Organic farming research report submitted to:

Organic Farming Research Foundation
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Title: ***Integrated caterpillar control in organic sweet corn***

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Background

The purpose of this project is to work with a group of diversified vegetable farmers in the Northeast to evaluate an integrated non-chemical strategy for managing key caterpillar pests in sweet corn. In New England, corn earworm *(Helicoverpa zea)* migrates annually into the region and causes serious ear damage in late-season corn. European corn borer *(Ostrinia nubilalis)* is a resident pest of sweet corn which also contributes to ear damage, especially in the later part of the season. Currently, organic growers have no tools for controlling corn earworm, and experience significant losses in retail sales as a result. Growers have identified corn earworm control as the most important barrier to organic sweet corn production.

Research at the University of Massachusetts and other institutions has shown that a direct silk application of a mixture of vegetable oil and *Bacillits thuringiensis* (Bt) prevents ear damage from corn earworm and other caterpillars that enter through the tip of the ear. A small quantity of oil (0.5 ml/ear) is applied 4-6 days after silk initiation and forms a toxic barrier within the silk channel. The addition of *Bt* improves the efficacy of the oil treatment. When integrated with foliar applications of *Bt* prior to silking for control of husk-boring caterpillars that enter through the side of the ear, this system can give commercially viable levels of clean ears in late-season corn. The materials used in this system are acceptable under most organic certification standards. There is strong interest in this method among Northeastern farmers who currently grow or would like to grow organic sweet corn.

The focus of this project was to conduct on-farm trials of this integrated organic management system. Eight farmers from different parts of New England each tested it in three plantings of late-season corn, reserving one area in each planting as an untreated control block. Ear quality and costs were compared for treated and untreated blocks. The project will be continued for two more seasons (2000 and 2001) with funding from the Northeast SARE program. The long-term goal of the project is to provide organic growers with a cost-effective tool that will open the door to expanded production and sales of worm-free organic sweet corn.

Objective: Evaluate effficacy and practicality of the integrated oil/Bt system in late-season sweet corn on eight cooperating farms in New England in the 1999 growing season.

Methods

Eight farmers from Maine, Vermont, Massachusetts, Rhode Island and Connecticut participated in the study (Table 1). Two of these farmers had used and tested the oil/Bt method in previous years, and six had not. All but one of the farmers market directly to consumers through a farmstand, farmers market. or Community Supported Agriculture. Three of the farmers wholesale their corn to supermarkets, individually or through a cooperative. Two of the farmers were growing sweet corn for the first time, while others have grown it for 5-15 years. Seven of the farmers grow all their vegetables according to organic standards, whether they are certified or not. One uses IPM and is interested in transitioning to organic production.

A pre-season meeting with farmers was held in May to discuss the project plans and methods for the season. Each grower was provided with seed, an oil applicator, corn oil, Bt (Condor WP), and the necessary data sheets for record-keeping. The oil applicator used was the Zealator™, a handheld syringe pump device with a waist-belt tank that was designed at the University of Massachusetts and Hampshire College for the purpose of making oil applications to silking corn.

Growers each made three plantings of sweet corn, 7-1 0 days apart, between May 30 and July 3. The target harvest dates were from August 14 to September 15, when corn earworm and European corn borer pressure is normally high. (See Table 1). All plots were planted to the variety 'Parfait' (76 day bicolor SE+), which was used at the suggestion of several growers.

Table 1. Summary data on 1999 sweet corn trials

			Dates					
Farmer	**Location**	**Block#**	**Planting**	**1^{st} silk**	**Bt Spray I**	**Bt Spray 2**	**Oil Trt**	**Harvest**
Coldwell	S. Deerfield, MA	1	5/30	7/20		7/28-7/30	8/9	
Goranson	Dresden, ME	1	6/19	8/108/12		8/10-8/11	8/24	
Harlow	Westminster,VT	1	6/8	8/1	8/5		8/6	8/24
Kaplan	Amherst, MA	1	5/28	7/26		8/2-8/3	8/11	
Mong	Stow, MA	1	6/5	7/26-8/1			8/2	8/18
Paul	Little Compton, RI	1	6/11	8/5			8/12	8/23
Caruso	Cromwell, CT	2	6/9	7/28-7/29			8/3 & 8/7	8/18
Coldwell	S. Deerfield, MA	2	6/13	8/1	8/9		8/9 - 8/10	8/24
Goranson	Dresden, ME	2	6/27		8/12	8/27		8/31
Harlow	Westminster, VT	2	6/15	8/7	8/5		8/16	8/30
Kaplan	Amherst, MA	2	6/7	8/2			8/5	8/24
Manix	Putney, VT	2	6/12	8/6	7/25	8/4	8/11-8/12	8/30
Mong	Stow, MA	2	6/15	8/7-8/8			8/13	8/27
Paul	Little Compton, RI	2	6/20	8/9			8/20 (est)	9/1
Caruso	Cromwell. CT	3	6/19	8/10-8/13			8/17	9/1
Coldwell	S. Deerfield, MA	3	6/23	8/12-8/13	8/11	8/16	8/18	8/31
Goranson	Dresden, ME	3	7/3		8/12	8/27	?	9/14
Harlow	Westminster, VT	3	6/23	8/168/11	8/24	8/26	9/8	
Kaplan	Amherst, MA	3	6/16	8/13		8/21	9/2	
Manix	Putney, VT	3	6/23	8/168/9	8/17	8/24	9/8	
Mong	Stow, MA	3	6/24	8/16-8/17			8/23	9/8

For analysis purposes, the three plantings have been grouped into three blocks -- Block I (harvested August 9-24), Block 2 (harvested August 18-3 1), and Block 3 (harvested August 31 -September 14). See Table I for details. These three groupings make it possible to compare pest trends over the course of the season. There were some overlapping harvest dates between blocks due to differences in plant growth rate and variations in growers' seeding schedules.

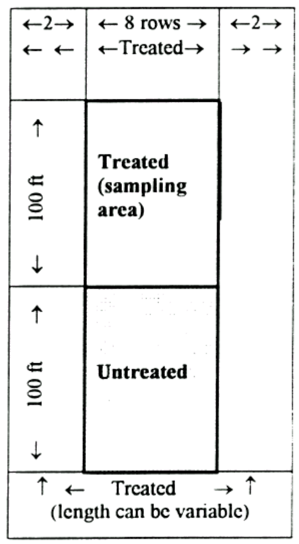
Each corn planting was at least 12 rows (36 feet) wide by at least 240 feet long (0.2 acre) (Table 2). In some cases plots were larger if the growers' field layout or crop needs required it, or the untreated section was reduced to 60 feet long if growers were extremely short of corn for sales. Drought conditions during June, July and for some farms into August reduced the rate of germination, decreased the plant stand or made it more uneven, and delayed growth on some farms. Raccoon damage eliminated one planting from the study. Weeds made oil treatment and harvest difficult in three plantings.

On each farm, pheromone traps for corn earworm, European corn borer, and fall armyworm were set up by July 15 and inspected at least weekly. One Heliothis net trap (Scentry Biologicals), baited for corn earworm, was placed within the block of silking corn. Two Heliothis net traps were placed in weeds at field borders, one baited for the Z (Iowa) strain of European corn borer and one for the E (New York) strain. Multiplier bucket traps (Bio-Controle Services) were placed in silking corn for fall armyworm. The University of Maine Cooperative Extension Sweet Corn IPM program conducted biweekly monitoring at Goranson Farm in Maine. At Walker Farm in Vermont, a farm employee checked the traps. At Wishingstone Farm in Rhode Island, the farmer checked his own traps. At other farms, the project field technician did the weekly scouting.

Each plot was scouted for infestation with European corn borer or fall armyorm when tassels began to emerge, by sampling 100 plants in groups of 10 or 20 throughout the field. If 15% or more of the plants were infested (had one or more caterpillars present), a foliar application of Bt was made to the entire block. This is the standard action threshold used in sweet corn IPM programs throughout New England. A *Bt kurstaki* product, Condor WP, was used for foliar sprays at 1.5 lb/acre. NuFlim (8 oz./acre) was used as a spreader-sticker. A second spray was applied if infestations remained above threshold.

Oil treatments were made by farm employees if corn earworm captures exceeded 2 moths per week at the time of silk initiation. Silks of the treated block and the border rows were treated with the oil/Bt mix, with an inner 8 row by 60- 100 foot section left untreated (Table 2). Growers were told to make the treatment when 50% of the field first showed wilting silk (which occurs approximately 4 days after silk initiation, or 2 days after silk is fully grown). Applications consisted of 0.5 ml per ear with a mixture of corn oil and Condor WP at the ratio of 1 liter of corn oil (Mazola) to 1 level tablespoon of Condor WP powder. Only the upper or most mature ear on each stalk was treated, with the oil applied directly onto the top of the silk or slightly into the silk channel. Growers were asked to keep records of the time required per block (or per row feet of treated corn.)

TABLE 2. Field layout for on-farm trials



When each block was ready for harvest, project staff picked 100 ears at random from each treatment plot. Each ear was rated for the presence and location of feeding damage. Insects present were identified. Ears with any feeding damage to kernels, even at the tip, were considered damaged. "Clean" ears were those with no damage to kernels.

Oil treatments can cause reduced fill in kernels at the tip and reduced ear length in the total ear. It appears that oil interferes with pollination of the late-emerging silks, which originate in the ear tip. Previous studies have shown that applications of oil more than 6 days after silk initiation have less interference with tip fill, however, late applications also reduce efficacy against caterpillars. To evaluate the effect of oil on tip fill, on five farms a sub-sample of 30 harvested ears was taken at random from the 100 ears used for damage assessment. On each ear, we measured the length of filled ear (from the beginning of filled kernels at the base of the ear to the end of filled kernels at the tip) and the total length of the ear.

Analysis of variance was conducted using the Chi Square test, with damage ratings (clean vs. damaged) and the number of earworm or European corn borer caterpillars (0 vs.1 or more) treated as categorical data. Treatment differences were considered significant at $p<0.01$, unless otherwise noted.
A daylong follow-up meeting was held on November 29, 1999 at Applefield Farm in Stow and all eight farmers attended. Results from the trials were presented and discussed.

Results

Corn earworm and European corn borer activity

All plantings on all eight farms were invaded by both second-generation European corn borer and corn earworm. Fall armyworm activity was negligible. Corn earworm trap captures of 2 moths per week (0.3 per night) are sufficient to cause unacceptable levels of damage and would trigger insecticide sprays under standard IPM practice. All farms had captures in excess of this level by the time silking occurred in each block (Table 1, Figure 1). Corn earworm flight varied among farms. As is normally the case, those nearest the coast (Goranson, Mong and Paul) experienced the heaviest migratory flights, with captures exceeding 30 moths per night (Figure 1). Corn earworm pressure increased as the season progressed. The average percentage of ears infested with corn earworm in untreated blocks was 19% in the first block, 25% in block 2, and 71% in block 3 (Figure 2).

European corn borer flights began in the last week of July or first week of August at all farms, and continued through August. The first two blocks were more heavily damaged by European corn borer than the last block (Figure 2), and the degree of damage varied among farms. Four farms had 1 or more blocks with European corn borer infestations above the threshold at the tassel stage, and these growers made foliar Bt applications to the entire block (both oiled and non-oiled sections) (see Table 1, Bt sprays1 and 2). Where European corn borer damage was found in harvested ears, the larval entry was primarily through the tip rather than through the side. This suggests that pre-silk infestations, where they existed, were successfully controlled by this foliar Bt sprays. It also indicates that borer can cause significant damage from tip entry during the silking period. In at least one instance (Coldwell Block 1, Figure 3), European corn borer larvae entered very late in ear maturation and were not adequately controlled by the oil treatment. In Block 2 the grower applied Bt sprays during silking (Table 1), which may have contributed to the high level of control achieved in this block (Coldwell, Figure 4).

The combined feeding activity of European corn borer and corn earworm caused 12-83% damaged ears in untreated control sections of Block 1, 22-96% damaged ears in Block 2, and 58-99% damaged ears Block 3 corn (Figures 3, 4, 5).

Evaluation of applicators, oil/Bt formulations, and sweet corn variety

The applicators used were the original prototypes of the Zealator, which were built by Doug Hartwell, one of the inventors of the device. Two growers had used the applicator in previous seasons, but this was the first time it had been used widely in commercial plantings of one-quarter acre or more. This provided a significant test of the design and durability of the Zealator. One key design feature that worked successfully was the handle shape and the degree of spring tension on the syringe pump. One squeeze releases one dose of oil. Workers were able to use the applicator for the repeated squeezing motion for several hours without significant hand fatigue. Workers also found that the design of the handle was suitable for comfortably reaching corn ears at about waist height, and that the waist-belt tank, worked well. There were problems with the piston inside the syringe pump, which was a pre-purchased part designed for short-term use that had to be drilled to screw it into place within the syringe. Repeated use and long-term storage with oil residue resulted in cracking, which in turn caused the pump to leak. Replacement of the part repaired this problem, but caused growers some frustration and delays. Commercial designs of the applicator, which are currently underway, need to address this problem.

In previous seasons we used liquid Bt products such as Dipel ES (Abbott Labs) or MVP and Mattch (formerly from Mycogen, Inc.) that mixed readily with vegetable oil. These products are now prohibited in many organic certification programs. The approved Bt products are dry formulations, such as Condor WP (Ecogen). Condor WP is formulated to dissolve in water; however, in oil it forms a suspension that requires continuous agitation. This was an annoyance to growers and may have resulted in uneven distribution of the Bt dose on treated ears. Components and mixing procedures which will meet organic standards and form a stable suspension or emulsion will be explored for the 2000 season.

Although growers liked the taste and ear quality of the variety 'Parfait', there were concerns about other characteristics. This variety responded to drought conditions by producing a high proportion of ears with poor husk cover at the tip. When tips become exposed, the silk channel no longer encloses the oil and the oil is not effective in controlling caterpillars. This problem probably contributed to poor control in some blocks. In addition, this variety showed a high level of sensitivity to interference of oil with tip fill compared to other varieties where oil was also used (see below). Furthermore, it was difficult to pull ears off the stalks at picking time. At the November meeting, farmers discussed the characteristics they consider important in selecting a variety: consistently good germination, ability to stand well in wind, drought tolerance, husk appearance, eating quality, tip fill, and good husk cover at the tip. Growers all preferred a bicolor SE variety for their markets. Based on these criteria, farmers decided on 'Delectable', another SE+ bicolor, for next year's trials.

Efficacy of oil treatments
Twenty-one blocks on eight farms were harvested and provided data for the trials. The oil treatment significantly increased the percentage of clean ears in eighteen blocks. The desired level of control for commercial crops (>90% clean) was achieved in five blocks: Goransen in Block 1, in Coldwell, Kaplan and Mong in Block 2, and Manix in Block 3 (Figures 3, 4, 5).

Control at the 75% level was achieved at five out of six farms in Block 1 and five of eight farms in Block 2. In blocks which had more than 80% damage in untreated corn, which included Paul in Block 1 and 2 and five of the seven farms in Block 3, the percentage of clean ears from the oil treatment was below 75%, ranging from 20-75%. There was no significant benefit from the oil treatment in Harlow Blocks 2 and 3 and Goransen in Block 3.

Efficacy can also be measured by the difference in damage or infestation between untreated and treated corn in each block. The amount of improvement gained from the oil treatment averaged 25%, and ranged from 0 to 55%. The amount of improvement varied among farms and among blocks. The treatment effect on damage and on corn earworm infestation increased in later blocks, at higher levels of corn earworm pressure (Figure 2). The average gain in percent clean ears between treated and untreated corn was 19.7 % in Block 1, 24.0% in Block 2. and 32.3 % in Block 3 (Figure 3, 4, 5).

Oil effect on tip fill
Oil treatments were associated with a longer section of unfilled tip and shorter overall ear length Measurements of ear fill and ear length were made on samples of 30 ears from untreated and treated sections in Block 2 plantings on five farms. Total ear length was lower in oil-treated ears, averaging 19.9 cm (7.8 in) compared to 20.4 cm (8.0 in) in non-oiled ears. The length of the filled ear was also lower, 18.0 cm (7.1 in) compared to 19.6 cm (7.7 in) in untreated. On average, ears were 90% filled in oiled corn compared to 96% in non-oiled corn. Thus total ear length averaged 0.2 inches less and filled length 0.6 inches less as a result of the oil. This was similar to a 1996 study in which oil treatments reduced the length of the filled kernels by an average of 0.6 inches and the total ear length by 0.5 inches.

Cost
Growers who kept track of time for oil treatments found that the labor requirement, once a worker was familiar with the applicator, was equivalent to about 10 hours per acre. While they were getting accustomed to the method, workers required more time, up to 15 hours per acre. Going too fast, however, appeared to result in poorer control. One grower whose employee achieved a faster time (7 hours/acre) also gained no significant benefit from the treatment (Harlow, Block 2 & 3).

Growers estimate their hourly cost for hired labor (including wages and other costs) to be $8 to $10 per hour. Total labor cost at 10 hours per acre would be $80 to $100 per acre. Materials costs are approximately $12 for 2 gallons of food-grade corn oil and $5 for the equivalent of one pint of Bt. Thus the total cost per application is $97 to $117 per acre. The purchase price for the applicator is expected to be approximately $100.

Foliar Bt applications cost approximately $28.50 per acre ($15/A for Bt product, 0.5 hours/A @ $15/hr for labor and 0.25 hours/A @ $24/hr for tractor and sprayer use). This cost is added to the cost of the oil application, but would be used only when needed to control infestations of caterpillars at the tassel stage. In 1999 the level of infestation at the tassel stage was relatively low, and only half the participating growers incurred the extra cost of Bt foliar applications.

Discussion

The high level of corn earworm and European corn borer activity in 1999 provide a very substantial test for the efficacy the oil direct silk method. The results showed that at moderate pest pressures, significant control of both pests -- >75% clean ears in many cases, and >90% clean ears in some blocks -- could be achieved. Some farms gained consistently better control than others. At all pest pressures, the oil treatment provided a significant improvement in ear quality, averaging 25% more clean ears. However, control fell below the 75% level when corn earworm numbers were severe enough to cause >80% damage in untreated corn.

Several factors may have contributed to inconsistent results and the poor control at high pest pressure. Six farmers were using the method for the first time and were somewhat uncertain as to the best timing for control. In some blocks, the oil was applied more than 6 days after first silk (see Table 1). Previous studies on timing have shown that treatment more than six days after silk initiation results in lower levels of control. Manix and Mong, the two farmers with past experience with the method, had more consistently good results. They oiled all their late-season com in 1999, not just the trial blocks. Mong oiled 4 acres of late corn (4-6 different plantings), and was satisfied with his control until the very last planting which was the trial block # 3 (see Mong, Blocks 1-3). The other six growers felt they needed more experience with the method to judge how well it can work and how it can fit in their operation. All farmers who participated in 1999 want to continue to test the method, and all plan to continue with the project in the coming season.

The impact of dry growing conditions and variety selection, which included poor tip cover and uneven plant age in some blocks, may also have influenced control. The problem of variability in maturity within blocks was discussed at the November meeting. Uneven emergence or variability in soil quality or water within a field can result in corn stands that are quite uneven in maturity at the time when oil treatments need to be applied. As a result, some corn plants are treated before or after the ideal age. Growers discussed techniques for getting the most even plant stand. They also asked if studies could be conducted to gain an understanding of the actual "window" in corn age which can be treated successfully.

The variations among blocks and farms suggest that there may be factors such as timing or application technique or crop management, which could improve the level and consistency of control. We plan to repeat these trials for two more years and expect that by addressing some of the problems encountered in 1999 trials we will see improved control. A sweet corn variety with better tip cover, better application timing, improved oil/Bt mixing, solving the leaking problem, and the benefit of experience and better understanding of the method by growers is likely to produce more consistent levels of control.

The poor control achieved at high corn earworm pressure raises questions about how to improve the efficacy of the oil when caterpillars invade the ear continually throughout the period of ear development. We plan several experiments at the UMass Research Farm to explore the question of application timing in relation to the time of larval entry into the ear and to evaluate the persistence and viability of the oil/Bt treatment during the silking period.

Another practical question raised by the growers is the use of a crew instead of a solo worker to make oil treatments. Many tedious jobs on farms are accomplished more quickly, effectively and comfortably by a crew who works a short time rather than a single person doing the same task for many hours. Some growers were concerned that tedium or tiredness would result in less accurate applications of oil and expressed an interest in having several applicators to enable a crew to do the oil treatment.

Farmers also discussed when the oil treatment is economically worthwhile, and its impact on sales. Some felt that if corn earworm pressure is low, the additional cost may not be worthwhile. However, all felt it would be worthwhile to invest the additional $100+ per acre if pressure is high enough to bring damage to 10% or more in untreated corn. The benefits include being able to add corn to their crop mix, being able to keep consumers satisfied at the farm stand or farmers market, and being able to sell in the wholesale market.

Outreach

The results of this project are being disseminated to farmers in the Northeast region, and beyond, by several means. We have made presentations at farmer conferences or twilight meetings in Maine. New Jersey, Vermont, Massachusetts, and Rhode Island. A fact sheet on *Biointensive Insect Management in Sweet Corn* has been distributed at meetings and in response to many requests made to my office. It is also available on the UMass Extension Vegetable Program website wwww.umass.edu/umext/programs/agro/vegsmfr/). We are planning to hold a twilight meeting in August 2000 at one of the farms which is participating in the project. Since we are continuing the project for two more summers, we expect to compile the results of future trials with the 1999 results to publish and share at grower and professional conferences.

Acknowledgements:
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Note: The Vegetable IPM office at the University of Massachusetts receives numerous inquiries about this project and about when the Zealator will be on the market. We are currently working with a manufacturer, Enabling Devices of Hastings-on-Hudson, New York (914-478-0960), to develop a commercial product. Interested farmers may contact my office or call the manufacturer directly.

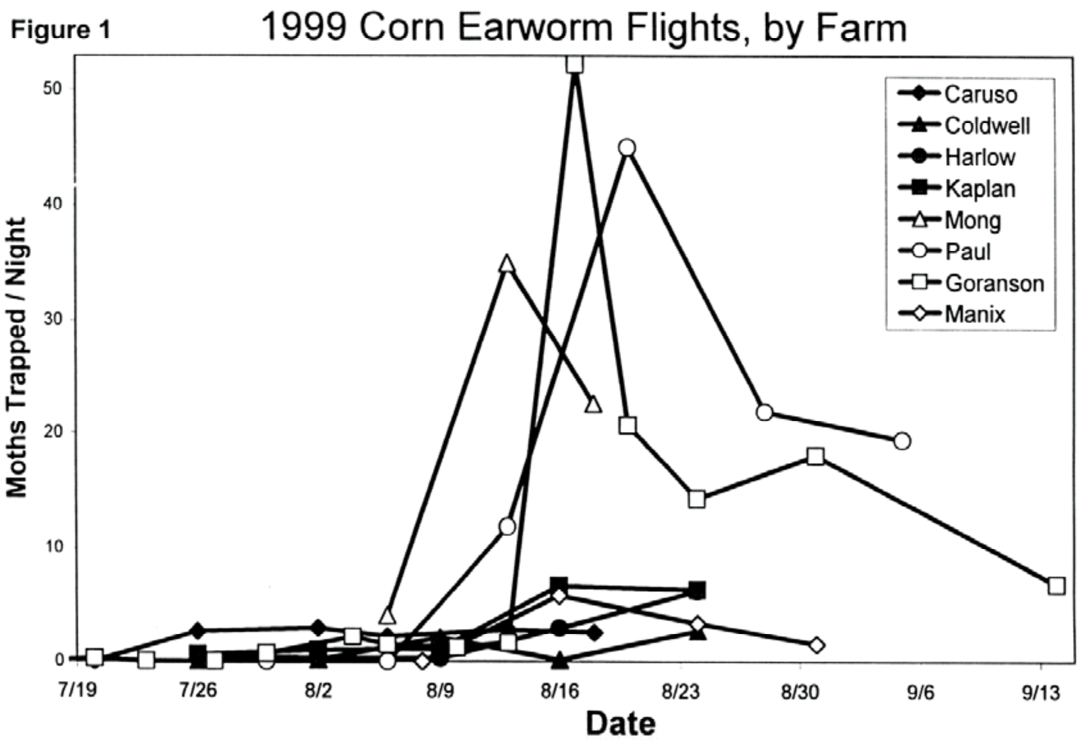
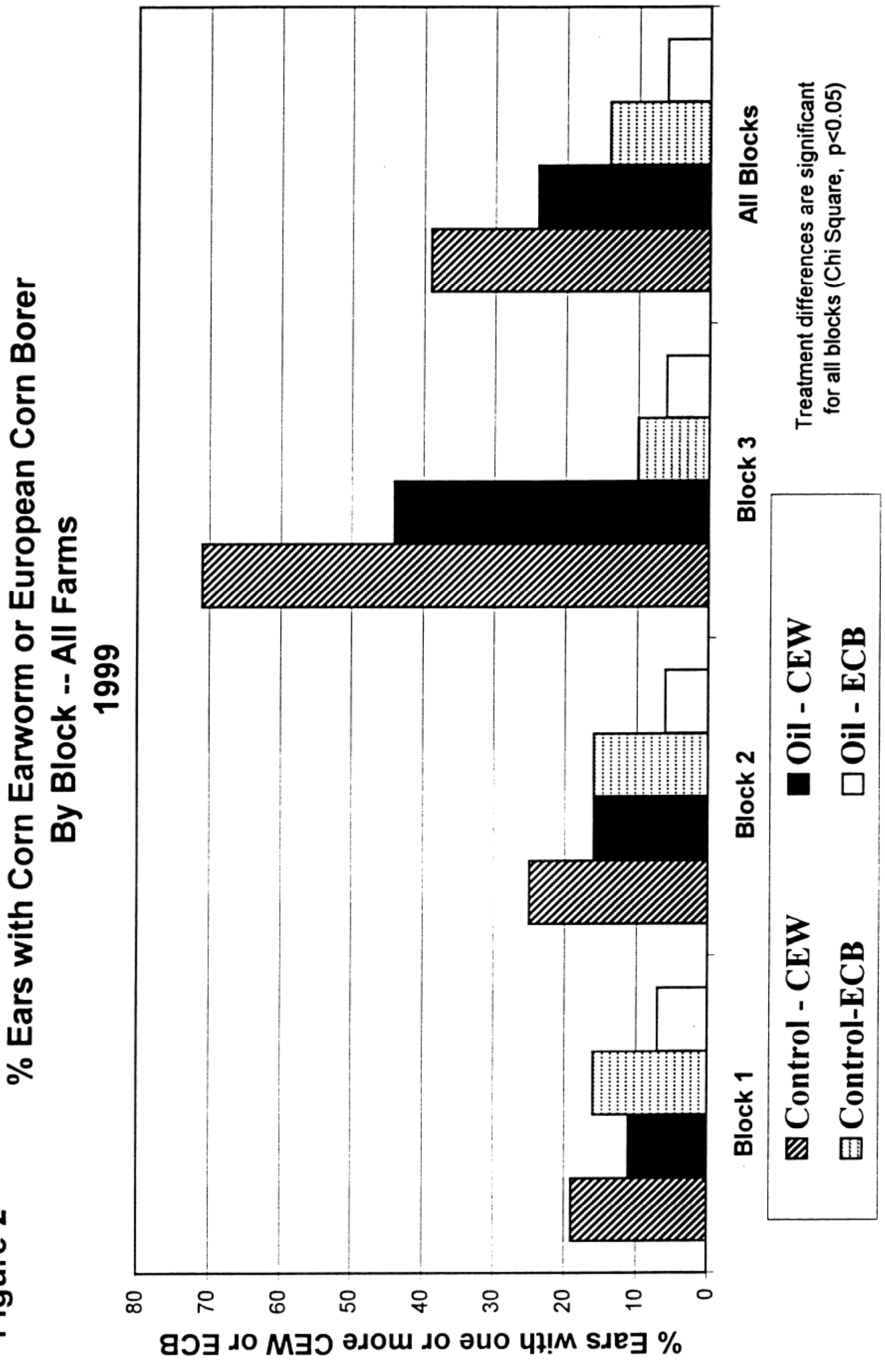


Figure 1
1999 Corn Earworm Flights, by Farm
Moths Trapped / Night
50
40
30
20
10
0
7/19
7/26
8/2
8/9
8/16
8/23
8/30
9/6
9/13
Date
Caruso
Coldwell
Harlow
Kaplan
Mong
Paul
Goranson
Manix

Figure 2


% Ears with Corn Earworm or European Corn Borer
By Block -- All Farms
1999
% Ears with one or more CEW or ECB
80
70
60
50
40
30
20
10
0
Block 1
Block 2
Block 3
All Blocks
Control - CEW
Oil - CEW
Control-ECB
Oil - ECB
Treatment differences are significant
for all blocks (Chi Square, p<0.05)

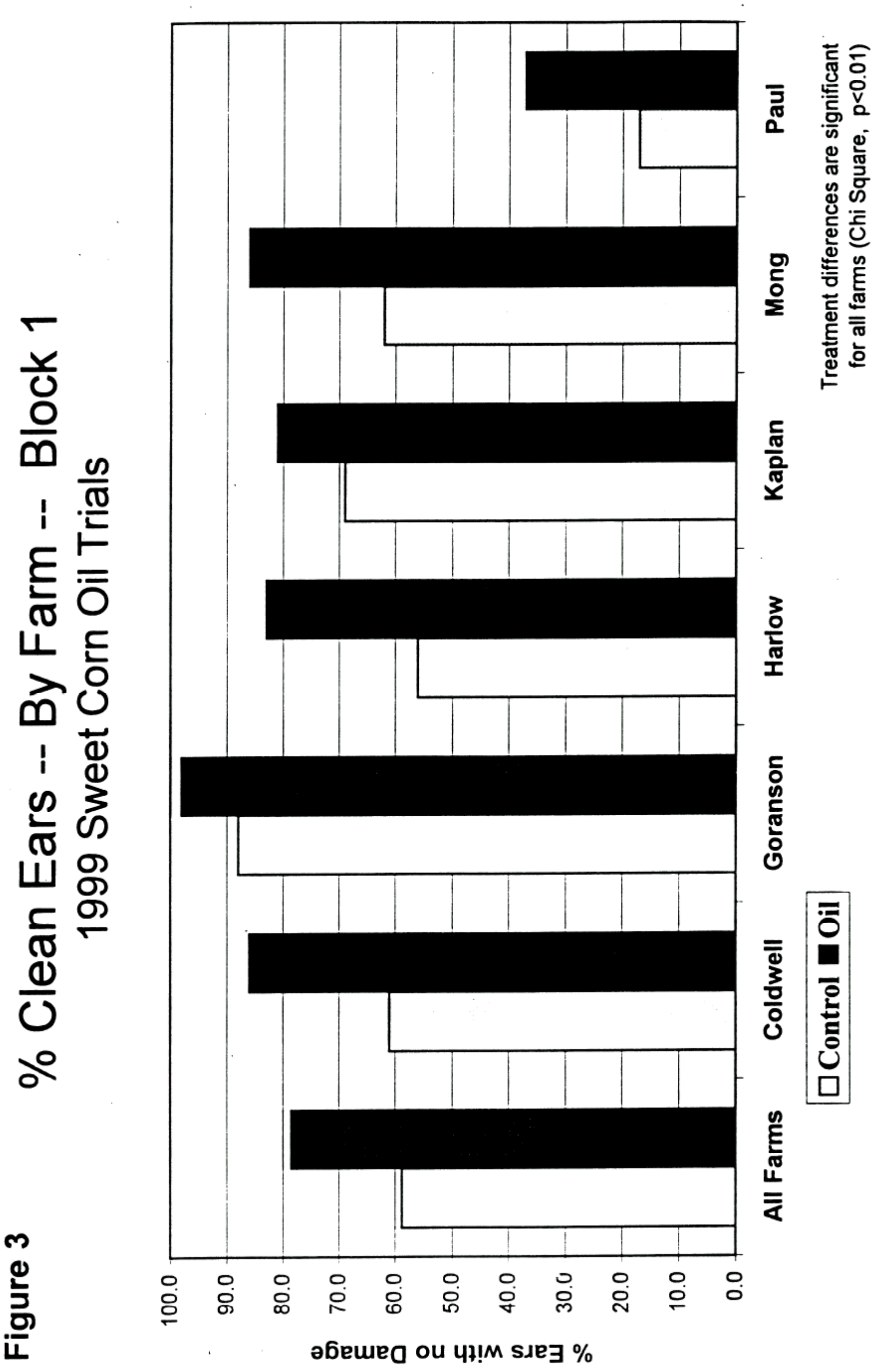


Figure 3
% Clean Ears -- By Farm -- Block 1
1999 Sweet Corn Oil Trials
% Ears with no Damage
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
All Farms
Coldwell
Goranson
Harlow
Kaplan
Mong
Paul
Control
Oil
Treatment differences are significant
for all farms (Chi Square, p<0.01)

Figure 4

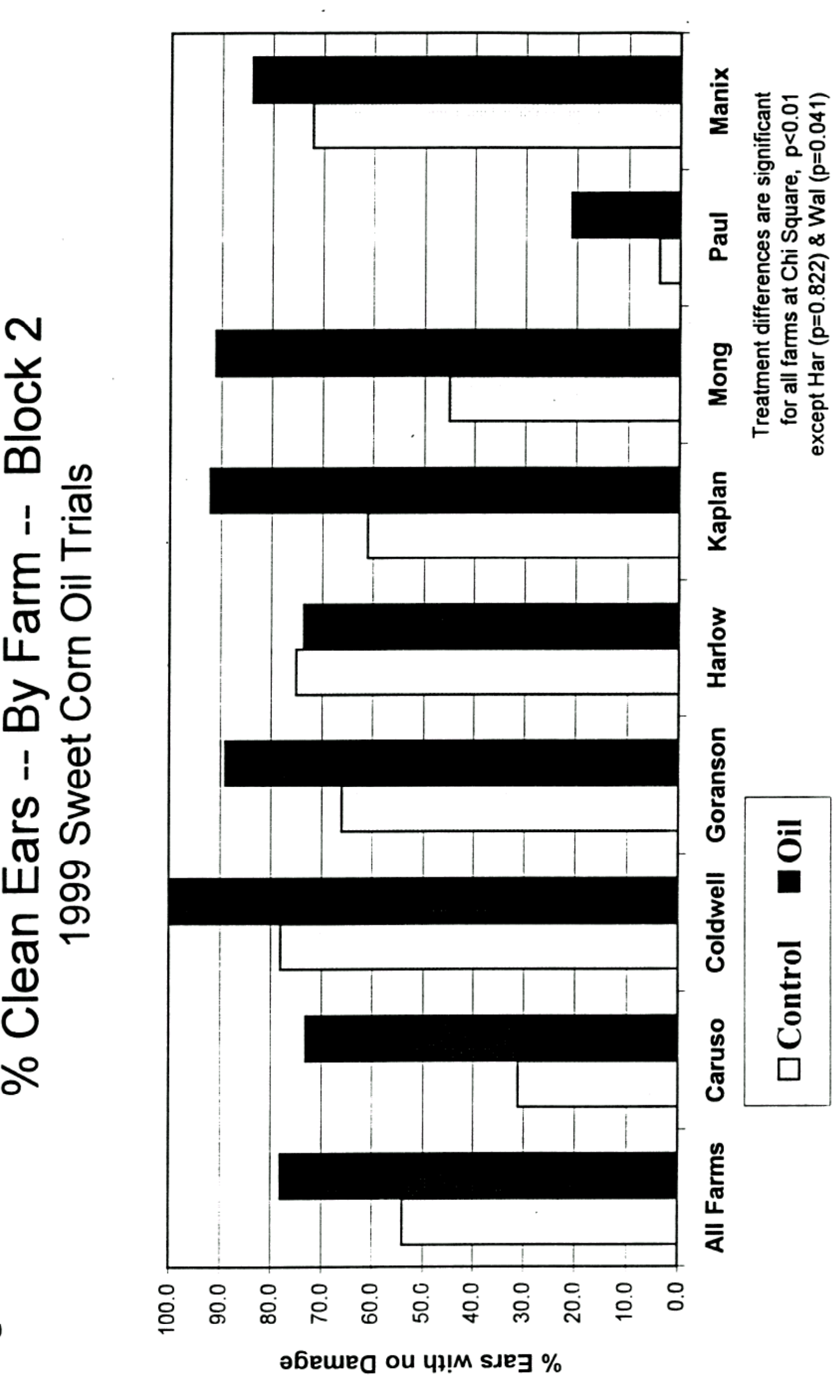
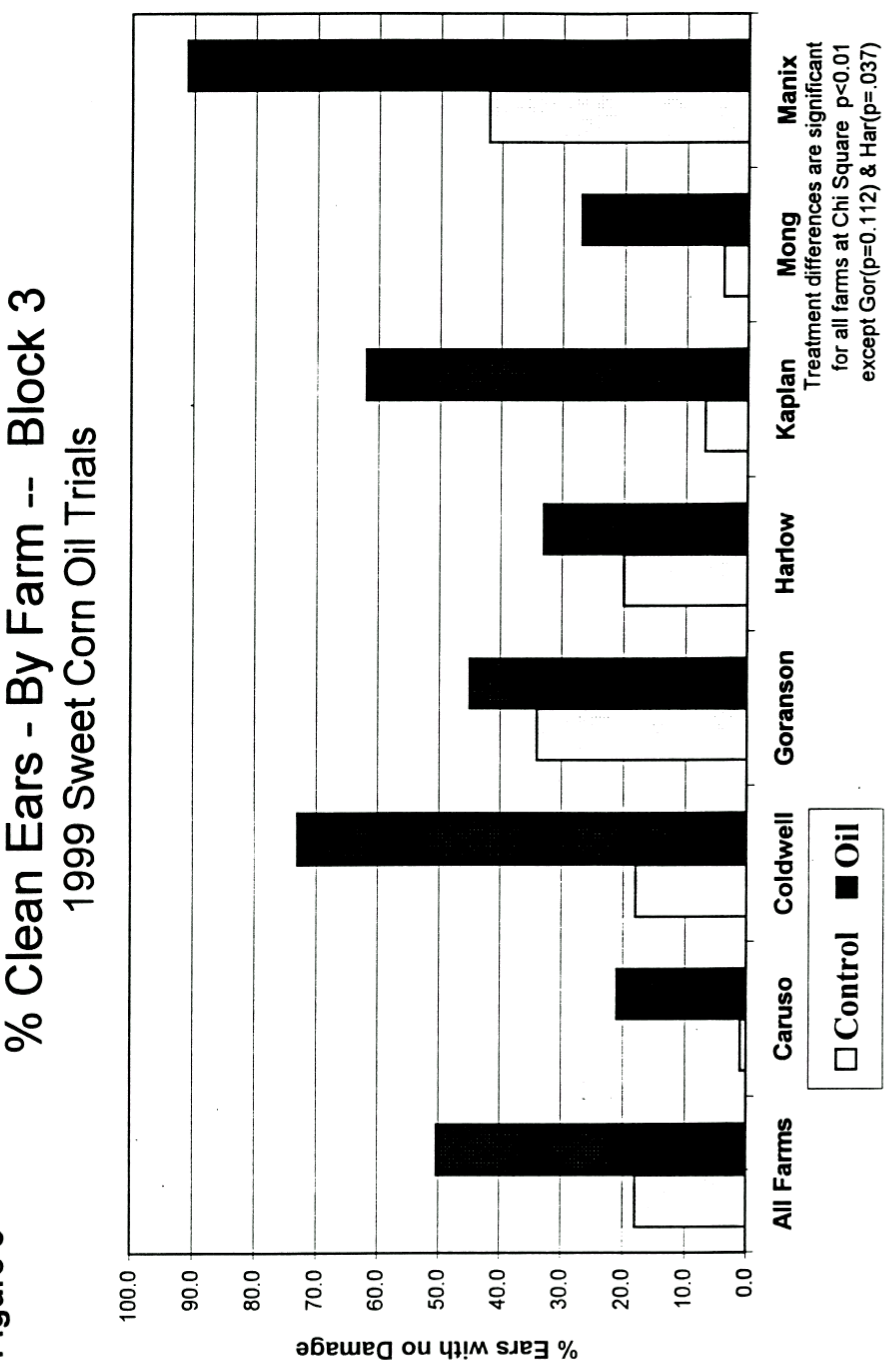

% Clean Ears -- By Farm -- Block 2
1999 Sweet Corn Oil Trials
% Ears with no Damage
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
All Farms
Caruso
Coldwell
Goranson
Harlow
Kaplan
Mong
Paul
Manix
Control
Oil
Treatment differences are significant
for all farms at Chi Square, p<0.01
except Har (p=0.822) & Wal (p=0.041)

Figure 5


% Clean Ears - By Farm -- Block 3
1999 Sweet Corn Oil Trials
% Ears with no Damage
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
All Farms
Caruso
Coldwell
Goranson
Harlow
Kaplan
Mong
Manix
Control
Oil
Treatment differences are significant
for all farms at Chi Square p<0.01
except Gor(p=0.112) & Har(p=.037)