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COMPARISON OF MECHANICALLY APPLIED PHEROMONE DISPENSING TECHNOLOGIES FOR MATING DISRUPTION OF TREE FRUIT PEST LEPIDOPTERA
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Abstract
A full-season mating disruption trial was conducted in 5–23-acre plots on five farms, to assess the efficacy of two different pheromone dispensing systems against codling moth (CM), oriental fruit moth (OFM), lesser appleworm (LAW), and obliquebanded leafroller (OBLR): Checkmate Puffers (against CM, OFM, and LAW), and SPLAT (against CM, OFM, LAW and OBLR). Pheromone treatments were used as a complement to the growers' normal insecticide programs. Both types of dispenser technology suppressed adult catches of oriental fruit moth and lesser appleworm to near-zero levels for the entire season, but at three of the sites, each of the treatments allowed some breakthrough of codling moths during the summer. Possible factors in this finding could have included placement of the CM traps in the tops of the tree canopies, lack of persistence of specific pheromone products, and difficulty in maintaining pheromone sources high enough in the canopies. Weekly on-tree fruit inspections detected very few damaged fruits in the disrupted treatments until late July. Total fruit damage by the internal-feeding species at harvest ranged from 0.0–1.9% across all sites and pheromone treatments (compared with 0.2–6.4% in the nondisrupted grower standards and 15.4% in one untreated check). OBLR fruit damage in the single site, which was treated late in the season, was 0.4% in the disrupted plot and 2.2% in the nondisrupted grower standard. In all cases but one (where the pressure was extremely low), damage in the disrupted plots was significantly lower than in the respective nondisrupted grower plots.
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This trial was conducted in mixed plantings of fresh and processing apples on five commercial farms in Wayne, Orleans and Tompkins Counties, NY. A low-density automated aerosol spray dispenser and a flowable wax emulsion were compared for efficacy in managing:

1 – Three internal-feeding Lepidoptera species, codling moth (CM), *Cydia pomonella*; oriental fruit moth (OFM), *Grapholita molesta*; and lesser appleworm (LAW), *Grapholita prunivora*, when applied against the all generations of these pests.

2 – Summer generation obliquebanded leafroller (OBLR), *Choristoneura rosaceana*.

Among the apple varieties included on the five farms were: Idared, Cortland, Red Delicious, Golden Delicious, Empire, Jonamac, McIntosh, and Fortune.

Materials & Methods

In 2008, internal worm management programs were tested in one "low-risk" and three "high-risk" apple orchards, and one de-fruited peach orchard using one of two different pheromone dispensing technologies, as well as (in the apples) a fruit sampling procedure to assess the need and timing for special pesticide sprays directed against the 2nd and subsequent generations of these species. Additionally, one of these technologies was tested for efficacy against OBLR in a moderate-risk apple orchard. The specifics of each of the pheromone products follow:

1) **Checkmate Puffer** (Suterra LLC, Bend, OR) pheromone dispensers consisted of a plastic cabinet enclosing an aerosol canister containing the pheromone blends: for CM, 69.35 g of (E,E)-8,10-Dodecadien-1-ol; for OFM, 24 g of Z8-12:OAc, E8-12:OAc, and Z8-12:OH. Every 15 min between 5 pm and 5 am each day, a battery-powered timer and plunger were activated, releasing a 40-mg puff containing 7.22 mg of CM and 2.5 mg of OFM active ingredient into the orchard. Puffer cabinets were suspended in the upper one-third of the tree canopies at a rate of 1 per acre, in a regular grid pattern spaced approximately 40 m (132 ft) apart and keeping roughly half that distance between the orchard edge and the nearest puffer unit. Every tree in the perimeter 2 rows (or 2 row-end trees) additionally received a **Checkmate CM-OFM Duel** membrane dispenser, consisting of a double packet of pheromone-loaded pads behind controlled-release membranes, containing (CM dispenser): 270 mg (17.54% by weight) of (E,E)-8,10-Dodecadien-1-ol and (OFM dispenser): 250 mg total of 11.93% Z8-12:OAc, 0.80% E8-12:OAc, and 0.15% Z8-12:OH, deployed at a rate of 500 ties per ha (200 per acre) in the upper one-third of the tree canopies.

2) **SPLAT** (ISCA Technologies, Inc, Riverside, CA) formulations consisted of target pest pheromones in a flowable wax emulsion delivered via a piston pump up an extension arm (held above the tree canopy) and into the hub of a centrifugal spinning emitter, which dispersed 0.25-g droplets into the canopy at a rate of ~6–10 droplets per tree or ~3000 droplets/A. The application unit was mounted on a tractor that was driven through the orchard at 3-5 mph to apply the products. The SPLAT formulations tested were:

- SPLAT OFM 30M-1, containing 3% a.i. OFM pheromone: Z8-12:OAc, E8-12:OAc, and Z8-12:OH in a 85.43%: 5.51%: 0.92% blend.
- SPLAT Cydia, containing 10% a.i. CM pheromone: (E,E)-8,10-Dodecadien-1-ol.
- SPLAT Cydia ver. 3.38, containing 6% a.i. CM pheromone plus apple secondary plant compounds (an experimental formulation).
- SPLAT OBLR, containing an undisclosed amount of OBLR pheromone (an experimental formulation).

The pheromone treatments against the internal-feeding species were all applied slightly before or coincident with the first flights of the respective target species, except for the SPLAT OBLR at the Fowler South Farm, which was delayed approximately 3 wk past the first adult catch because of a miscommunication between the manufacturer and the distributor:

- Burnap North, Sodus (10A): SPLAT OFM, 8 May; SPLAT Cydia, 25 May
- Burnap South, Sodus (5A): SPLAT OFM, 8 May; SPLAT Cydia ver. 3.38, 25 May
- Burnap peaches, Sodus (20A): SPLAT OFM, 8 May
- Fowler Home Farm North, Wolcott (20A): SPLAT Cydia, 2 June
- Fowler Home Farm South, Wolcott (18A): SPLAT Cydia ver. 3.38, 2 June
- Fowler South Farm, Sodus (20A): SPLAT OBLR, 1 July
- Hartley, Newfield (23A): Puffer CM/OFM, 7 May
- Oakes, Lyndonville (9A): Puffer CM/OFM, 13 May

Pheromone product efficacy in depressing adult male trap catch was monitored by using 5–6 Pherocon VI (Large Delta) traps per plot for each target species (including LAW, as this species has a similar pheromone blend to OFM). Traps were located at least 3–5 trees/rows interior to the orchard edges at each corner, plus in center locations as appropriate, according to the specific orchard dimensions. Each was baited with a standard Suterra Biolure (for CM and OFM) or a Scentry rubber septum lure (for LAW and OBLR), and checked weekly from 6 May to 29 August. In addition, a similar grouping of traps in a non-disrupted check plot nearby was also monitored at each farm, to maintain information on background levels of each of these species and for purposes of fruit injury comparison at harvest. Lures in all CM, OFM and LAW traps were changed at the beginning of July, and additionally during the first week of August for CM.

The fruit sampling protocol consisted of weekly on-tree fruit inspections conducted from the week of 16 June to the week of 18 August, comprising 300 fruits per plot (20 on each of 15 trees) during the first week and 100 fruits per plot (10 on each of 10 trees) on subsequent weeks, to detect the initial occurrence of any larval fruit damage in time to curtail further infestation. Whenever an inspection session resulted in the detection of at least one damaged fruit, the grower or his consultant was notified so that they could determine whether a special spray of a selective pesticide was needed for control of the target pest. An evaluation of larval fruit-feeding damage at harvest was made by taking random samples of 1000 fruits from each plot (choosing trees from along each plot edge and throughout the plot interior) and examining them for internal and surface injury. Pre-harvest samples were taken between 12–23 Sept.

Results

Trap catches of adults were generally suppressed to low levels in all pheromone treatment plots during the mid- and late summer, although some breakthrough captures did occur, particularly for codling moth, so trap shutdown was not absolute in all cases (Figs. 1 & 2). At the Hartley Puffer site, near-zero captures were recorded for OFM and LAW throughout the season, but one trap site sporadically caught some CM adults in early June (Fig. 1). A canister weight check later in July disclosed one unit near this trap site with more product remaining in it than expected, so it was replaced. Unfortunately, the tree in which it was hung had an overly heavy fruit load, which severely bent all the branches and lowered the unit's height, so its ability to dispense pheromone into the upper canopy region was impeded, and further CM captures were recorded in that portion of the orchard. This situation emphasizes the need for proper maintenance of the Puffer units and the trees that must support them; because there are so few deployed per unit area, less than optimum performance in just one unit can have a major effect on the treatment's efficacy. At the Oakes Puffer site, virtually no target species adults were caught in the disrupted plot throughout the season; however, as seen in the nondisrupted plot catches, the population pressure was unexpectedly very low on this farm, so it is difficult to make an objective assessment of the treatment's performance in this case (Fig. 1; LAW numbers were zero in all traps and are therefore not presented in the graph).

Two SPLAT sites with notable CM catches were the Burnap and Fowler plots, where dissimilar trends were noted between the standard SPLAT Cydia and the experimental Cydia ver. 3.38 formulations. At Burnap, CM adult catches were almost completely suppressed throughout the season in the Cydia ver. 3.38 plot, while in the standard SPLAT Cydia plot, CM were frequently caught at rates of between 5-12 adults per trap per week starting in early June (Fig. 2). Conversely, at Fowler, CM catches in the standard SPLAT Cydia plots generally remained in the range of 0–4 adults per trap while those in the Cydia ver 3.38 plot several times peaked at more than twice those levels. It is not known what factors may have been responsible for these results, although the CM pressure at both of these sites was quite high, so in relative terms the proportional trap shutdown was still fairly good.

The trap shutdown of OFM captures in the SPLAT OFM peach traps was generally adequate under the high pressure situation existing on the Burnap farm, with catches remaining below 5 adults per trap per week throughout the season. The fruit on these processing trees was thinned off shortly after bloom, as the grower was only interested in maintaining the trees during a season with no access to an acceptable market outlet. At the Fowler South Farm, the appropriate SPLAT OBLR application timing was unfortunately missed because of a miscommunication that delayed the product's shipment from the factory, so the bulk of the OBLR flight had already taken place by the time the treatment was applied. No difference in trap numbers was evident between the disrupted and non-disrupted plots until the second flight began in early August (Fig. 2).

The fruit sampling procedure was simple and convenient to implement, requiring 10–15 min per plot, and appeared to effectively allow detection of low-level infestations at a very early stage, so that the growers could be notified of any extra needed control measures in a timely fashion. Incidence of fruit injury was extremely low all season in all blocks until late July, when damage began to show up in the Fowler SPLAT plots, which persisted through most of the August sample dates. Relatively low amounts of fruit damage were seen in the Burnap and Hartley disrupted plots; pressure in the nondisrupted standards was considerable (Table 1). Likewise, very little OBLR damage was detected in the Fowler South Farm SPLAT plot.

Fruit damage at harvest caused by internal-feeding Lepidoptera at harvest was very low in all the disruption treatments, and almost always significantly different from that observed in the respective nondisrupted check plots. Levels of total (stings plus internal tunneling) damage at Burnap averaged 0.8–1.5% in the different SPLAT plots, compared with 0.4% in the nondisrupted grower standard, and 15.4% in an adjacent untreated check block. At Fowler Home Farm, total damage averaged 0.7–1.9% in the SPLAT plots, and 6.4% in the nondisrupted grower standard (Table 2). The Hartley Puffer plot had 0.6% total fruit damage, compared with 6.4% in the nondisrupted check (Table 2). Mating disruption has been in use for three years on this farm, and the overall level of damage has progressively diminished each year. No fruit damage occurred at the Oakes Puffer site, compared with just 0.2% in the nondisrupted grower standard block. Finally, the OBLR larval damage to fruit at Fowler South Farm was 0.4% in the SPLAT plot, compared with 2.2% in the nondisrupted standard (Table 2). As the product was not applied until after much of the first generation mating would have likely taken place, it may be inferred that any treatment differences would have been a result of its impact on the second summer generation's mating period.

The Puffer canisters were weighed in midseason (24-25 July) and again after the preharvest evaluations (15 and 23 Sept, respectively) to obtain a measure of the operating reliability of the dispensers, to gauge how much pheromone remained in them after 73–79 and 131–133 days of use. Most of canisters at Hartley had expended a similar amount of pheromone by the first weighing (141.9 ± 6.6 g), but one of the canisters had released only 73.4 g (52% of the others), and was therefore replaced.

Although it can be argued that the pheromone treatments tested improved the overall control of the lepidopteran management programs in these orchards, some factors, as before, can be identified as being potential contributors to less than perfect control:

1 – Although an effort was made to establish larger plots than in past years' trials, plot size still may not have been large enough to overcome the possibility of immigration by mated females. While this applies to both types of dispenser technology evaluated, it is probably more critical in the case of the Puffers, which are deployed at such low densities that a large number of them (over a correspondingly large area) are required to produce a comprehensively permeated region of orchard canopy space. The results of this year's trials underscores the implication, reflected in the product's label instructions, that the best efficacy using Puffers for mating disruption will be obtained in uses over larger areas (e.g., optimally 40 A or greater).

2 – Operational difficulties in the application and maintenance of the pheromone treatments need to be addressed. The Puffer units are relatively heavy and complex, which means that care should be taken in locating them on tree branches capable of supporting their weight over the entire season, and they should be checked periodically to ensure they are operating properly (again, as the manufacturer recommends). The SPLAT technology also offers great promise as a convenient and effective method of pheromone application over large areas. However, because the customized application equipment is

complex and not easy to use, it may be difficult to promote widespread adoption of this technique by growers until some improvements are made along these lines.

3 – The population pressure may sometimes be too high to be completely disrupted by the pheromone treatments. Depending on the success in addressing the first two points noted, there will be the potential for less-than-complete mating disruption in situations of severe population pressure, so these methods will usually need to be supplemented with at least some form of insecticide application, particularly in the case of difficult to control species such as CM and OBLR.

The in-season fruit inspection regimen continues to appear effective and reliable, but there remains a difficulty in convincing growers to wait for evidence of even a low level of damage in their orchards before applying a special spray against these pests. In general, considering the overall levels of pest pressure occurring in these orchards, and the economics (considering both materials and labor) of implementing such pheromone treatments, it is possible that many internal worm problems in NY orchards could be adequately and economically addressed by adjusting pesticide spray schedules—and particularly, coverage—or with the use of selective products in a smaller number of designated sprays.

Acknowledgments

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Table 1. Worm-damaged apples found during summer fruit inspection dates in pheromone-treated plots, 2008.

	week of:	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11	8/18
	No. fruit inspected	300	100	100	100	100	100	100	100	100	100
Site	**Treatment**	**Number Detected**									
Burnap	SPLAT OFM + Cydia		0		0	0		0	0	1.5	0
(Sodus)	SPLAT OFM + Cydia exp.		0		0	0		0	0	0	0
	Untreated Check		8.5		11	2		14	5.5	8.5	7
Fowler Home	SPLAT Cydia		0		0	0		3	2.5	1	0
(Wolcott)	SPLAT Cydia exp.		0.5		0	0		0	5	4.5	0.5
	Nondisrupted Grower Std		0.5		3	0		0.5	5	1.5	0.5
Hartley	Puffer CM/OFM	0	0	3.5	0	0	0	0	1	1	1
(Newfield)	Nondisrupted Grower Std	7	0	2	2	5	9	9	6	1	3.5
Oakes	Puffer CM/OFM		0	0		0	0	0	0	0	0
(Lyndonville)	Nondisrupted Grower Std		0	0		0	0	0	0	0	0
Fowler South	SPLAT OBLR				0	0		0	0	0.5	0
(Sodus)	Nondisrupted Grower Std				0	0		0	1	0	0

Table 2. Percent deep (internal) and sting (surface) fruit injury[1] at harvest in pheromone-treated plots, 2008.

Site	Treatment	Sting	Deep	Total	Clean
Burnap	SPLAT OFM 30M-1 *plus* Cydia	1.2 a	0.3 a	1.5 a	98.5 a
(Sodus)	SPLAT OFM 30M-1 *plus* Cydia v. 3.38	0.7 a	0.1 a	0.8 a	99.2 a
	Nondisrupted Grower Standard	0.4 a	0.0a	0.4 a	99.6 a
	Untreated Check	1.0 a	14.4 b	15.4 b	84.6 b
Fowler	SPLAT Cydia	0.4 a	0.3 a	0.7 a	99.3 a
(Wolcott)	SPLAT Cydia v. 3.38	1.0 a	0.9 a	1.9 a	98.1 a
	Nondisrupted Grower Standard	4.6 b	1.8 a	6.4 b	93.6 b
Hartley	Puffer (CM *plus* OFM)	0.1 a	0.5 a	0.6 a	99.4 a
(Newfield)	Nondisrupted Grower Standard	1.6 a	4.8 b	6.4 b	93.6 b
Fowler South	SPLAT OBLR	0.4 a	99.6 a		
(Sodus)	Nondisrupted Grower Standard	2.2 b	97.8 b		

[1]Within a site, values in the same column followed by the same letter are not significantly different at *P*=0.05 level (Fisher's protected lsd test).

Table 3. Insecticides applied by grower during appropriate pest control windows to all plots in NY mating disruption trials, 2008

Farm/Block/Date	Material	Rate/Acre	Comments
Fowler Home H1C			**SPLAT (CM) plots**
6-May	Assail 30SG	3.2 oz	
25-May	Leverage 2.7SE	3.2 oz	
	Proclaim 5SG	3.0 oz	
4-Jun	Calypso 4F	4.8 oz	
19-Jun	Guthion 50WS	1 lb	
	Dipel 10.3DF	0.8 lb	
7-Jul	Imidan 70WP	1.5 lb	
	Thionex 50WP	1.5 lb	
25-Jul	Calypso 4F	4.8 oz	
	Thionex 50WP	1.5 lb	
6-Aug	Assail 30SG	3.2 oz	
	Delegate 25WG	3.9 oz	
29-Aug	Imidan 70WP	1.5 lb	
	Danitol 2.4EC	6.4 oz	
Fowler Home M3E			**Non-disrupted Std**
1-May	Assail 30SG	3.2 oz	
21-May	Leverage 2.7SE	3.2 oz	
	Proclaim 5SG	3.0 oz	
5-Jun	Calypso 4F	4.8 oz	
16-Jun	Danitol 2.4EC	8.0 oz	
9-Jul	Imidan 70WP	1.5 lb	
	Thionex 50WP	1.5 lb	
22-Jul	Calypso 4F	4.8 oz	
	Thionex 50WP	1.5 lb	
7-Aug	Assail 30SG	3.2 oz	
	Delegate 25WG	3.9 oz	
26-Aug	Guthion 50WS	1.5 lb	
	Danitol 2.4EC	6.4 oz	
Fowler South Farm			**SPLAT (OBLR)**
3-Jun	Calypso 4F	4.8 oz	**plus Non-disrupted**
8-Jul	Imidan 70WP	1.5 lb	**Std plots**
	Thionex 50WP	1.5 lb	
20-Jul	Calypso 4F	4.8 oz	
	Thionex 50WP	1.5 lb	
9-Aug	Imidan 70WP	1.5 lb	
	Assail 30SG	3.2 oz	

Table 3, cont. Insecticides applied by grower during appropriate pest control windows to all plots in NY mating disruption trials, 2008

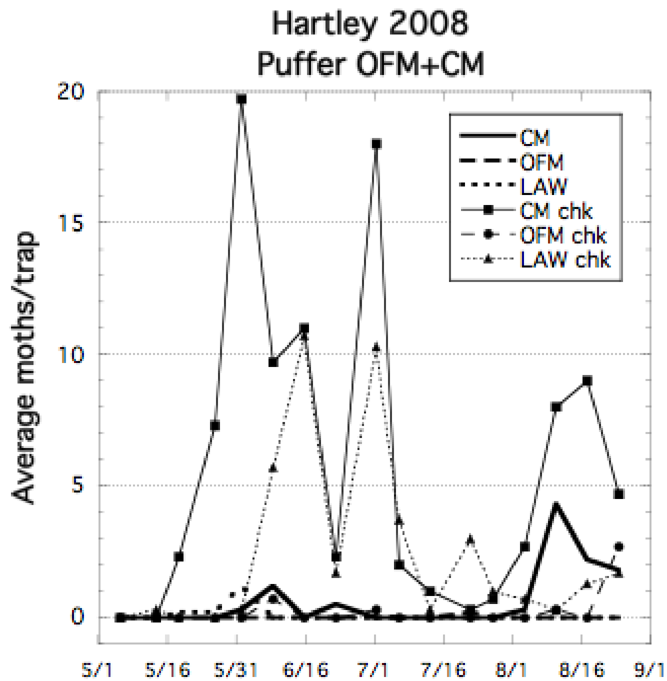
Farm/Block/Date	Material	Rate/Acre	Comments
Oakes Home H6			**Puffer (CM+OFM)**
22-May	Proclaim 5SG	3.3 oz	**plot**
22-May	Warrior 1CS	4.0 oz	
4-Jun	Calypso 4F	4.9 oz	
18-Jun	Imidan 70WP	2.7 lb	
1-Jul	Intrepid 2F	15.9 oz	
11-Jul	Proclaim 5SG	3.4 oz	
29-Jul	Imidan 70WP	1.3 lb	
Oakes Home H3			**Non-disrupted Std**
22-May	Proclaim 5SG	3.3 oz	**plot**
22-May	Warrior 1CS	4.0 oz	
4-Jun	Calypso 4F	4.9 oz	
18-Jun	Imidan 70WP	2.7 lb	
1-Jul	Intrepid 2F	15.9 oz	
11-Jul	Proclaim 5SG	3.4 oz	
31-Jul	Imidan 70WP	1.6 lb	
Burnap Boller 517, 518			**SPLAT (CM & OFM)**
2-May	Lorsban 4EC	1.3 qt	**plots**
23-May	Avaunt 30WDG	5.6 oz	
23-May	Intrepid 2F	17.8 oz	
24-May	Calypso 4F	4.5 oz	
12-Jun	Calypso 4F	5.0 oz	
27-Jun	Calypso 4F	5.7 oz	
15-Jul	Imidan 70WP	2.9 lb	Block 518 only
15-Jul	Proclaim 5SG	6.2 oz	
15-Jul	Provado 1.6F	2.8 oz	Block 517 only
28-Jul	Delegate 25WG	5.5 oz	
28-Jul	Provado 1.6F	2.3 oz	
18-Aug	Delegate 25WG	5.8 oz	
3-Sep	Assail 30SG	6.6 oz	
Burnap Grower Std			**Non-disrupted**
2-May	Lorsban 4EC	1.3 qt	**standard plot**
23-May	Calypso 4F	5.3 oz	
23-May	Proclaim 5SG	2.7 oz	
12-Jun	Calypso 4F	5.0 oz	
27-Jun	Imidan 70WP	2.4 lb	
14-Jul	Imidan 70WP	3.1 lb	
15-Jul	Dipel 10.3DF	1.0 lb	

15-Jul	Provado 1.6F	2.8 oz	

Table 3, cont. Insecticides applied by grower during appropriate pest control windows to all plots in NY mating disruption trials, 2008

Farm/Block/Date	Material	Rate/Acre	Comments
Burnap Grwr Std, cont			
29-Jul	Provado 1.6F	1.7 oz	
1-Aug	Dipel 10.3DF	1.1 lb	
1-Aug	Imidan 70WP	2.0 lb	
29-Aug	Imidan 70WP	2.0 lb	
Hartley Farm		**Rate/100 gal**	**Puffer (CM+OFM)**
21-Apr	oil	2 gal	**plus non-disrupted**
28-May	Dipel 10.3DF	0.5 lb	**standard plot**
28-Jul	Imidan 70WP	1.0 lb	

Fig. 1. Pheromone trap catches of codling moth, oriental fruit moth, and lesser appleworm in Puffer-treated apple orchards, Tompkins Co. and Orleans Co., NY 2008.



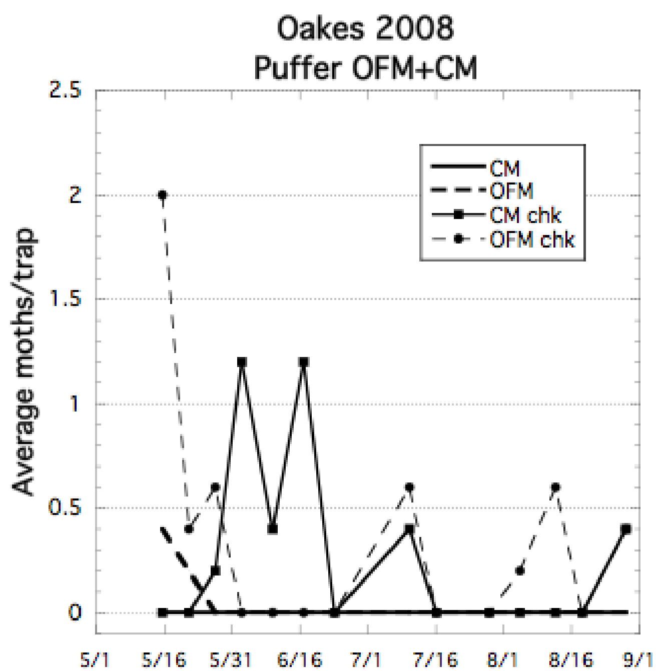


Fig. 2 Pheromone trap catches of codling moth, oriental fruit moth, lesser appleworm, and obliquebanded leafroller in SPLAT-treated apple and peach orchards, Wayne Co., NY 2008.