ORGANIC FARMING RESEARCH FOUNDATION

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Project Report Summary

MANAGING INSECT PESTS IN ORGANIC SWEET CORN

Integrated caterpillar control in organic sweet corn

Corn earworm and European corn borer are significant caterpillar pests of sweet corn in the northeast. Corn earworm (CEW) migrates annually into the region, causing serious ear damage during August and September. European corn borer (ECB) is a resident pest that causes damage in its first and second-generation flights, which occur in June and August in most areas of New England.

Organic sweet corn growers have successfully used foliar applications of *Bacillus thuringiensis* (Bt) products for many years to control ECB, however, these are ineffective against CEW larvae, which do little feeding on exposed surfaces before entering the silk channel of the ear. The inability to grow worm-free organic corn can be a barrier to the whole-farm transition to organic, and to expanding the acreage of organically-grown sweet corn. From its inception in 1992, our effort to develop a system for season-long organic insect control has been guided by farmer input and participation.

Over three years we evaluated an integrated strategy of direct silk oil and Bt applications for caterpillar control. This strategy is both old and new. Applying mineral oil directly to silk was widely used by sweet corn growers in the 1930s and 1940s and during this period extensive research on this method was conducted at Cornell University. Studies from 1938-1941 determined that the most effective direct silk application was a dose of 0.5 to 0.75 ml mineral oil combined with pyrethrum, which could protect 75% of sweet corn ears under conditions in which 100% of untreated ears were infested. Prior to our work at the University of Massachusetts, which began in 1992, the last published research on the direct silk oil application method was in 1944.

Zea-later™ applicator being used to apply 0.5 ml of oil/Bt to silking corn.

To facilitate oil application, we collaborated with Hampshire College to develop an easy to use hand-held syringe pump applicator with a lightweight backpack tank, for delivering oil by hand to each silk along the row. The Zea-later™ reduces the labor requirement for the single oil application to 8-10 hours per acre, and is now available through Johnny's Selected Seeds.

Our early experiments focused on the ingredients corn oil and Bt. Together, they provide equal effectiveness to mineral oil, corn oil is exempt from pesticide registration requirements and food residue tolerances, and both substances meet organic certification standards. By the late 1990's the only Bt products approved for organic production were dry formulations designed to dissolve in water. In oil, powdered Bt does not form a suspension and requires continuous agitation; therefore, our later studies included experiments with additional oils and emulsifiers, and in one experiment Bt was substituted with a neem product. Neem is available as a liquid in an oil base, and emulsifiers are not needed.

Oil applications may result in slightly reduced ear length and tip fill, called cone-tip, as a result of oil interfering with kernel pollination. Application timing requires balancing the need for caterpillar control from beginning to end of the silking period—especially when corn earworm pressure is high—with minimal physiological effects to the kernels at the corn ear tip, which can occur when oil is applied too early. Experiments were conducted over three years at farms in different parts of New England. Ten farms participated from Massachusetts, Vermont, Rhode Island, Connecticut and Maine, and trials were also conducted at the University of Massachusetts Crops Research and Education Center in South Deerfield, MA. Our experiments evaluated various aspects of the direct silk oil application method, including the optimum timing of application during the silking period, the dose to apply, the type of oil and the rate of Bt.

Project Notes

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Year 1

Our initial objectives were to conduct on-farm trials of the corn oil/Bt system in sweet corn to control CEW and ECB under a range of pest conditions, and to evaluate costs for labor and materials and the practicality and ease of use of the applicator tool. This work lead to an examination of the residual efficacy and optimum timing of the oil/Bt application for corn earworm control, and evaluation of several different vegetable oils, emulsifiers, Bt rates, and in one trial a neem product was substituted for Bt. Efficacy in controlling earworm caterpillars, feeding damage to corn ears, and their physiological effects on ear development were evaluated.

In the first year of on-farm trials, data were analyzed from twenty-one sweet corn plots planted on eight farms. Plantings were grouped into three harvest blocks. One treatment application was conducted consisting of a corn oil/ Bt powder mixture of 20 parts corn oil to one part concentrated Bt. This was applied at 0.5 ml per ear to ear tips at silking, regardless of corn earworm pressure. All farms were invaded by high levels of second generation ECB, providing a substantial test for the efficacy of the oil direct silk method.

The oil treatment significantly increased the percentage of clean ears in 18 plots. At moderate pest pressures, the desired level of control for commercial crops (>90% clean) was achieved in 5 plots. Control at the 75% level was achieved at five out of six farms in harvest Block 1 and five out of eight farms in Block 2. At all pest pressures, the oil treatment provided a significant improvement in ear quality, averaging 25% more clean ears. Control fell below the 75% level when corn earworm numbers were severe enough to cause >80% damage in untreated corn.

Total ear length was lower in oil-treated ears by a tiny (1/40 decrease in length), but statistically significant amount, averaging 7.8 in. in oiled ears compared to 8.0 in. for non-oiled ears. The average filled length of the ear was also lower, 7.1 in. compared to 7.7 in for untreated ears. Application time was 10 hrs/acre, averaging $97-$117 per acre.

Some farms gained consistently better control than others. Six farmers using the method for the first time were uncertain as to the best timing for control. In some blocks, oil was applied more than 6 days after the first silk. Previous studies have shown that treatment more than six days after silk initiation results in lower levels of control.

The applicator was easy to use and comfortable to carry, but the pump part cracked and caused the pump to leak, resulting in further work on applicator design and material formulation. Keeping Bt powder in suspension in the oil was difficult without continuous agitation.

In the following two years, these trials were repeated on the same farms, with funding from the Northeast SARE program, and we addressed many of the difficulties encountered in year one. This work is reported at the Northeast SARE website (see reference below).

Years 2 and 3

Further experiments were conducted during years 2 and 3 to evaluate residual efficacy of the treatments, optimum timing, a variety of different oils and emulsifiers, Bt application rates and a neem product.

Note: This report refers to "silk days." As a reference point, "silk day 1" is the first day that more than 50% of the ears have one inch or more silks emerging from husks.

Experiment 1. Determine the residual efficacy of the oil & Bt application for CEW control.

Field studies over two seasons rated the efficacy and longevity of four treatments: 1) corn oil; 2) Bt sbsp. *kurstaki* ; 3) oil + Bt; and 4) an untreated plot. All treatments were applied on silk day 5 using the Zea-later™. Two first-instar CEW larvae were placed directly into the silk channel of selected ears on 6 different days, ranging from days 3-18 after first silk. Ears were harvested 4 days after placement, and scored for CEW presence, feeding damage, and kernel development.

Close-up of applicator with the Zea-later tip in the top of the silk channel.

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.

The use of corn oil gave the lowest caterpillar feeding damage ratings on almost all harvest days in both years and, therefore, the highest number of marketable ears. Oil-treated ears also had a higher percentage of undeveloped kernels at the tip of the ear (average of 6% to 9% of total ear length) compared to non-oiled ears (average of 0.3% of total ear length). The oil and Bt treatments appeared to control CEW for at least 17 days, from silking through maturity. One application of oil/Bt, on day 5 after first silk, was shown to be adequate to control CEW throughout ear development.

Experiment 2. Determine the influence of application timing on ear quality at harvest.

Each year two blocks of corn were planted to observe treatment effects under varying CEW and ECB pressure. Treatment consisted of 0.5 ml of corn oil containing a suspension of Bt at 0.08 g per ear applied to different aged ears throughout ear development. Oil/Bt treatments were applied on each day of silking from day 3 through day 11 after first silk, with individual ears getting only one application. Ears were harvested at milk stage on silk day 25, and scored for caterpillar presence, feeding damage and cone-tip.

The percentage of ears rated as free of feeding damage ranged from 71% to 100% in treated plots compared to 30% to 77% in the untreated controls. There was a linear decrease in marketability with later application days in two of the four plantings. The greatest decrease in marketability was after application day 7. The number of ears with cone-tip decreased linearly with the later application days in all plantings. There was 10% or less cone-tip after day seven in year 2 and after day six in year 3.

The best combination of effective insect control resulting in the highest rate of marketable ears with the least degree of cone-tip was achieved by application of oil + Bt suspension on day 7. Year to year variation in the environment would suggest an optimum timing range of application from days 6 to 8.

Experiment 3. Evaluate the impact of Bt concentration rates on efficacy of the direct silk oil method for CEW control, and on ear development.

In year 2, treatments were 0.5ml of oil containing 10% of the emulsifier Atlox 1087, mixed with different concentrations of Bt (Dipel DF): 0 lb/ac Bt, 1/16 lb/ac Bt, 1/8 lb/ac Bt, ¼ lb/ac Bt, ½ lb/acre Bt, 3/4 lb/ac Bt, and 1 lb/ac Bt. These same treatments and three additional treatments were tried in year 3—the neem product Aza-direct was applied at concentrations of 1:20, 1:10 and 1:1.

Bt concentration had no effect on the number of ears with cone-tip, the size of the cone-tips, or the development of corn ears in either year. The control (oil without Bt), all concentrations of Bt in oil, and in year 3 the three concentrations of neem in oil, were not statistically different in the proportion of ears with cone-tip. When looking at caterpillar control there was a significant dose effect of increasing Bt rates, with the higher rates producing less caterpillar feeding damage. The effects leveled off as the rate increased, with moderate Bt rates (between ¼ - 1 lb/ac) producing fewer ears with tip damage (Fig. 1). The percent of the ear that was undeveloped due to cone-tip was higher in year 2 (8% to 12%) than in year 3 (4.7% to 8.4%), most likely due to drought conditions, and supports observations that drought-stressed corn has a more severe response to the oil resulting in more cone-tip compared to adequately watered corn.

Experiment 4. Evaluate several different vegetable oils for efficacy in CEW control and effect on ear development.

Ten treatments consisted of four different oils: canola, corn, safflower and soy, and a water control—with or without Bt—at a rate of ½ lb/ac. In each treatment 0.5 ml of oil containing 5% lecithin as an emulsifier was delivered to the top ear of each plant.

In both years of the trials, there was no difference between the oils in the proportion of ears with cone-

A note on figures: The complete project report includes five figures; representing data for experiments 3-5. Figures 1, 3 and 4 are shown here.

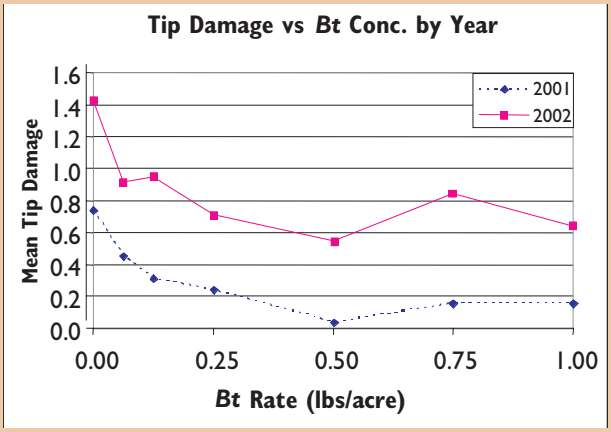


Fig. 1. Mean tip damage due to caterpillar feeding for the Bt rates tested in 2001 and 2002. The 1/2 lb/acre rate produced the cleanest ears in both years. In 2001 the rates of 1/2, 3/4 and 1 lb/acre were all equally effective. In 2002, all Bt rates and neem concentrations were equally effective.

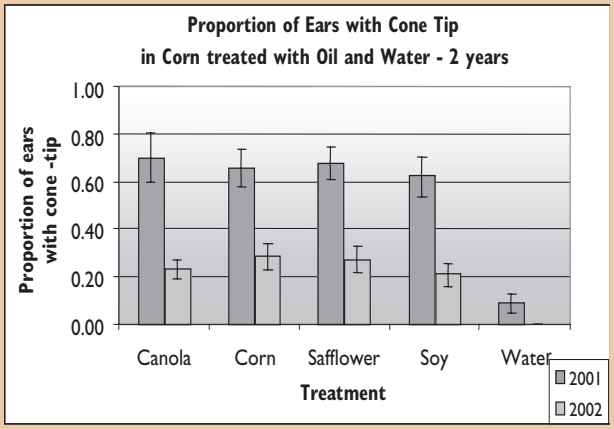


Fig. 3. Mean number of ears with cone-tip in ears with different oil treatments and water only. In 2001 dry conditions resulted in a much higher rate of cone-tip in ears that received an oil treatment.

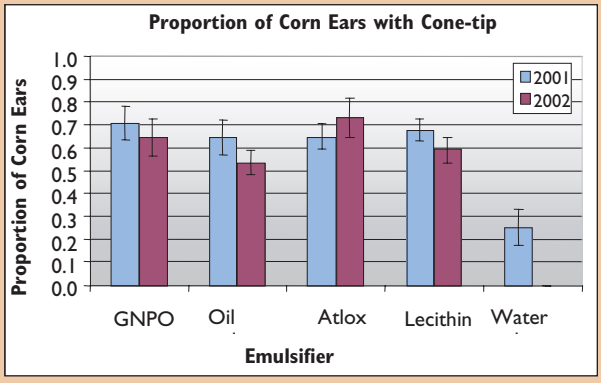


Fig. 4. Proportion of corn ears with cone tips in 2001 and 2002. There were no statistical differences between any of the ears that were oiled, regardless of whether an emulsifier was used, or which emulsifier.

tip, the length of the cone-tip, (averages all <1.4 cm), or the size of the cone-tip relative to the rest of the ear (Fig. 3). Compared to water, however, all four oils—corn, soy, safflower and canola—had significantly more ears with cone-tip. Mean ear length was lower in the oiled ears compared to the controls in year 3 but not different in year 2. As in the Bt concentration experiment, the number of ears with cone-tip in year 2 was much greater than in year 3, most likely due to the drier conditions.

Among the different oil treatments, tip damage due to caterpillar feeding was not statistically significant between any of the oils in either 2001 or 2002, or both years combined.

Experiment 5. Evaluate several different emulsifiers in soy oil for efficacy in CEW control and effect on ear development.

Ten treatments consisted of four different emulsifiers in soy oil and a water control, all with and without ½ lb/ac of Bt. Treatments:. 1-2) Soy w/lecithin, +/- Bt; 3-4) Soy w/Atlox, +/- Bt; 5-6) Golden Natr'l Soy Oil, +/- Bt; 7-8) Soy oil +/- Bt; 9-10) Control +/- Bt.

When data from both years were combined, all differences were due to whether oil was in the treatment or not. There were no statistical differences in the mean number of ears with cone-tips between any of the treatments containing soy oil regardless of the emulsifier used (Fig. 4). As for feeding damage, any oil treatment, regardless of emulsifier type, provided better control than the water control applied with or without Bt.

Conclusions

These experiments give more information about the optimization of oil and Bt treatment added directly to the silk of the ear for caterpillar control. Since only one treatment is applied the timing of that application is critical. The timing of the oil application has to balance the need to control the CEW caterpillar with the deleterious effects of the oil on kernel development. The earlier in development that the oil is applied the more severe the cone-tip. 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 of the oil and Bt suspension on day seven. At this time, nearly all kernels have been pollinated, the silk has separated from the kernels on most of the ear, and the silk has begun to wilt. In very hot weather this stage may be reached more rapidly, so that the oil treatment should be applied a day or two earlier. All of the oils and emulsifiers tested provided significant control of the corn earworm pest. Addition of Bt improves control. The best rate to use of the Dipel DF product is ½ lb/acre, the labeled rate for corn earworm control in sweet corn.

For the complete project report: *Integrated caterpillar control in organic sweet corn* (17 pp), go to http://ofrf.org/funded/reports/hazzard_02s18

Additional Links and Project References:

UMass Extension Vegetable Program, Caterpillar Control in Organic Sweet Corn
http://www.umassvegetable.org/soil_crop_pest_mgt/crops/corn_sweet.html

The Zea-Later oil applicator is available through Johnny's Selected Seeds:
http://www.johnnyseeds.com/catalog/product.aspx?category=292&subcategory=315&item=9038

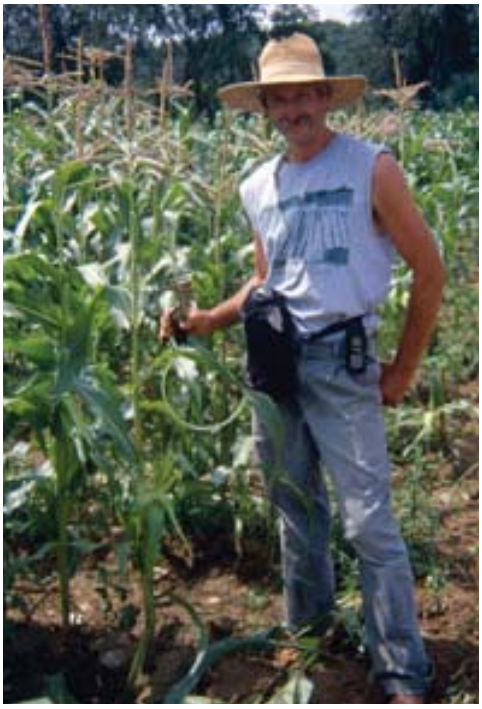
Fact Sheet. Agricultural Innovations: Organic Insect Management in Sweet Corn
http://www.sare.org/publications/factsheet/0105.htm

Refereed journal articles:

Hazzard, R. V, B. B Schultz, E. Groden, E. D. Ngollo, and E. Siedlecki. 2003. Evaluation of oils and microbial pathogens for control of Lepidopteran pests of sweet corn in New England. Journal of Econ. Ent. 96:6, 1653-1661. December, 2003 Available in PDF format from:
http://lysander.esa.catchword.org/vl=13476537/cl=15/nw=1/rpsv/cw/esa/00220493/v96n6/s5/p1653

Cook, R., A. Carter, P. Westgate, and R. Hazzard. 2003. Direct silk applications of corn oil and Bacillus thuringiensis as a barrier to corn earworm larvae in sweet corn. HortTechnology 13(3):509-514.
http://www.electronicipc.com/journalez/detail.cfm?code=04200030130323&cfid=&cftoken=

Cook, R., A. Carter, P. Westgate, and R. Hazzard. 2003. Optimum timing of an application of corn oil and *Bacillus thuringiensis* to control Lepidopteran pests in sweet corn. HortTechnology. 14: 3 (307-314).
http://www.electronicipc.com/journalez/detail.cfm?code=04200030140301&cfid=&cftoken=



Steve Mong, one of the farmers who helped to develop the oil method, using the Zea-later™ to control CEW, in his sweet corn field at at Applefield Farm in Stow, Massachusetts.