Testing the "PETE" Insect Development Prediction Model to Limit the Resurgence of Codling Moth in Apples

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Codling moth (CM) is becoming an increasing problem in apple orchards complicating Integrated Pest Management (IPM) strategies for apple pests. The trend of larvae detection in apples at receiving stations (mainly processors) is steadily increasing and if current trends remain, Western NY State will approach 600 truckloads of apples with larvae detected from as many as 150 growers in 2009 (Figure 1). The hotter and drier the season, the greater the infestation by codling moth. Increased infestations will result in increased loss of fruit value for growers in most seasons. Any fresh fruit infested with worms is culled with little or no loss in value. In response to the high economic risk of minimal fruit infestation of processing fruit, growers and consultants may revert to the old system of cover sprays at 10 to 14 day intervals. Although this may be warranted for some orchards, this would be a step back for IPM programs in NY, which have taken years to develop. However, the current IPM programs have many tools – tools that can be implemented to improve control of CM for most growers.

> "Codling moth is the predominant worm found in Western NY State apples in recent years. Without improved management of this pest we predict that more than 600 truckloads of apples will have larvae detections in 2009. The PETE model was used to predict spray timing but it did not accurately predict the timing of sprays to control codling moth in high population blocks. A Modified PETE model that used trap catches and degree days was much better at predicting the timing of sprays and should help NY growers better control this pest."

When the industry began to note increases in fruit damage due to internal lepidopteran larvae, processor receiving stations and a few fresh apple packers collected the larva samples for identification by Cornell Cooperative Extension. We identified the proportion of larvae as CM, Oriental fruit moth (OFM), and lesser appleworm (LAW) from 2002-2008 (Table 1). The proportion of codling moth in NY apples compared to other internal fruit feeders has increased from 21% of larvae found in infested fruit in 2002, to 88% in 2007. In the early years the primary pest was OFM accounting for 60-80% of the larvae found. The population dynamic is clearly leaning toward CM as the main pest but there are still growers with mixed populations.

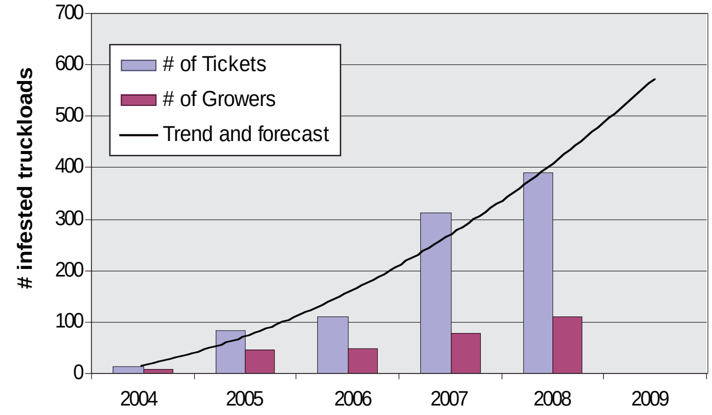

Figure 1. Trend of truckloads and growers with Lep infested fruit from 2004-2008 in Western NY State.

Most of the truckloads identified with infested fruits from the fruit inspection surveys collected from processors have had only 1% of the fruit infested (Figure 2). Although there were 391 truckloads of fruit with larvae detected at inspection, only 24 loads had more than 2% infestation and were actually rejected for sauce and downgraded to juice in 2008 since infestations levels were very low. If the infestation level in 2009 is greater than that measured in 2008, many more loads will have to be downgraded to juice. If processors had used a zero tolerance of internal fruit worms, then the 2008 infestation level would have resulted in more than $500,000 loss in fruit value. Over the next several years, the infestation level of these pests is likely to increase unless there is a focus on control for these pests. In addition,

Table 1. Internal Lepidoperan Larva ID Trends 2002-2008 in Western NY State.

Pest	2002	2005	2006	2007	2008
CM	21	56	49	88	74
OFM	61	20	24	10	26
LAW	11	7	6	2	
unknown	7	16	15		

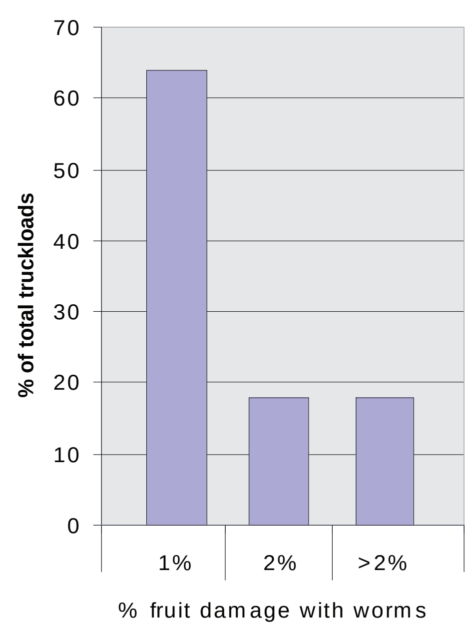

Figure 2. Percent of truckloads with worms at low, medium and high infestation levels in Western NY State in 2008.

the cost of management of CM in a very high pressure could require as much as $300/acre for control.

Approaches to Management of Codling Moth

When a new pest strikes, the first step after identification is to understand the biology of the insect. The next step is to identify the weakness in the life history of the insect; then, review the tools that may be available for various stages in its life history. The first tools for use against new pests are monitoring methods for adult activity with pheromone traps and implementing any existing insect development models based on degree-days. We have been managing an extensive trap network along the lakeshore counties for the past several years to include CM, OFM, and LAW and have been documenting significantly higher populations in some orchards.

In the early 70's, researchers in Michigan (Reidl et al., 1976) produced a CM timing model based on physiology of the insect development correlated with degree-day accumulation for control of CM that has been incorporated into our management program in some fashion for many years in several locations. The model is called the "PETE" model (Predictive Extension Timing Estimator), and is based on first sustained trap catch for the season to predict first and second generation egg hatch and control timing. The model is based on the assumption that the biofix is the same for most orchards in a region. However, using this standard model has resulted in less than satisfactory control for some growers not only in NY but in other states including Washington (Knight 2007; Jones et al. 2008) and Pennsylvania.

Field Trials

In 2007 and 2008 we conducted a project funded by the New York Farm Viability Institute to test the "PETE" model developed at Michigan State University to predict egg hatch and larval development of codling moth and more accurately time insecticide applications to mitigate the risk of infestation.

Four growers assisted with validation of the "PETE" degree-day model to predict and manage egg hatch for control of codling moth in NY. The growers compared two spray timing models: a) MSU "PETE" CM model with recommended timing of 200-250 DD (using a base temperature of 50 degrees F and 1250 DD after the first trap catch of the season, followed by a second application for each generation 10-14 days after the first, and if greater than five moths per trap per week, then continue spraying for the third "suicide" generation, b) "Modified PETE" – an alternative CM model based on seasonal trap data with the first spray applied at 200-250 DD after sustained flight using the base temperature of 50 degrees F, but then including additional sprays timed about 200 DD after the high catch of moths using a suggested trap threshold of five moths per trap per week. The "Modified PETE" treatments incorporated the degree-day timing for the first generation but continued to incorporate weekly trap numbers and the addition of 200-250 DD50F after high trap catch for additional control for the remainder of the season. The "Grower Standard" was generally a compromise of the two treatments.

Results

We have observed a great variability in the date of first sustained trap catch across the Lake Ontario fruit belt, even within the same town. In 2007, the biofix date ranged from May 15 to June 5; and in 2008, from May 15 to June 10. Therefore the prediction of first egg hatch, and application of the first insecticide targeting CM can vary by as much as two-three weeks.

The model also assumes a fairly condensed flight of the first generation of moths emerging in the spring. Our trap data show that there is often a lag in the first generation of moths, extending flight out from mid-bloom to mid-July, consequently extending the egg hatch period for the first generation. Testing and adapting the "PETE" model for NY will help fruit growers optimize

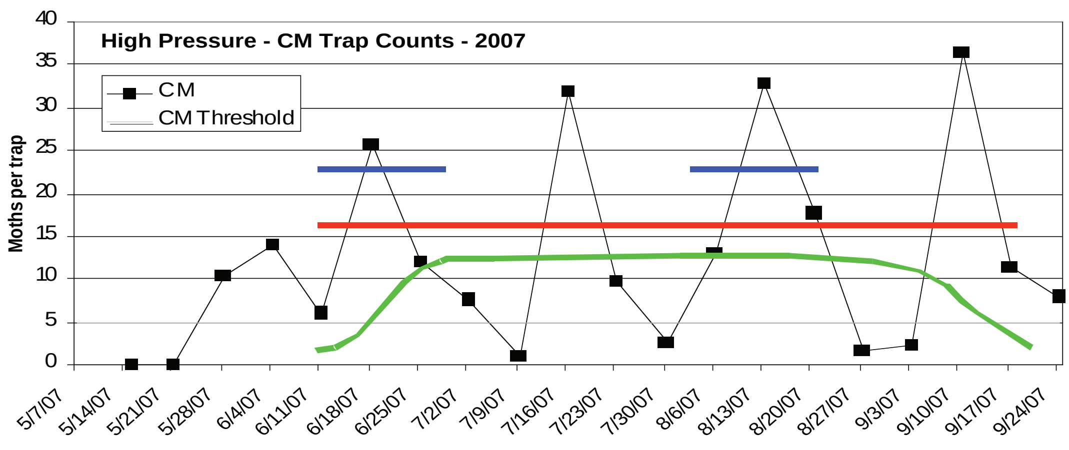

Figure 3. Seasonal trap catches of CM in high pressure orchards in Western NY State in 2007. Green line is predicted egg hatch; blue line is suggested spray coverage windows using the "PETE" model; and red line is suggested spray coverage windows using the "Modified-PETE" model.

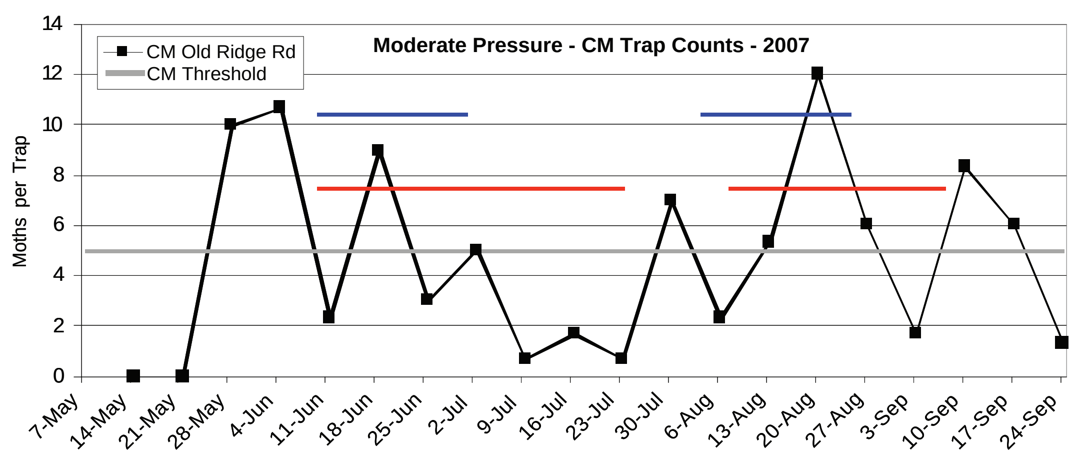

Figure 4. Seasonal trap catches of CM in moderate pressure orchards in Western NY State in 2007. Blue line is suggested spray coverage windows using the "PETE" model; and red line is suggested spray coverage windows using the "Modified-PETE" model.

pesticide usage by improving predictions of egg hatch of CM, improving timing of insecticide applications, and ultimately improving control results.

The first season of testing under the resurgence of CM in NY showed that the "PETE" model was not adequate for control of high populations of CM in orchards with total seasonal trap catch of 150 or more per trap. In low populations with seasonal trap catch of less than 50 moths per trap, the "PETE" model recommended too many sprays. Figures 3-5 show the predicted egg-hatch periods in 2007 and the resulting windows when insecticide spray coverage was recommended by the "PETE" vs. "Mod-PETE" models. Figures 6-8 show the recommended spray coverage windows for "PETE" vs. "Mod-PETE" models for 2008. Figures 3 and 6 show that under relatively high CM pressure and a consistent flight throughout the season, there are no open spray coverage windows in the "Mod-PETE" treatment after the first spray recommended by the "PETE" model because of continuous flight and predicted egg hatch. But there were only four to five sprays recommended using the "PETE" model. Under moderate pressure, Figures 4 and 7 show only a small gap between the first generation and second-generation spray coverage windows recommended in the "Mod-PETE" due to an extended flight activity of the first moth flight. The spray coverage windows in the low pressure site (Figure 5) were overestimated by the "PETE" model, suggesting only one application would be made for the first generation starting at 250-350 DD50F, but the second generation sprays seemed unwarranted at the 1250 DD50F timing of the "PETE" model in 2007, but the "Mod-PETE" model recommended the second generation spray later in the season to respond to the late flight of CM exceeding the suggested trap threshold on August 13. In 2008, Figure 8 shows the second spray might have been late if following the "PETE" model.

In the second season, growers implemented mating disruption pheromones in the two high- pressure orchards trying to alleviate some of the dependence on insecticides as demonstrated in 2007. Site P3 used SPLAT (a flowable wax formulation) and P4 used Checkmate Duel (a hand-applied membrane dispenser). Using mating disruption for CM reduced catch per trap by 44% in orchard P3 and 88% in P4; and OFM by 77% in P3 and 97% in P4 (Table 2). Both of these high-pressure orchards were adjacent to abandoned sites. The trap catch reduction implied some reduction of the potential mating, egg laying, and egg hatch, so these orchards were, theoretically, more like moderate pressure sites with less difference in control. However, the actual pheromone traps, especially in P3 shown in Figure 6, did not actually result in reduced spray recommendations using the "Mod-PETE" model.

Fruit damage was rated as "deep" when larvae penetrated more than 1/8 inch deep and often to the core, or "sting" when CM created only a small hole in the skin and penetrated less than 1/8 inch deep. The first season, there was significantly more fruit damage in the "PETE" model treatments in orchards P2 and P3, with more "deep" damage in P4 (Table 3). The incidence of larvae found was low in all treatments in all orchards except for P4, which resulted in detections at the receiving stations. The second season, there was no significant difference between treatments in any of the four orchards due to the reduction in population pressure however, control in P4 was less effective than P3 orchard which was comparable in population pressure.

More sprays were recommended for CM in the "Mod-PETE" treatment in "High' and "Moderate" population orchards due to high trap counts extending past the treatment timings recommended by the "PETE" model. The "PETE" model recommended two sprays per generation starting at 220-250 DD50F for the first and 1250 DD50F for the second generation. Orchard P1, with a low population of CM, showed for two seasons that the "PETE" model recommended more sprays than actually necessary for control of CM (Table 4). Fewer sprays were applied in the P1

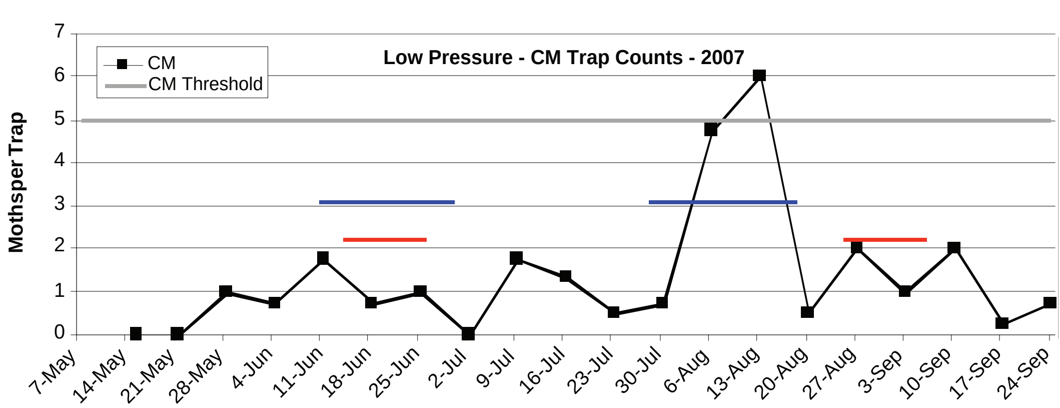

Figure 5. Seasonal trap catches of CM in low pressure orchards in Western NY State in 2007. Blue line is suggested spray coverage windows using the "PETE" model; and red line is suggested spray coverage windows using the "Modified-PETE" model.

"Mod-PETE" plot with no difference in control results. However, the moderate population in P2 had five sprays recommended, three against the first generation and two against the second with a possible late application for a third generation in September for late harvested varieties. P3 and 4, however, had very high populations the first season, requiring continual spray coverage in the "Mod-PETE" plots, compared to four-five sprays recommended by the "PETE" model. Even in the second season of the "PETE" test with mating disruption, it was necessary to recommend an additional insecticide spray due to high trap counts. However, in the second season, no additional control was observed from the increased insecticide applications for the "Mod-PETE" plots compared to the "PETE" treatment timings when using mating disruption. Control results in P4 were not satisfactory even with the additional investment of mating disruption pheromones. This led to an investigation of other possible factors impacting on control including sprayer calibration and spray coverage testing.

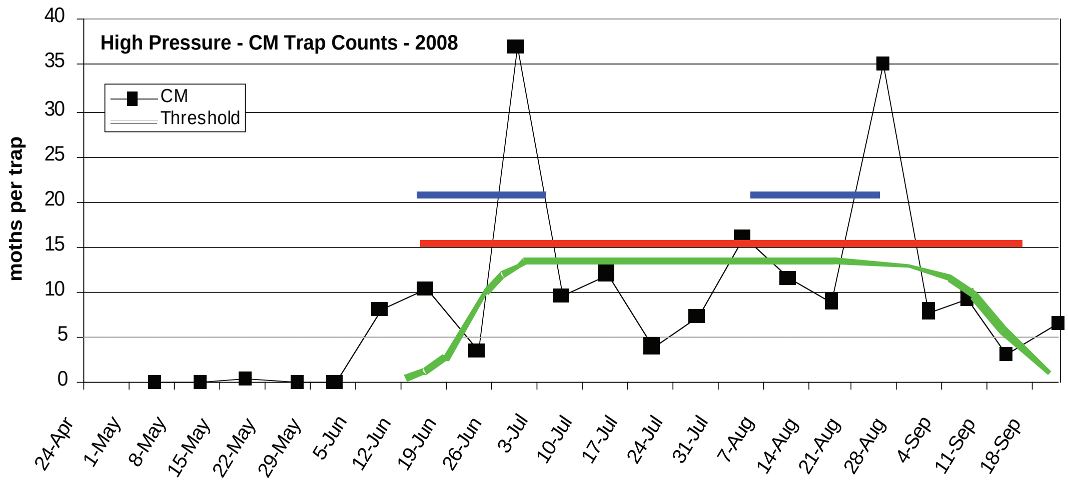

Figure 6. Seasonal trap catches of CM in high pressure orchards in Western NY State in 2008. Green line is predicted egg hatch; blue line is suggested spray coverage windows using the "PETE" model; and red line is suggested spray coverage windows using the "Modified-PETE" model.

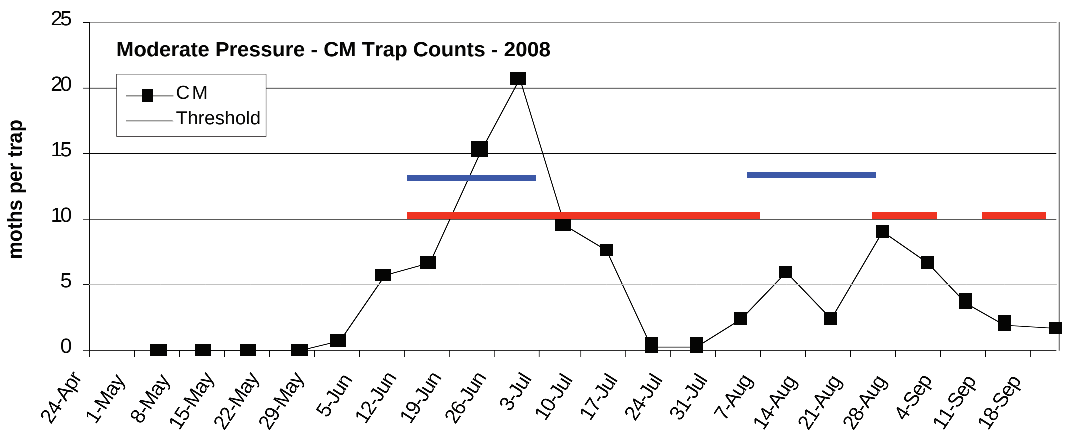

Figure 7. Seasonal trap catches of CM in moderate pressure orchards in Western NY State in 2008. Blue line is suggested spray coverage windows using the "PETE" model; and red line is suggested spray coverage windows using the "Modified-PETE" model.

Conclusions

In the past, when control of CM was done with organophosphate pesticides to control adult insects (moths), the "PETE" model was very effective and useful in timing insecticide applications. However, many researchers across the country have noted a loss of efficacy of the organophosphates, or pyrethroids on adults, shifting the control strategy to using newer insecticide chemistries, which have little or no effect on adults but rather control young larvae. This necessitates a prediction of egg hatch and sometimes sprays must be adjusted to a different timing.

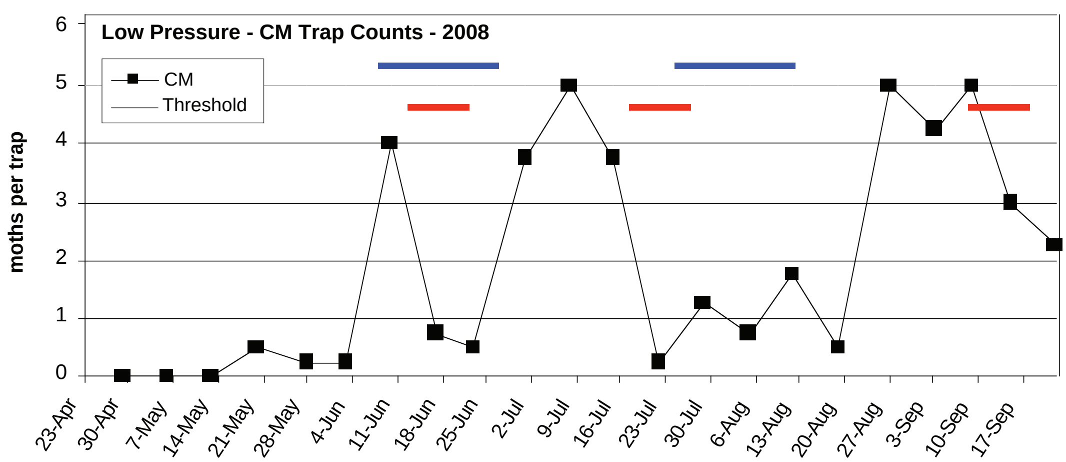

Figure 8. Seasonal trap catches of CM in low pressure orchards in Western NY State in 2008. Blue line is suggested spray coverage windows using the "PETE" model; and red line is suggested spray coverage windows using the "Modified-PETE" model.

Using a regional biofix to run the "PETE" model for regional insecticide application timings could lead growers into a false sense of security. In 2007, the date of biofix ranged between May 15 to June 5; and in 2008, from May 15 to June 10. It is critical for growers to have pheromone traps on their farms to document the biofix date in problem blocks, and/or in orchards where there

Table 2. Seasonal totals trap catches of CM and OFM by block in 2007 and 2008 in Western NY State.

	P1		P2		P3		P4	
PEST	2007	2008	2007	2008	2007	2008	2007	2008
CM	27	43	93	101	244	137	213	26
OFM	207	418	163	216	382	86	253	8

has been no history of fruit infestation. The biofix date is essential to identify the critical spray window for early egg hatch.

In general, there was essentially no difference in implementing the first generation insecticide sprays between the two models since the first sustained flight and consequential egg hatch starts at 220-250 DD50F. The difference in timing recommendations between the two models was in the recommendation for three sprays for the first generation in the "Mod-PETE" plots when observing continuous or extended emergence of adult moths of the first generation into July. This extended flight has been referred to as the "B" peak, and if it escapes control will lead to an offset second generation after the normal second generation from the "A" peak flight resulting in essentially continuous seasonal adult activity. The biggest difference between the two models was the suggested delay in spraying the "PETE" model when trap data was calling for sprays with the "Mod-PETE" model.

The second-generation timings predicted by "PETE" were not correlated with the beginning of egg hatch relative to high trap catch. In high pressure orchards, the Mod-"PETE" model spray windows overlapped the "PETE" recommendations for the second generation, but the "PETE" timing recommendations did not extend late enough into the season. The "Mod-PETE" model recommended three sprays for the second generation. CM populations actually get high enough in some orchards that the 10-14 day spray interval of past calendar spray programs is necessary to control this pest.

The weaknesses we have identified in the "PETE" model appear to be nationwide and there appears to be consensus emerging that we should time sprays by egg-hatch predictions using the 200-250 D50F after the beginning of each flight for the best control. In the future it will be critical to understand how the new pesticide materials affect newly hatching larvae and how the degree-day timing model should be adjusted for the various chemistries. In light of the resistance to organophosphates, pyrethroids, and carbamates being reported around the country, it is important to consider insecticide choice for orchards with a history of infested fruit or "worm holes." Growers should review the insecticide ratings in the Cornell 2009 Pest Management Guidelines for Commercial Fruit Production in Table 12 on page 65, and pick the materials rated with a "3" (= good) when targeting critical timing windows.

Presentations at NY fruit schools in 2009 have provided some guidelines regarding when to apply various chemistries:

- Rimon (registration not anticipated in NY in 2009) should be applied at 75-100 DD 50F since the target is the egg.
- Intrepid and Neonicotinoids including Calypso and Assail at peak egg laying and prior to egg hatch at 150-220 DD50F.
- Granulosis virus such as Cyd-X, Virosoft, or Carpovirusine at first generation egg hatch, 220-250 DD50F.
- Delegate and Altacor (check NY registration status) at first egg hatch, 220-250 DD.

Table 3. Fruit damage from internal Leps at harvest using the PETE and Modified-PETE models in 2007 and 2008 in Western NY State

			% Fruit Damage at Harvest from Internal Leps					
			2007			2008		
Pressure	Farm	Treatment	% deep	% sting	% worms	% deep	% sting	% worms
Low	P1	PETE	0.0	0.3	0	0	0.1	0.1
		Modified PETE	0.0	0.2	0	0	0	0
		Grower Std	0.0	0.1	0	0.1	0	0
Moderate	P2	PETE	0.2	2.3 a	0 b	0.1	0	0
		Modified PETE	0.1	0.8 b	0 b	0	0	0
		Grower Std	0.7	0.3 b	0.5 a	0	0	0
High	P3	PETE	2.5 a	2	0.5 a	0.8	0.9	0.1
		Modified PETE	0.2 b	1.1	0 b	0.9	1.5	0
		Grower Std	0.4 b	0.9	0.1 b	0	0.4	0
High	P4	PETE	7.6	1.6 b	3.3	0.6	1.5	0
		Modified PETE	3.7	3.3 ab	1.7	1.4	3.9	0.5
		Grower Std	8.3	4.9 a	3.1	4.4	2	1

Table 4. The number of sprays recommended by the PETE and Modified PETE models and actual number of sprays applied in research plots in Western NY State in 2007 and 2008.

			Number of sprays			
			2007		2008	
Pressure	Farm	Treatment	Recommended	Actual	Recommended	Actual
Low	P1	PETE	4	3	4	4
		Modified PETE	1	2	3	3
		Grower Std		2		3
Moderate	P2	PETE	4	4	4	4
		Modified PETE	5	6	5	6
		Grower Std		6		6
High	P3	PETE	5	6	5	6
		Modified PETE	8	6	6	7
		Grower Std		5		5
High	P4	PETE	5	5	5	7
		Modified PETE	8	7	6	8
		Grower Std		7		8

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