FINAL PROJECT REPORT **YEAR 2/2**
WTFRC Project # 04-432

Project title: Spinosad and granulovirus effects on codling moth
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OBJECTIVES:

1. Compare the efficacy of Entrust (spinosad) and codling moth granulovirus (CpGV) at recommended label rates and application frequencies for codling moth control.
2. Determine the impact of such applications on the population density and diversity of beneficial insects and other nontarget organisms in the orchard agroecosystem.

SIGNIFICANT FINDINGS:

- Spinosad was effective at suppressing codling moth populations in apple and pear (e.g. < 2% fruit damage in a heavily infested Bartlett pear in an experimental orchard).
- CpGV was less effective than spinosad at preventing fruit damage, but killed the majority of CM larvae that reached the fruit. CpGV appeared to be more effective against the first larval generation of CM.
- The predatory mirid *Deraeocoris* spp. were frequently found in spinosad-treated plots and showed no negative effects of the spinosad treatment.
- Spinosad reduced the abundance of parasitoids, *Anthocoris* spp. and non-target Diptera in small plots, but we did not observe any resultant increase in pest densities.
- No evidence for phytophagous mite resurgence (2 species) resulting from spinosad use.
- Sweep net samples suggested several epigeal taxa were not affected by spinosad treatments.

METHODS

Efficacy of CpGV and spinosad on codling moth

Experimental orchard: In 2004 and 2005 we compared the efficacy of codling moth granulovirus (Cyd-X, Certis, USA) and spinosad (Entrust, Dow Agrosciences) in replicated Bartlett pear blocks at the USDA experimental orchard in Moxee, WA. Treatments were applied in a full-season for program for codling moth using an ATV-mounted 25 gal. airblast sprayer (Hauff Company, Yakima WA). A large tarp was used to minimize contamination between plots and spraying occurred early morning during calm conditions. Applications were made at 7-8 day intervals throughout the season (starting 250 DD post biofix in each generation) in accordance with pheromone trap catches and the WSU phenology model (Beers et al. 1993). The study was a complete randomized block design with 5 (2004) or 4 (2005) replicates for each treatment including an untreated control (12-16 trees per block). Entrust and Cyd-X were applied within recommended label rates (3 fl.oz/A for both) plus sticker (NuFilm17 @ 8 fl.oz/A) at volume application rate of 100 gal./A. Fruit damage was assessed mid season (after the first larval generation) and before harvest from a minimum of 150 fruit/block. Wormy fruit from the virus and untreated control blocks were returned to the laboratory and dissected to assess mortality of larvae inside the fruit.

Commercial orchards: Trials were conducted in commercial orchards where formulations of spinosad (Entrust or Success) and CpGV (Cyd-X or Carpovirusine) were used operationally; mixed pear (Mellow) and Delicious (Knutson). Growers applied spinosad or CpGV in separate blocks (2 replicate blocks per treatment each approximately 1 A). Application rate and frequency were in accordance with label recommendations and localized pest pressure determined on site. Treatment blocks were sprayed concurrently (within 2 days of each other) at 7-10 day intervals starting at ca. 250 DD. Because spinosad is restricted for resistance management (9 oz/A season for Entrust, 29 oz/A for Success), in the second larval generation it was either alternated with the virus treatment (Mellow) or replaced with an IGR (Intrepid) in the Delicious blocks (Knutson). In a mixed 6 A Golden Delicious/Granny Smith orchard another grower (Ing) replaced part of his OP program (Imidan) with the Carpovirusine formulation of CpGV.

Non-target effects of spinosad and CpGV
In the Moxee trial, beat trays samples were conducted to monitor the abundance of beneficial species including predatory bugs, spiders, lady beetles, lacewings and parasitoids. Pear psylla (Homoptera: Psyllidae), which were the predominant herbivore prey associated with population of beneficial species, were also noted. The central 4 trees in each plot were sampled early in the morning every 1-2 weeks (2004) or 7-10 days (2005) and seasonal trends compared between the different spray treatments. Sweep net samples were also used to census leafhoppers and other non-target taxa on the orchard floor during spraying periods. The central area of each plot was used for collecting samples. Leaf and shoot samples were also monitored for aphids and mites outbreaks within the plots. In addition collections of pear psylla nymphs were made twice to estimate levels of parasitism by *Trechnites insidiosus* or other parasitoids.

Because of anacedotal reports of pest resurgence (aphids and mites) in plots treated with spinosad in 2003 and supporting literature on spinosad's toxicity to certain beneficials found in orchards, we compared late season populations of phytophagous mites in spinosad-treated plots with CpGV and untreated plots at Moxee and a commercial orchard (Mellow).

RESULTS AND DISCUSSION

Efficacy of CpGV and spinosad on codling moth
Experimental orchard: First generation codling moth infestations were not severe in either year (younger fruit were apparently difficult for larvae to penetrate) but significant damage occurred following the second flight, especially in 2005 (Table 1). Entrust worked well at protecting fruit with ≤1.8% injury in both years, compared with up to 37% fruit injury in the untreated blocks. Cyd-X was less effective at protecting fruit in both years, although were fewer deep entries (> ¼″) in virus treated fruit (39 ± 8.7%) compared with untreated fruit (82 ± 4.2%) and some fruit may have still been suitable for processing. The majority of larvae inside virus-treated fruit were dead (also indicated by shallow failed stings). Larval mortality was 71% in 2004 versus 20% on controls and 70% in 2005 versus 23% in controls (at harvest), suggesting the virus is more effective at population suppression in the second generation than prevention of fruit injury. These rates of larval mortality are lower than we have observed with apples treated at equivalent rates of virus (Arthurs et al. 2005).

Commercial orchards: Data from commercial orchards are shown in Tables 2-4.

There was a relatively high initial infestation in the mixed pear orchard (Mellow), with Bartlett the more susceptible variety to codling moth compared with Anjou (Table 2). Both spray programs (i.e. Cyd-X followed by Entrust against the first and second generations respectively and visa versa) were effective at reducing fruit injury and significantly reduced trap catches in the second year. Lowest damage occurred when Entrust was applied against the first larval generation. The grower felt satisfied the programs were effective for CM control and dropped the virus application rate from 3 to 1.5 fl.oz/A in the second year. Larval mortality varied from 63-90% in sprayed fruit in the blocks.

In Delicious, Success was more effective at protecting fruit compared with virus in the 1st generation; although the vast majority (average 92%) of CM were killed in the virus plots indicating the virus was highly effective at population suppression early in the season (Table 3). Virus was less effective compared with an IGR (Intrepid) against second generation larvae (66% mortality), although at harvest fruit damage was similar (3.5 - 4.1%) between the blocks treated with either program. A protracted emergence from a large fruit bin pile was responsible for the increased late season damage in these plots.

Carpovirusine applied at 10-d intervals killed 91-93% CM larvae in the 1^{st} and 2^{nd} generation respectively, but was not as effective as Imidan at protecting fruit (Table 4).

Table 1. Efficacy of spinosad (Entrust) and codling moth virus (Cyd-X) in Bartlett pear over 2 years; % fruit injury in replicated 12-16 tree blocks (Moxee experimental orchard).

Treatment	2004		2005	
	Mid season	Harvest	Mid season	Harvest
Untreated control	0.45	14.8a	3.9a	36.9a
Cyd-X	0.19	11.6a	0.9b	26.0a
Entrust	0.00	1.2b	0.9b	1.8b

Different letters indicate significant differences (P<0.05, Fisher's LSD)

Table 2. Efficacy of spinosad (Entrust) and codling moth virus (Cyd-X) over 2 years; % fruit injury in 1A pear blocks (2 replicates per spray program) in Hood River, OR (Mellow). The Entrust and Cyd-X blocks were switched between the first and second generations to avoid the 9 oz/A cap with Entrust.

Spray program $1^{st}/2^{nd}$ generation	cv.	2004		2005	
		Mid season	Harvest	Mid season	Harvest
Cyd-X/Entrust	Bartlett	8.3a	na	1.4	1.2
	Anjou	1.9b	1.1	0.4	na
Entrust/Cyd-X	Bartlett	6.2a	na	0.7	0.5
	Anjou	0.8b	2.4	0.0	na

Different letters indicate significant differences (P<0.05, Fisher's LSD)
na = not assessed

Table 3. Efficacy of codling moth virus (Cyd-X or Carpovirusine) versus spinosad (Success) in 1 A blocks of Delicious (2 replicates per spray program). Data shows % CM fruit injury and mortality in sprayed fruit. Success was replaced with Intrepid in the second generation (Knutson, Mattawa).

Spray program $1^{st}/2^{nd}$ generation	Mid-season (450 fruit/block)		Harvest (1080 fruit/block)	
	% injury	% mortality	% injury	% mortality
CM virus	3.3	92.5	3.5	66.0a
Success/ Intrepid	0.8	80.0	4.1	82.0b

Different letters indicate significant differences (P<0.05, independent T-test)

Table 4. Efficacy of codling moth virus (Carpovirusine) versus Imidan in 6A Golden Delicious and Granny Smith. Data shows % CM fruit injury and mortality in virus sprayed fruit in unreplicated plots (Ing, Hood River).

	Mid-season (n = 1056 fruit)	Harvest (n = 3357 fruit)

Spray program (interval)	Mid-season (n = 1056 fruit)		Harvest (n = 3357 fruit)	
	% injury	% mortality	% injury	% mortality
Carpovirusine (10 days)	4.5	91.8	6.3	92.9
Imidan (20 days)	0.25	NA	0.33	NA

Non-target effects of spinosad and CpGV

Data from beating tray samples in the experimental plots are shown in Figure 1. In both years a mid-season peak of pear psylla (1st adult summer generation) was not observed in the spinosad plot, although unaffected by virus treatments. The reasons are unclear, but suggest psylla fecundity or oviposition was reduced by spinosad applications. However, a key psylla predator, the mirid *Deraeocoris brevis*, was apparently unaffected by spinosad treatments, despite the reduced density of its main prey, and undoubtedly contributed to the decline in psylla populations. Although most commonly a pest during bloom, secondary populations of thrips (predominantly *Frankliniella occidentalis*) were suppressed by spinosad treatments. Although less frequent than *D. brevis*, mid-season populations of another predator, *Anthocoris* spp., and to a lesser extent lacewings (*Crysoperla* spp. and *Hemerobius* spp.) were reduced by spinosad treatments. There was no evidence that the large diversity of spiders recovered from the foliage was affected by spinosad treatments. Populations of other beneficials including ladybeetles, *Orius* spp. and hoverflies (Syrphidae) remained fairly low throughout the season. Secondary outbreaks of aphids have been noted by growers following spinosad use, although aphid populations remained below damaging thresholds in our plots. Overall biological control of aphids was effective; a mid-season outbreak of apple aphid (*Aphis pomi*) was noted in one of the Entrust-plots, but quickly bought under control by beneficials. Other secondary pests including western tentiform leaf miner *Phyllonorycter elmaella*, *Campylomma verbasci*, *Geocoris* spp. stink bugs, lygus bugs and leafhoppers (mainly the white apple leafhopper *Typhlocyba pomaria*) were present but remained below damaging thresholds in all plots.

The most significant negative of spinosad on beneficials was noted for parasitoids, of which a wide diversity were noted (Figure 2). Other research indicates spinosad is directly toxic to a wide range parasitoids (Hill and Foster, 2000; Consoli et al., 2001; Mason et al., 2002; Williams et al., 2003). It was not clear if the reduction in parasitoids in our study may have been partly mediated by the reduced prey (psylla), although parasitoids mainly comprised encyrtids (Figure 2), of which 51% were *Trechnites insidiosus* (an important parasitoid of psylla). In conclusion, spinosad treatments negatively affected parasitoids and some predators, but not *D. brevis*, but we did not observe any resultant increase in pest densities. However care should be taken in extrapolating these results to orchards where few or no beneficial species are present to control outbreaks of aphids or other phytophagous pests.

Late season assessments of leaf samples with a leaf brushing machine revealed no difference in the abundance of phytophagous mites between spinosad, virus-treated or untreated plots; species sampled were pear rust mite (PRM), *Epitremerus pyri,* and pearleaf blister mite, *Phytoptus pyri* (Figures 3 and 4).

Sweep net samples also revealed no differences in abundance of several epigeal taxa, notably leafhoppers (comprising 74% *Dikraneura* spp.) (Figure 5). However several non-target dipterans, mainly fungus gnats (family Mycetophilidae) and shore flies (family Ephydridae), were less commonly recovered from spinosad-treated plots. Spider and adults syrphids were also recorded, but may not have been reliably captured. A more complete dataset for 2005 is still being collated.

Figure 1. Psylla, aphids, thrips and non-target taxa monitored with beating trays (Bartlett pear, Moxee 2004). Data show mean for 16 tree plots (4 or 5 replicates). Arrows show timing of spray treatments.

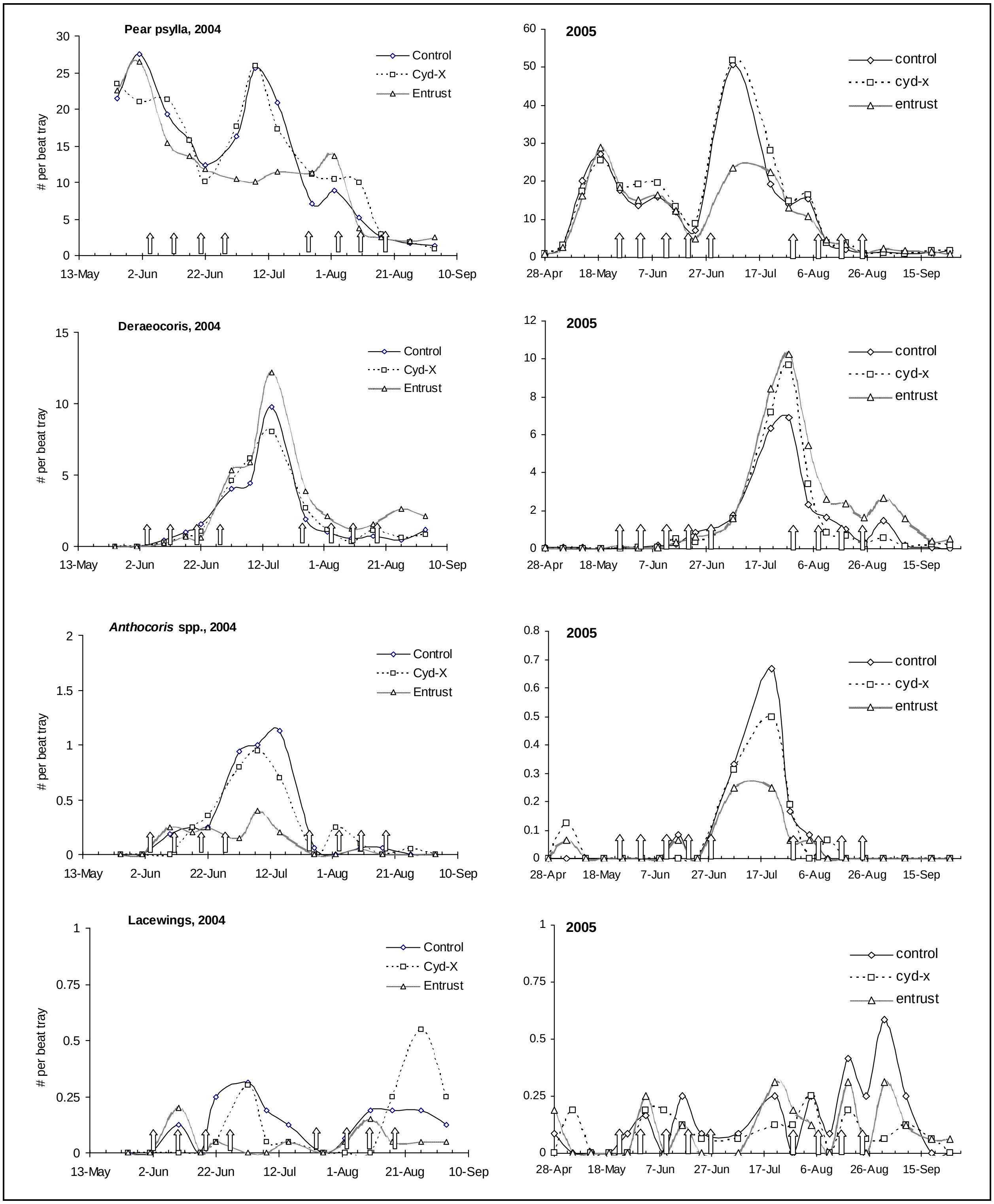
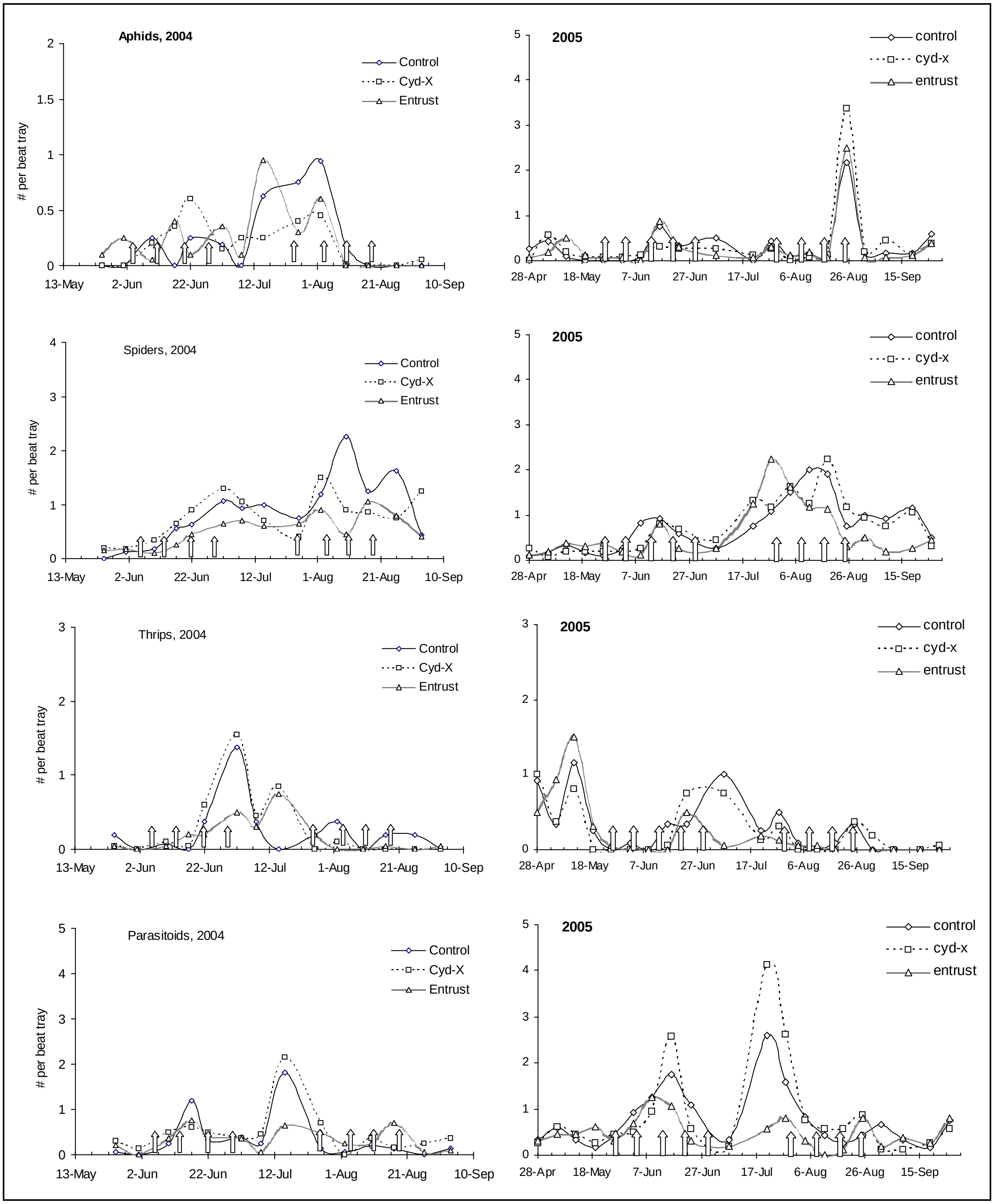


Figure 1. (cont.)



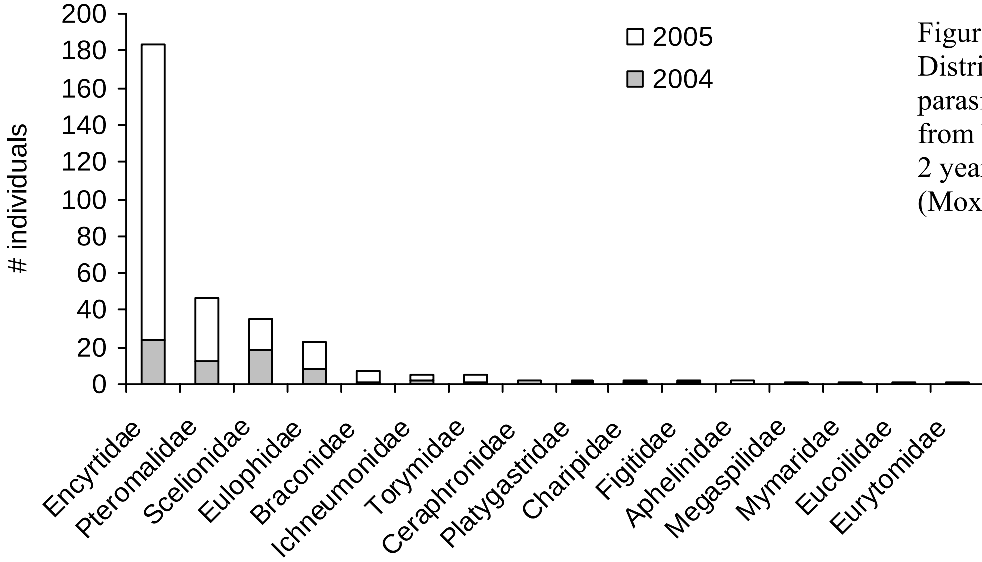


Figure 2. Distribution of parasitoids collected from beat trays over 2 years, Bartlett pear (Moxee)

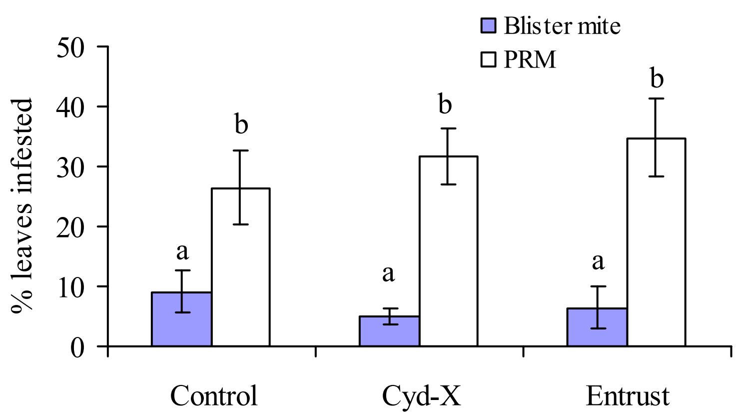


Figure 3. Tests for late season mite resurgence in 2004, Bartlett pear; 12-16 tree blocks replicated 4 or 5 times (Moxee)

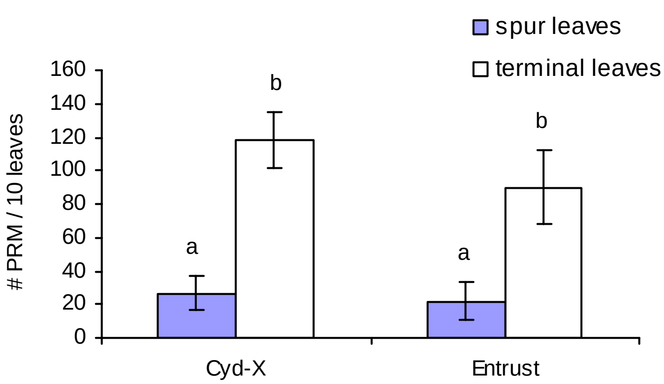


Figure 4. Tests for late season mite resurgence in 2004, Anjou; 1A blocks replicated twice (Mellow)

Conclusion

Codling moth granulovirus was less effective than spinosad at preventing fruit damage, but killed the majority of CM larvae that reached the fruit and was safe for non-targets. Spinosad reduced the abundance of parasitoids, *Anthocoris* spp. and non-target Diptera in small plots. We found no evidence for increased densities of phytophagous pests or mite resurgence resulting from spinosad use.

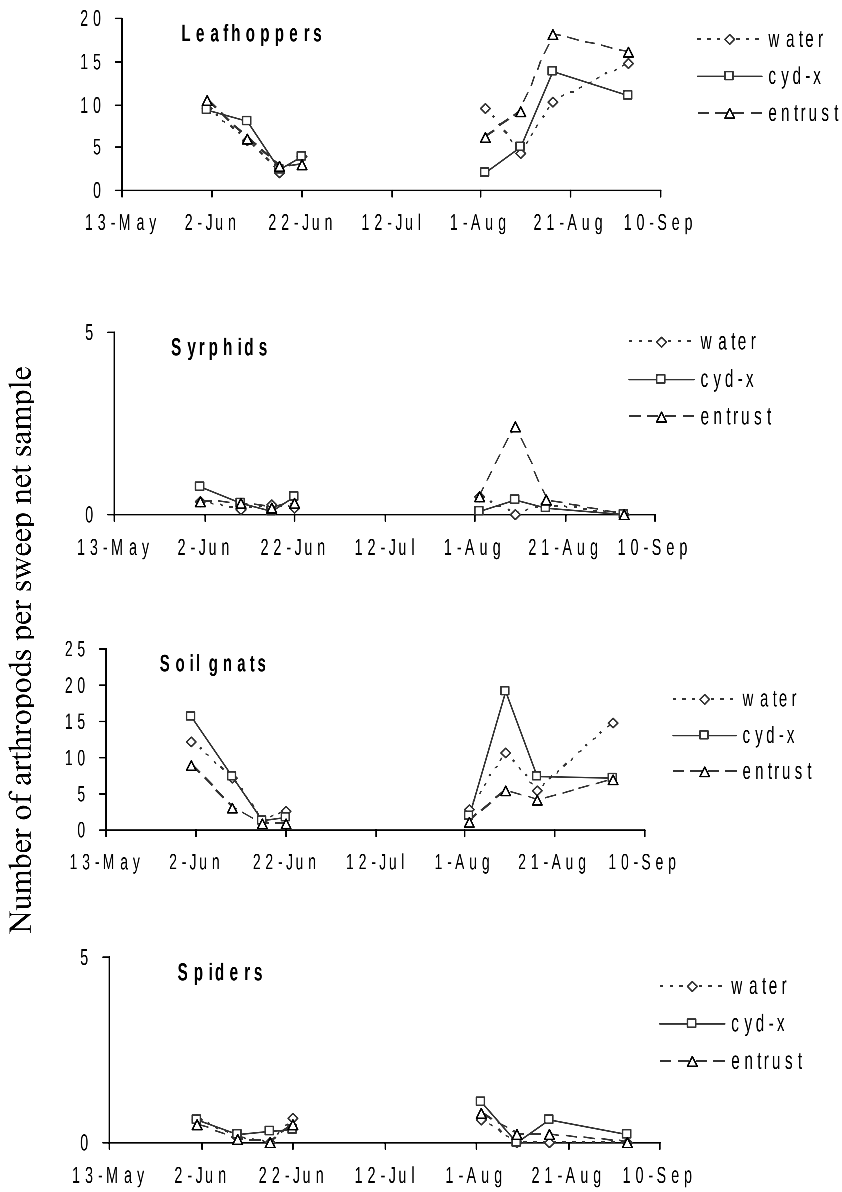


Figure 5. Non-target taxa monitored in sweep net samples. Treatments were applied at approx. 8-day intervals in replicated 12-16 tree plots. (Bartlett pear, Moxee experimental station).

REFERENCES

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BUDGET SUMMARY

Title: Impact of Entrust (Spinosad) and codling moth granulovirus on codling moth, beneficials and other nontarget organisms in apple and pear.
PI: Lawrence A. Lacey
Project duration: 2004-2005 (2 years)
Project total: $30,000

	2004	2005
Salaries and wages (includes benefits)		
Technician, partial support for GS-4	10,000	10,000
Summer help, GS-3, 1 FTE (3 mos.)	3,500	3,500
Subtotal	$13,500	$13,500
chemicals, plasticware, misc. materials	1,500	1,500
Subtotal	1,500	1,500
Total	$15,000	$15,000