# Granulosis virus for codling moth management in Ohio apple orchards

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SUMMARY: A field trial on codling moth management was conducted to evaluate the effects of codling moth granulosis virus used alone and in combination with insecticide. Treatments evaluated were virus alone, insecticide alone, insecticide plus virus, and an untreated check. The virus product Cyd-X was applied 12 times at 7-day intervals, while the insecticide (Asana then Assail) was applied 6 times at 14-day intervals. Control of codling moth was equally good from virus only, insecticide only, or a combination of insecticide and virus, and these three treatments were significantly better than the untreated check treatment. Virus sprays offer an excellent alternative to conventional insecticides, particularly in orchards where the codling moth population has developed resistance to insecticides or in orchards where organic management is used.

Background: As codling moth has been increasingly hard to control with organophosphate insecticides in some orchards during the past few years, some growers have been experimenting with alternative management tactics. One alternative is spray application of codling moth granulosis virus products, which are now commercially available. Use of virus has generally shown positive results, although effects of virus are difficult to evaluate because most growers are using them in conjunction with conventional insecticides. Data is needed on how the virus performs when used both with and without insecticide.

Objectives: The primary objective was to evaluate control of codling moth by applications of codling moth granulosis virus used alone and combined with insecticide. Secondary objectives were to valuate a neonicotinoid insecticide for control of a population of white apple leafhopper that is no longer susceptible to pyrethroid insecticides, and to evaluate density of pest mites and predatory mites as part of a long-term study on mite tolerance of pyrethroid insecticides.

Methods:

The trial was conducted in small plots in a block of 13-year old Jonafree and Liberty apple trees at Ohio State University's Waterman Laboratory in Columbus, Franklin County, central Ohio. Insect control in this block has relied primarily on low rates of pyrethroid insecticides for the past 10 years, and mite control has relied on pyrethroid-tolerant predatory mites. There were four treatments each with four replicates in a randomized complete block design, with eight adjacent trees per plot. The eight trees per plot were four Liberty and four Jonafree. The four treatments were insecticide only, virus only, insecticide plus virus, and untreated.

The insecticide-only treatment was Asana applied at first cover (5/25/06; 215 degree-days after trap-based biofix) and second cover (6/7/06) for first generation codling moth control, Asana at fifth cover (7/19/06) and sixth cover (8/3/06) for second generation codling moth control, and Assail applied at seventh cover (8/18/06) and eighth cover (8/31/06) for third generation codling moth control. The virus-only treatment was Cyd-X applied four times at weekly intervals (5/25, 5/31,6/7, 6/15) for first generation codling moth control, another four times for second generation control (7/19, 7/28, 8/3, 8/9), and four more times for third generation codling moth control (8/18, 8/24, 8/31, 9/7). Product formulations and rates were Cyd-X (codling moth granulosis virus) at 3 fl oz per acre, Asana XL 0.66EC (esfenvalerate) at 4.8 fl oz per acre, and Assail 30SG (acetamiprid) at 5 oz per acre applied with oil at 0.5%. The insecticide plus virus treatment was the combination of the two individual treatments at the same rates and timings. All plots except the untreated checks were treated at the pink bud stage (4/18/06) with Esteem 35WP, 3 oz/A, for San José scale. All plots except the untreated checks were treated at petal-fall (5/1/06) and first cover (5/17/06) with Calypso 4F (thiacloprid) at 6 fl oz per acre for white apple leafhopper and plum curculio. For fruit thinning, Sevin XLR Plus at 1 quart per 100 gallons was applied to all plots including untreated checks on 5/17/06. Insecticides were applied in a dilute volume of 150 gallons of water per acre by a handgun sprayer operated at pressure of 100 psi, with a D6 ConeTip nozzle tip.

A reduced fungicide program was used in all plots. Fungicides were applied by an AgTech 4002 airblast sprayer operated at pressure of 20 psi, with TeeJet 6510 and 6520 nozzle tips. On all trees including checks, Kocide was sprayed at green-tip on 4/6/06 and Mancozeb was sprayed at 3/4-inch green on 4/12/06. Further applications were not needed due to the disease resistance of these cultivars.

Pheromone traps were used to monitor adult populations of codling moth and lesser appleworm. The date of sustained flight of codling moth was used as a biofix to start a degree-day count on which insecticide timing was based. Multipher-3 funnel traps were used with lures made by Trécé; for codling moth, long-life lures were changed every 8 weeks, while for lesser appleworm, standard lures were changed every 4 weeks. Oriental fruit moth was not monitored due to its absence at this site in the previous few years.

Insect injury to fruit was evaluated on 100 fruit in the center of each plot, non-destructively on 7/25/06 to evaluate injury by first-brood codling moth, and destructively at harvest on 9/11/06. Plots were scouted for nymphs of white apple leafhopper on 5/9/06, and for cumulative leafhopper damage on 6/12/06, using a sample of one mid-cluster leaf, and 25 samples per plot. Pest mites and predatory mites were sampled on 5/22/06 and 8/22/06 on 25 leaves per tree in the center of each plot. Data were subjected to analysis of variance (ANOVA) and mean comparisons by least significant difference (LSD) tests in the SAS 9.1 microcomputer statistics program. Percentage data were transformed by arcsine square root before analysis.

Results and discussion:

Fruit evaluated in mid-summer showed that the most important insect injury was internal Lepidoptera, which affected 0.8 to 8.5% of fruit (Table 1). Injury from internal Lepidoptera was significantly less where either Asana or Cyd-X or the combination Asana plus Cyd-X was used than in the untreated check treatment. Virus alone was as effective as insecticide alone for control of internal Lepidoptera. Plum curculio oviposition injury, tarnished plant bug injury, and San José scale were found in some plots but these did not differ significantly among treatments.

At harvest in September, the most important insect injury again was internal Lepidoptera, which affected 2.4 to 24.1% of fruit (Table 2). Again the internal Lepidoptera injury did not differ statistically among the insecticide only, virus only, or insecticide plus virus treatments, but fruit in all three of these treatments were significantly less injured than the untreated check. The incidence of stings from codling moth infestation was twice as high in the virus-only treatment than the insecticide treatments but these were not significantly different. Injury from plum curculio oviposition, apple curculio oviposition, plum curculio adult late feeding, San José scale, and tarnished plant bug were found in most plots but did not vary significantly among treatments. There was a trace of late leafroller damage, early fruitworm damage, and an unidentified pest, but these did not vary significantly among treatments.

Insect control treatments were well timed based on population trends apparent in trap data. Codling moth adults reached peak density in pheromone traps on 6/21/06 for the overwintering generation, on 8/9/06 for the summer generation, and on 8/30/06 for a partial third generation (Table 3). Lesser appleworm adults peaked on 5/31/06 and 8/2/06 (Table 3). Based on an estimate of 1118 degree days per generation, the cumulative degree-days showed the potential for a third brood of larvae (Table 3).

White apple leafhopper showed a noticeable but statistically insignificant effect by treatment with two applications of Calypso at petal-fall and first cover. There were fewer leafhopper nymphs per leaf in treated plots than in the untreated check plots on both 5/9/06 and 6/12/06, and less damage on 6/12/06 (Table 4), but none of these differences were statistically significant. This pest had reached very high density during the previous two years after apparently developing resistance to pyrethroids. This trial in 2006 was the first time that a neonicotinoid (Calypso) had been used in this block.

The European red mite population was present at low density (Table 5). Phytoseiid predatory mites were more abundant than stigmaeid predatory mites in May, but the opposite was found in August. There were no significant effects of insecticide treatments on mites.

Conclusions: Control of codling moth was equally good from virus only (Cyd-X), insecticide only (Asana and Assail), or a combination of insecticide and virus, after virus was applied 12 times at 7-day intervals and insecticide was applied 6 times at 14-day intervals. Virus sprays offer an excellent alternative to conventional insecticides, particularly in orchards where the codling moth population has developed resistance to insecticides or in orchards where organic management is used.

Table 1. Effect of virus and insecticide on insect injury by early-summer insects to Liberty apple fruit, by non-destructive evaluation, mean of four blocked replicates, July 2006 at OSU's Waterman Lab, Columbus, Ohio.

| Treatment | Percentage of fruit [a] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Clean | Internal Lepidoptera | | | Plum curculio oviposition | Tarnished plant bug | San José scale |
| | | entry | sting | total | | | |
| Insecticide only | 96 A | 0.2 B | 0.5 | 0.8 B | 1.8 | 2.0 | 0.0 |
| Insecticide + virus | 94 A | 0.2 B | 0.8 | 1.0 B | 1.2 | 3.0 | 1.0 |
| Virus only | 96 A | 1.0 B | 1.0 | 2.0 B | 0.7 | 1.0 | 0.2 |
| Untreated | 83 B | 6.0 A | 2.5 | 8.5 A | 4.8 | 2.2 | 1.8 |
| *Probability value for treatment effect from ANOVA* | *0.0032* | *0.0012* | *0.21* | *0.0073* | *0.09* | *0.52* | *0.09* |

[a] Within each column, means followed by same letter are not significantly different ($P$>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

Table 2. Effect of virus and insecticide on insect injury to Liberty apple fruit at harvest, September 2006, mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

| Treatment | Percentage of fruit [a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Clean | Internal Lepidoptera | | | Ap-ple cur-culio | Plum cur-culio ovipo sition | Plum cur-culio late feed ing | San José scale | Tarn-ished plant bug | Leaf-roller | Fruit wom | Unid entif ied[b] |
| | | entry | sting | total | | | | | | | | |
| Insecticide only | 91.9 A | 1.7 B | 1.7 | 3.5 B | 0.5 | 2.0 | 0.0 | 0.5 | 1.5 | 0.0 | 0.2 | 0.0 |
| Insecticide + virus | 90.8 A | 0.2 B | 2.2 | 2.4 B | 0.5 | 2.2 | 0.0 | 2.2 | 2.4 | 0.0 | 0.0 | 0.0 |
| Virus only | 80.2 B | 2.0 B | 5.1 | 7.1 B | 0.7 | 3.5 | 2.5 | 5.2 | 2.0 | 0.2 | 0.0 | 0.0 |
| Untreated | 47.7 C | 20.6 A | 3.5 | 24.1 A | 9.4 | 12.3 | 7.7 | 4.8 | 1.8 | 1.1 | 0.0 | 0.2 |
| *Probability value for treatment effect from ANOVA* | *<0.0001* | *<0.0001* | *0.21* | *0.0008* | *0.09* | *0.11* | *0.21* | *0.11* | *0.38* | *0.28* | *0.44* | *0.44* |

[a] Within each column, means followed by same letter are not significantly different ($P$>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

[b] Damage by an undetermined pest, possibly apple curculio larvae, caused internal damage in some plots. At harvest, this damage was clearly different than internal Lepidoptera damage, but at the mid-summer non-destructive evaluation, it was recorded as internal Lepidoptera damage.

Table 3. Seasonal activity of codling moth and lesser appleworm as monitored by pheromone traps, and degree days for codling moth after trap-based biofix on 5/4/06, in orchards at OSU's Waterman Lab, Columbus Ohio.

| Date | Codling moths caught in previous 7 days | | | | Lesser appleworm caught in previous 7 days | Cumulative degree days[c] after biofix |
|---|---|---|---|---|---|---|
| | Trap 1[a] | Trap 2[a] | Trap 3[b] | Mean of 3 traps | | |
| 4/26 | 0 | 0 | 0 | 0.0 | 0 | – |
| 5/3 | 1 | 1 | 0 | 0.7 | 5 | – |
| 5/10 | 4 | 7 | 12 | 7.7 | 19 | 87 |
| 5/17 | 7 | 0 | 5 | 4.0 | 1 | 131 |
| 5/25 | 11 | 10 | 5 | 8.7 | 6 | 192 |
| 5/31 | 13 | 7 | 4 | 8.0 | 50 | 358 |
| 6/7 | 9 | 6 | 13 | 9.3 | 22 | 470 |
| 6/14 | 3 | 1 | 4 | 2.7 | 9 | 562 |
| 6/21 | 28 | 9 | 12 | 16.3 | 11 | 709 |
| 6/28 | 7 | 4 | 5 | 5.3 | 7 | 861 |
| 7/5 | 6 | 0 | 0 | 2.0 | 5 | 1020 |
| 7/12 | 7 | 0 | 2 | 3.0 | 10 | 1165 |
| 7/19 | 14 | 6 | 2 | 7.3 | 29 | 1365 |
| 7/26 | 16 | 4 | 11 | 10.3 | 18 | 1538 |
| 8/2 | 14 | 7 | 9 | 10.0 | 34 | 1749 |
| 8/9 | 22 | 5 | 6 | 11.0 | 21 | 1936 |
| 8/16 | 12 | 3 | 7 | 7.3 | 6 | 2094 |
| 8/23 | 14 | 5 | 9 | 9.3 | 5 | 2251 |
| 8/30 | 21 | 10 | 12 | 14.3 | 7 | 2413 |
| 9/6 | 8 | 8 | 8 | 8.0 | 12 | 2508 |
| 9/13 | 14 | 6 | 5 | 8.3 | 22 | 2632 |
| 9/20 | 10 | 5 | 1 | 5.3 | 6 | 2719 |
| 9/27 | 6 | 2 | 2 | 3.3 | 3 | 2797 |
| 10/4 | 2 | 2 | 2 | 2.0 | 2 | 2878 |
| 10/11 | 3 | 0 | 0 | 1.2 | 2 | 2942 |

[a] Traps 1 and 2 located in check plots in younger apple orchard 50 meters from orchard where trial was conducted.
[b] Trap 3 located in check plot in apple orchard where virus trial was conducted.
[c] Degree-days calculated as mean of daily maximum and minimum temperature, base 50F, with low cutout at 50F (50F substituted for minimum temperature if actual minimum below 50F) and high cutout at 88F (88F substituted for maximum temperature if actual maximum above 88F).

Table 4. White apple leafhopper density and damage rating on Liberty and Jonafree apple leaves on two dates in 2006, mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

| Treatment | Evaluation on 5/9/06 | Evaluation on 6/12/06 | | | |
|---|---|---|---|---|---|
| | Nymphs/leaf | Nymphs/leaf | | Damage rating [a] | |
| | Liberty | Liberty | Jonafree | Liberty | Jonafree |
| Insecticide only | 0.00 | 0 | 0 | 0.33 | 0.15 |
| Insecticide + virus | 0.02 | 0 | 0 | 0.31 | 0.10 |
| Virus only | 0.01 | 0 | 0 | 0.46 | 0.19 |
| Untreated | 0.16 | 0.06 | 0.08 | 0.58 | 0.46 |
| *Probability value for treatment effect from ANOVA* | *0.30* | *0.44* | *0.09* | *0.34* | *0.18* |

[a] Damage rating scale: 0 = none; 1 = light; 2 = moderate; 3 = heavy.

Table 5. Number of European red mite (ERM) motiles, ERM eggs, phytoseiid predatory mite motiles, stigmaeid predatory mite motiles per leaf, and density rating for apple rust mite on Liberty apple leaves in four treatments on two sampling dates in 2006, mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

| Treatment | Number per leaf | | | | | | | | Density rating[a] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ERM motiles | | ERM eggs | | Phytoseiids | | Stigmaeids | | Apple Rust Mite | |
| | 5/22 | 8/22 | 5/22 | 8/22 | 5/22 | 8/22 | 5/22 | 8/22 | 5/22 | 8/22 |
| Insecticide only | 0.10 | 0 | 3.0 | 0.1 | 0.06 | 0 | 0 | 0.46 | 1.5 | 0 |
| Insecticide + virus | 0.02 | 0.02 | 0.8 | 0 | 0 | 0.04 | 0 | 0.26 | 0.8 | 0 |
| Virus only | 0.44 | 0 | 5.4 | 0 | 0.02 | 0.02 | 0.04 | 0.40 | 1.5 | 0 |
| Untreated | 0.04 | 0.02 | 0.4 | 0 | 0.02 | 0.02 | 0 | 0.48 | 0.8 | 0 |
| *Probability value for treatment effect from ANOVA* | *0.41* | *0.63* | *0.48* | *0.13* | *0.07* | *0.55* | *0.44* | *0.93* | *0.09* | – |

[a] Density rating scale: 0 = none; 1 = low (<5 per leaf); 2 = moderate (5 to 50 per leaf); 3 = high (>50 per leaf).