk channel, and kills larvae as they enter. This technique was widely used by sweet corn growers in the 1940's, before the development of synthetic insecticides. Since 1992, when a group of sweet corn growers brought this to our attention, UMass researchers have been exploring how to make this method economical and effective. We have worked closely with farmers and with students and faculty from the UMass School of Engineering and Hampshire College to develop a hand-held oil applicator, and to improve on previous techniques. The following recommendations are based on this work.

Selecting the proper oil. It is important to use a vegetable oil, which is exempt from both federal pesticide labeling, and residue tolerance requirement, or to use an oil-based product, which has a pesticide label for sweet corn. Corn oil and soybean oil can be legally used for this purpose, because they are exempt. Corn oil has been used in most of our trials, and is being used by many growers. Currently, soy and corn oils also meet most organic standards. Vegetable oil products with a pesticide label and organic certification include Golden Natural Spray Oil (Stoller Enterprises, Inc), which is soybean oil with an emulsifier. If you wish further clarification of any product's regulatory status, contact your state pesticide board or regional EPA office.

Mixing a Bt product with the oil improves control. In trials we see about 15% more clean, marketable ears when a *Bacillus thuringiensis* subspecies *kurstaki* product is mixed with the oil, compared to oil used alone. Bt products labeled for sweet corn come in liquid or dry formulations; in either case, it is important to achieve a stable, fine suspension of the Bt crystals in the oil. For dry products, this requires an emulsifier in the oil. Most liquid products will form a suspension, but should be tested to be sure. Regular agitation may be needed. Follow mixing instructions provided with the Zea-Later.

Timing. In the field, corn silks grow to their full length in about 2 days. The best time to apply oil is 4-6 days after silk growth starts or 2-4 days after the silk is full-grown. At this time, most of the pollination has taken place, and the exposed silks are wilting and beginning to turn brown (Figure 2). Earlier applications do not appear to give better control, but result in a higher rate of "cone" tips–poor kernel fill in the last one-half inch. This occurs when oil interferes with pollination of the silks produced by the tip, which are the last to grow out and be pollinated. Oil applied later than 6 days after silk initiation can result in poorer control. This is especially true when corn earworm pressure or temperatures are high and larvae have entered ears before oiling. One application to each block of corn is adequate.

The Zea-Later oil applicator. The Zea-Later consists of a hand-held applicator, which is connected by a clear plastic tube to a 2-liter waist-belt tank (Figure 3). The applicator has a shell of strong molded plastic, with an internal pumping mechanism of stainless steel and plastic components which have been selected for durability, repeated use, and tolerance to corn oil (surprisingly enough, corn oil corrodes many types of plastic and rubber). The handle is molded to fit easily into the hand,

Figure 1

and the hand stroke, which pulls the "trigger" to release a dose of oil, uses all the fingers together. Growers and workers who use it are surprised at the lack of hand fatigue, even with several hours of use. It delivers a dose of 0.5 ml per with each stroke. The pointed tip is placed on the hollow at the center of the silk ear or pushed slightly into the silk channel, leaving the oil where gravity will pull it all the way into the silk channel. It works best to walk down each row, treating the top ear of each corn plant. One tankful treats about 1/4 acre. Soapy water is used for cleanup.

Know when corn earworm is active in your area. Corn earworm may be active for only part of the season, but its activity may be unpredictable. This is especially true in northern areas, where migratory flights arrive suddenly. Flights can be monitored with the *Scentry Heliothis* net trap, baited with *Hercon™ luretapes* for corn earworm, placed at about ear height in freshly silking corn. Trap captures of two moths per week, or more, indicate damaging numbers. Refer to Extension recommendations for your region for more details. Oil treatments are warranted when potential losses exceed the cost of treatment.

TABLE 1. RESULTS OF SWEET CORN TRIALS AT UMASS RESEARCH FARM, 1996 AND 1997

Treatment	% Clean Ears		# CEW/100 Ears		# ECB/100 Ears	
	1996	1997	1996	1997	1996	1997
Oil on Silks	57% b	89.5% b	1 b	8.0 b	44 b	2.9 b
Oil + Foliar Bt	100 %c	93.3% b	0 b	5.0 b	0 c	1.0 b
No Treatment	24% a	56.6% a	14 a	36.3 a	123 a	22.0 a

Note: Within each column, means followed by the same letters are statistically different (P<0.05, LSD)

TABLE 2. RESULTS OF ON-FARM TRIALS IN NEW ENGLAND, 2000

	% Ears w/o Tip Damage	% Ears w/o Corn Earworm	% Ears w/o CEW, ECB or FAW
Oil Treatment	83% a (range: 59-93%)	85 % a	76 % a
No Oil	59% b	63 % b	47 % b

Note: Within each column, means followed by the same letters are statistically different (P<0.05, Chi Sq.)

Figure 2

Controlling both sides and tip damage. Caterpillars which tunnel through the side of the husk may not encounter oil or Bt. For an integrated organic strategy, use foliar Bt sprays against European corn borer or fall armyworm that are feeding in the tassel, before silking. If ECB moths are active during silking, a second Bt spray is warranted. Use at least 2/3 the high labeled rate, add a sticker, and design your sprayer for good coverage of tassels and silks.

A healthy stand of sweet corn produces the best results. You may find less than satisfactory results if there are tall weeds that get in the way of reaching each ear, if corn is very uneven in plant age (which means some ears are treated too early and some too late), or if plants are undernourished with poor ear growth. Remember that sweet corn needs 100-130 lb./acre of nitrogen, whether from organic or inorganic sources. Grow the healthiest, most weed-free, most even stand of corn that you can. Plant when soils are warm enough for rapid germination. Select a variety with good tip cover, since the oil only works when it is enclosed inside the silk channel.

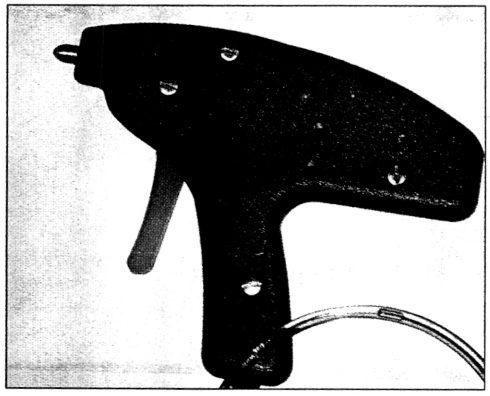
Cost and benefits. At first glance, it hardly seems possible that treating every ear could be cost-effective. In fact, the cost is in the same range as conventional methods. The one-time oil treatment usually takes 8-10 hours per acre and can be done by any employee who is careful and reliable. Labor cost, then, ranges from $60-80/acre. Materials include about 2 gallons of oil (at $6 per gallon) and 1 pint Bt ($5-7) per acre. For a grower with 15 acres of sweet corn or less, each successive block is typically less than an acre, so it can be treated in one day or less. This can be done in windy conditions, on two successive days if necessary, and does not have to be re-applied after a rainstorm. Some growers would prefer to use a crew of two or three because, as with many repetitive jobs on the farm, it is more pleasant to work in a group and get the job done faster. And at harvest, having clean corn keeps customers coming to the stand.

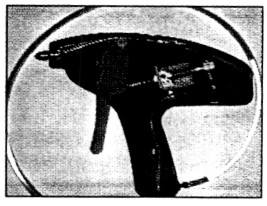
SUMMARY OF RESEARCH RESULTS, ZEA-LATER PROJECT.

We have conducted trials in late-season corn at the UMass Research Farm and on cooperating farms. In 1996 and 1997, we compared using the oil/Bt treatment of silks, by itself, with an integrated system that combined the oil treatment with foliar Bt sprays applied twice during tasseling. Results were measured in terms of the % of ears with no damage or the number of corn earworm (CEW) or European corn borer (ECB) per 100 ears (Table 1). The oil treatment provided control of both CEW and ECB. In 1996 when many ECB were tunneling in the side of the ear, ear quality was greatly improved by the addition of foliar sprays. In 1997 when both ECB and CEW were entering through the tip, foliar sprays made very little difference.

We are currently working with eight growers around New England to test the Zea-later in commercial plantings. Each farm has several plantings, with oiled and non-oiled plots within each planting. The results from summer 2000, pooling data from 15 blocks, showed that the oil improved ear quality by an average of 24%, from 59% of ears without tip damage in the non-oiled to 83% in the oiled (Table 2). The gain in undamaged tips from using the oil ranged from 8-44%, with the best improvement occurring on farms with the highest corn earworm pressure. Some of the farmers used a foliar Bt spray in addition to the oil; it was these blocks that had the best results.

Oil treatments also had an impact on the percent of ears without corn earworm and without caterpillars of any type, supporting earlier data indicating that the treatments have an effect on European corn borer as well as corn earworm. Interestingly, we also saw a slight increase in the number of ears of corn without side damage, from 89% to 93%, suggesting that the oil prevented some damage from larvae tunneling through the husk, as well as those entering through the tip.





ZEA-LATER Oil applicator (above) and inside (at left)

* Patent # 5,964,380