Comparisons of Pheromone Dispenser Technologies for Mating Disruption of Internal-Feeding Lepidoptera in Apples, 2004-2006

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In recent years severe outbreaks of internal-feeding worms (primarily oriental fruit moth and lesser appleworm) has caused severe financial losses to growers throughout Western NY State. Numerous loads of apples were rejected for fresh or processing markets. We have studied the use of various pheromones for mating disruption in conjunction with properly timed pesticides to reduce the economic losses caused by these worms.

In 2002, severe outbreaks of two species of internal-feeding Lepidoptera (worms) began occurring in apple production regions of Western NY. These outbreaks caused severe financial losses to growers throughout this region because numerous loads of apples were rejected for fresh or processing markets. Initial studies conducted in field efficacy trials showed that neither the organophosphate (OP)-based technology commonly used at the time nor programs relying on more selective reduced-risk products could reliably provide adequate, cost-effective control of these pests in high-risk commercial orchards within these outbreak areas.

The two primary species responsible for this problem were oriental fruit moth (OFM), *Grapholita molesta*, and lesser appleworm (LAW), *G. prunivora*. Although they have been present for years, these pests have only recently become a source of concern to NY growers. Because of insecticide resistance, regulation-driven changes in pesticide programs, and possibly ecological factors, growers have had to start making special efforts – often for the first time in their experience – to control them. The initial reaction of many growers who discovered internal worms in their fruit was to respond with multiple preventive applications of harsh broad-spectrum or specialty pesticides; eventually, some added mating disruption in combination with the sprays. The fact that these decisions were often made without any formalized evaluation of the need or effectiveness of the specific tactics employed, makes it difficult to assess whether these programs were worthwhile or justified.

Orchards affected by these pests can require up to four extra sprays of conventional pesticides during the summer. These late-season sprays are problematic because of secondary pest outbreaks and greater concerns over farm worker risk. Our goal was to mitigate this potential risk by preventing the problem before it could occur, through the use of least-toxic alternatives such as mating disruption and biopesticidal materials, with a selective reduced-risk toxicant being called for only in the event that these tactics were not effective. During the past five years, pheromones for mating disruption went from being a tactic that was seldom considered to one that has generated substantial interest, but recommendations on their use has been hampered by the lack of experience with this approach in NY and the evolving product choices in the market. From 2004 to 2006 we conducted a number of assessments of three different pheromone-dispensing technologies available to determine their potential usefulness in controlling internal-feeding

Figure 1. Isomate twist tie

Figure 2. Isomate Twin-tube tie.

Figure 3. MSTRS pheromone packet

Figure 4. Deployment of MSTRS dispenser using a pole applicator

worms in NY apple orchards. Our approach was to run side-by-side comparison plots of the different pheromone products on commercial farms judged to be at various levels of risk for this type of pest attack.

Procedures

Specifics of the test sites each year are as follows:

2004 This trial was conducted in mixed plantings of fresh and processing apples on six commercial farms in Wayne and Ontario Counties. Plot size varied from 3.0–5.0 acres. Apple varieties included Gala, R.I. Greening, Golden Delicious, Red Delicious, Monroe, Ida Red, Empire, and McIntosh.

2005 Tests were conducted in mixed plantings of fresh and processing apples on five commercial farms in Wayne, Orleans and Niagara Counties. Plot size ranged from 4.0–5.0 acres. Apple varieties included Gala, Rome, Golden Delicious, Red Delicious, Ida Red, Mutsu, Ben Davis, 20-Ounce and McIntosh.

2006 Plots were set up in mixed plantings of fresh and processing apples on nine commercial farms in Wayne, Orleans and Niagara Counties. Plot size was between 2.2–8.2 acres. Apple varieties included Cortland, Empire, Fuji, Gala, Golden Delicious, Honeycrisp, Ida Red, McIntosh, Monroe, Mutsu, Red Delicious, Rome, and 20-Ounce.

The pheromones were deployed over the top of the growers' normal insecticide program, thus serving as a supplement to the chemical control method. The pheromone treatments used were: 1) Isomate polyethylene ties; 2) MSTRS OFM high-yield, low-density pheromone packets; 3) Hercon Disrupt Micro-Flake, a sprayable plastic laminate, all applied against the 2nd and subsequent generations of OFM, LAW, and codling moth (CM). Codling moth was a target species only in some sites during 2006, so specific Isomate and Hercon products were used as appropriate to each farm's pest pressure; the MSTRS product was available only for OFM. Because of the limited amount of information on CM mating disruption generated by these trials, efficacy against codling moth is not addressed in this report. The OFM products were directed additionally against LAW, as these two species have similar pheromone blends (OFM, 98:2% of Z:E8-12:OAc; LAW, 92:8% Z:E8-12:OAc). In all cases, growers managed the first generation broods of these pests with their conventional pesticide applications that were directed primarily against plum curculio and obliquebanded leafroller occurring at and immediately following petal fall.

The Isomate (CBC America Corp., Commack, NY) products were applied primarily between 14–22 June over the three years (except for the Isomate-M Rosso, as noted below), and included the following:

- Isomate-M 100, a polyethylene tie (Figure 1) containing 232.1 mg of OFM pheromone blend (88.5 : 5.7 : 1.0% of Z:E8-12:OAc : Z8-12:OH), deployed at a rate of 100 ties per acre.
- Isomate-CM/OFM TT, a "twin tube" assembly of two ties (Figure 2) containing 423.6 mg of a multi-species blend for all three species: 58.4% E8,E10-12:OH; 9.23% 12:OH; 1.87% 14:OH; 21.25% Z8-12:OAc; 1.36% E8-12:OAc; and 0.23% Z8-12:OH, deployed at a rate of 200 ties per acre.
- Isomate-M Rosso, an extended-life tie containing 250.2 mg of OFM pheromone blend, as above, applied between 16–22 April at a rate of 200/ties acre at four of the six sites used in 2004.

A pheromone packet (Figure 3), using "MSTRS" technology (Metered Semiochemical Timed Release System, AgBio Inc., Westminster, CO) consisted of food-grade plastic enclosing a 6.4 x 6.4 cm natural fiber pad containing 2.63 g of OFM pheromone (85.4 : 5.5 : 0.9% of Z:E8-12:OAc : Z8-12:OH), which was deployed in a grid pattern at a density that varied from 5–8 per acre in 2004 and 2005, to 10 per acre in 2006. A pole+hoop applicator was used to position the dispensers, hung by a rubber band or wire loop, in the top one-third of the tree canopy (Figure 4). Deployment of these dispensers took place from 9–13 July in 2004, and 17–23 June in 2005 and 2006.

The Disrupt Micro-Flake (Hercon Environmental, Emigsville, PA) products were 3 x 3 mm solid matrix laminate chips

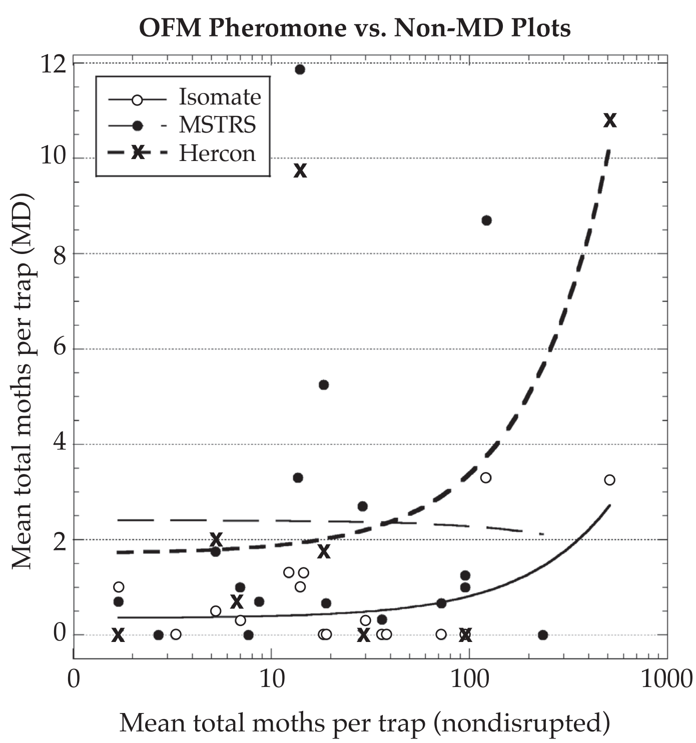
Figure 5. Hercon Micro-Flakes

Figure 6. Application of Hercon Micro-Flakes using an ATV-mounted modified leaf-blower.

Figure 7. Hercon Micro-Flakes stuck to apple foliage

(Figure 5) impregnated with OFM pheromone (7.83 : 0.51 : 0.08% Z:E8-12:OAc : Z8-12:OH), applied at a rate of 19.2 g a.i. per acre, or 8 oz of flakes per acre. Applications were made using a modified leaf blower (Arena Turbo-Tac) mounted on an ATV traveling at 6–7 mph down the rows (Figure 6). The flakes were stuck to the tree foliage (Figure 7) using an acrylic sticker (Micro-Tac) applied as they were blown from the machine. The Hercon Flake treatments were applied at four sites between 7–8 July in 2005, and at three sites between 29 June–14 July in 2006. Attempts to apply this treatment at three additional sites in 2006 were prevented by equipment malfunction caused by jams in the hopper feeder mechanism and sticker blockages in the flake auger.

Pheromone treatment efficacy in depressing adult male trap catch was monitored with pheromone traps in each disrupted plot as well as in a nondisrupted comparison planting on the same farm or in the same general area. Pheromone traps were checked weekly starting before deployment of the mating disruption treatments until shortly before harvest. Although OFM adult catches were monitored all three years, LAW trap data was taken only in 2005 and 2006. Because pheromone mating disruption was not anticipated to be effective enough to eliminate the need for all additional insecticide sprays, a fruit sampling procedure was used to assess the need and timing for specific pesticide sprays directed against the 2nd and subsequent generations of these species. The fruit sampling



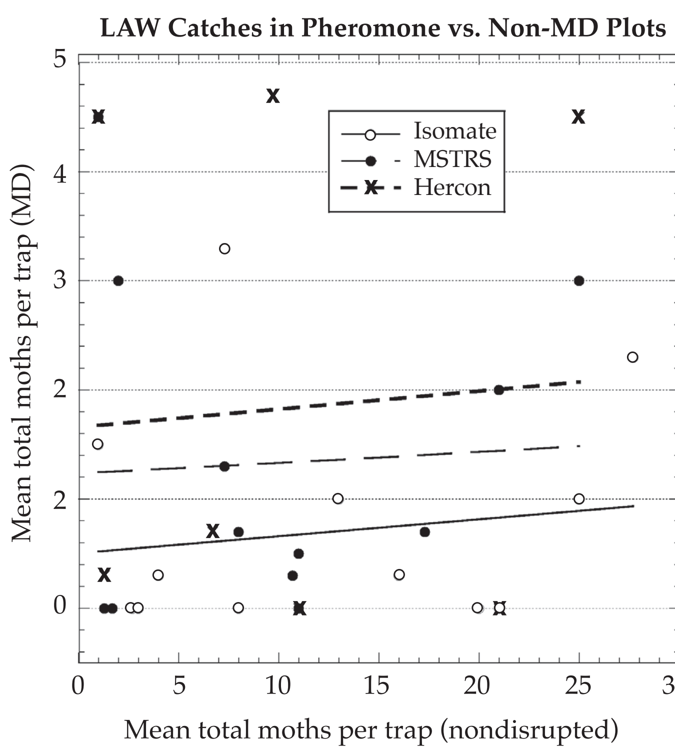


Figure 8. Total oriental fruit moths per trap caught during July and August in all pheromone treatment plots compared with numbers caught in the respective nondisrupted comparison plots, 2004–2006.

Figure 9. Total lesser appleworm moths per trap caught during July and August in all pheromone treatment plots compared with numbers caught in the respective nondisrupted comparison plots, 2005–2006.

protocol consisted of weekly on-tree fruit inspections conducted from mid-July through August, comprising 300 fruits per plot during the first week and 100 fruits per plot on subsequent weeks, to detect the initial occurrence of any OFM or LAW larval fruit damage in time to curtail further infestation. Whenever an inspection session resulted in detection of at least one damaged fruit, the grower or consultant was notified so that they could determine whether a special spray of a selective pesticide was needed for adequate control of internal Lepidoptera. An evaluation was made of larval fruit-feeding damage at harvest by examining fruit samples from each pheromone plot for internal and surface injury. When possible, comparisons were made with fruit from nondisrupted plantings in most, but not all cases, for the 2005 and 2006 trials.

Results

Pheromone Deployment. As ease of use and labor requirements are considerations in deciding the type of pheromone dispenser to be used in a particular situation, data were taken on the time and number of people required to deploy the pheromone dispensers in each plot. In 2004, the MSTRS product required between 7.1–12.0 min for one individual to apply one acre. Time measurements for hand-applied deployment of the twist-tie OFM dispensers averaged approximately 240 ties/hr/person, or 25 min per acre for the Isomate M-100, and 50 min per acre for Isomate Rosso. The MSTRS time requirements correspond to a ~50–70% reduction over the M-100 ties, and ~75–85% over the Rosso ties. Records were also kept in 2006 of the amount of time required for application of each type of pheromone dispenser, and although there was some variability due to differences in the orchards' physical characteristics and treatment combinations, the following average times were determined: Isomate-M, 37 min/acre/person; Isomate CM/OFM, 34 min/acre/person; MSTRS, 14 min/acre/person; Hercon, 5 min/acre (one person driving, but a second was needed to assist, and setup time required was considerable).

Trap Catches. 2004. Pheromone trap catches of OFM adult males in the test sites were lower than they might normally have been, owing to unfavorable cool and rainy weather during July and August. Nevertheless, sufficient numbers of moths were caught in the non-disrupted comparison plots to indicate the degree of effectiveness of the pheromone treatments in the adjacent plantings. Both the Isomate M-100 and Rosso treatments completely suppressed OFM trap catches in their respective plots for the duration of the study; in four of the six sites, traps in the MSTRS plots caught 1-2 moths on one or two occasions.

2005. Trap catches of OFM and LAW were generally suppressed to low levels in all pheromone treatment plots during the mid- and late summer, although some breakthrough captures did occur. Thus trap shutdown was not absolute in all cases. Two plots with notable OFM catches were the MSTRS and Hercon treatments at the Newfane site. These plots were located near a non-disrupted organic apple planting with a high OFM population, so it is possible that immigration from that block was too severe to be completely disrupted by the pheromone treatments in our plots.

2006. Oriental fruit moth pressure was considerable at the Williamson, Newfield, and Kendall sites, but all treatments showed low trap numbers throughout the season; likewise, lesser appleworm was very numerous at Ridgeway, Gaines, Williamson, Newfield, and Kendall, but the respective OFM pheromone treatments effectively depressed these trap numbers as well.

As a means of assessing the relative ability of the three pheromone treatments to disrupt the chemical communication between male and female moths over the course of all the trials conducted at these 20 sites over a three-year period, the total number of moths per trap caught in each of the pheromone plots during the disruption period (2nd and subsequent generations) was compared against the number caught over the same period in a nondisrupted planting nearby. This was done for both oriental fruit moth (Figure 8) and lesser appleworm (Figure 9). While all of the pheromone products exhibited substantial activity in depressing trap catches, a plot of the comparisons showed that the Isomate ties, in general, tended to be the most effective of the three dispeners, and the Hercon flakes were less effective, particularly as population pressure increased. It must be acknowledged that both the MSTRS and Hercon products were still in the developmental process, and their performance was likely impacted by some factors yet to be both addressed and improved upon by the manufacturers.

Fruit Damage. In no case did the grower rely exclusively on mating disruption to prevent fruit damage by internal-feeding larvae, so it is not possible to assess the treatments' efficacy as a sole tactic in managing these pests. Nevertheless, these trials did afford an opportunity to evaluate each pheromone treatment's relative management value when used in combination with the grower's normal insecticide program, and in many cases as compared with that program without the use of pheromones (Table 1).

Our notifications to the growers of finding fruit damage during the in-season fruit inspections did not always result in a decision to apply an extra spray for internal worm control. In 2005, the two such occasions at the Yates site happened to correspond with the grower's scheduled applications of materials against other pests that also had some activity against OFM. The Alton orchard, which was an organic block with a history of severe internal worm pressure, was on a preventive schedule of presumably the most effective organically acceptable materials available against internal worms (B.t., codling moth virus, and kaolin clay), so the grower was not relying on our reports for his spray decisions. At the Newfane site, a spray was applied for internal worms in all the pheromone plots because of the grower's concern about the orchard's proximity to nondisrupted moth populations, even though damage had been found in only one treatment during one inspection. In 2006, incidence of in-season fruit injury was extremely low except at Newfield, Williamson, and Gaines, each of which required two notifications of damage to the grower or their consultant. In contrast to the previous year, these farms, as well as Ridgeway (one notification), did receive 1-2 directed applications of a selective insecticide against encroaching larval populations as a result.

Fruit damage caused by internal-feeding Lepidoptera at harvest was very low in all the 2005 treatments at three of the five pheromone-disruption sites (Table 1). At the Newfane site, the Isomate plot sustained approximately 10% fruit damage, although its proximity to a nondisrupted organic planting with a high population could have been a contributing factor. Additionally, an unanticipated large codling moth population occurred that was not being disrupted, so damage from this species was likely included in the harvest evaluation, as no effort was made to distinguish between OFM and CM damage. The Alton organic site had previously suffered relatively

TABLE 1

Percent deep (internal) and sting (surface) fruit injury[1] at harvest in pheromone-treated and nondisrupted grower standard plots, 2005-2006.

Site	Treatment	Sting	Deep	Total
2005				
Newfane	Isomate	0.3 b	9.3 b	9.6 b
	MSTRS	0.1 ab	2.0 a	2.1 a
	Hercon	0 a	1.0 a	1.0 a
Yates	Isomate	0.1 a	0.1 a	0.2 b
	MSTRS	0.2 a	1.6 b	1.8 ab
	Hercon	0.1 a	0.6 a	0.7 b
	Grower Std	0.2 a	1.6 b	1.8 a
Lake	Isomate	0 a	0 a	0 a
	MSTRS	0 a	0 a	0 a
	Hercon	0 a	0 a	0 a
	Grower Std	0 a	0 a	0 a
Ridge	Isomate	0 a	0.1 a	0.1 a
	MSTRS	0.1 a	0.1 a	0.2 a
	Hercon	0 a	0 a	0 a
Alton	Isomate	0.6 a	7.2 a	7.8 a
	MSTRS-1	2.1 a	15.6 b	17.7 b
	MSTRS-2	0.9 a	6.0 a	6.9 a

Site	Treatment	Sting	Deep	Total
2006				
Ridgeway	Isomate	0 a	0.1 a	0.1 a
	MSTRS	0.1 a	0.4 a	0.5 ab
	Hercon	0.1 a	0.3 a	0.4 ab
	Grower Std	0.1 a	0.6 a	0.7 b
Williamson	Isomate	0.1 a	2.8 a	2.9 a
	MSTRS	0 a	1.8 a	1.8 ab
	Grower Std	0 a	0.1b	0.1 c
Lake	Isomate	0 a	0 a	0 a
	MSTRS	0 a	0 a	0 a
	Grower Std	0 a	0 a	0 a
Gaines	Isomate	0.1 a	0.3 a	0.4 a
	Grower Std	0.3 a	0.4 a	0.7 a
Sodus	Isomate	0 a	0.2 a	0.2 a
	MSTRS	0 a	0.1 a	0.1 a
	Hercon	0 a	0.1 a	0.1 a
	Grower Std	0 a	0 a	0 a
Newfield	Isomate	0.1 a	0.3 a	0.4 a
	Hercon	0.1 a	2.7b	2.8 b
	Grower Std	0.2 a	4.0b	4.2 b
Olcott	Isomate	0 a	0 a	0 a
	MSTRS	0 a	0.0 a	0 a
	Grower Std	0 a	0.2 a	0.2 a
Wolcott	Isomate	0 a	0 a	0 a
	MSTRS	0 a	0 a	0 a
	Grower Std	0.1 a	0 a	0.1 a
Kendall	Isomate	0 a	0 a	0 a
	MSTRS	0 a	0.1 a	0.1 a
	Grower Std	0 a	0 a	0 a

[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).

high fruit damage the previous season. Damage in all the treatments here ranged from 7–17% damage, which the grower indicated was relatively acceptable for the organic processing market, and a measurable improvement over the previous season.

In 2006, fruit damage at harvest was very low in all treatments, and at six of the nine sites there was no statistical difference between the pheromone plots and the respective Grower Standards (Table 1). Only two of the nine sites, Ridgeway and Newfield, had significantly less fruit damage in one of the pheromone plots—Isomate, in both cases—than in the non-disrupted Grower Standard, and at one site, Williamson, fruit damage was actually higher in the pheromone treatments than in the Standard. In this case, proximity to a large bin storage area (that may have been a source of uncontrolled moths) was undoubtedly a contributing factor. This was likely a situation where the use of farm-wide mating disruption would have been a potential solution.

Assessment

Although the pheromone treatments tested were generally a useful component of the OFM and LAW management programs in these orchards, some factors can be identified that potentially contributed to less-than-optimal management: plot size was not large enough to overcome the possibility of immigration by mated females; moth population pressure was sometimes too high to be effectively disrupted by the pheromone treatments; the pheromones were mostly applied against only the 2nd and subsequent generations, leaving the potential for damage from the 1st generation. The in-season fruit inspection regimen appears to be effective and reliable, but it is difficult to convince growers to wait for evidence of even a low level of damage in their orchards before applying a special spray against these pests. Pesticide use against these species could be reduced in situations of low to moderate population pressure, where mating disruption could be relied upon to adequately mitigate potential fruit infestations.

In general, considering the overall levels of pest pressure occurring in some of these orchards, and the economics (considering both materials and labor) of implementing these pheromone treatments, it is possible that internal worm problems in many NY orchards could be adequately addressed by adjusting pesticide spray schedules, improving spray coverage, or by using selective products for a limited number of designated sprays. In 2006 and 2007, we have seen evidence of the increasing importance of codling moth as a contributor to internal fruit-feeding damage in a number of Western NY orchards. This certainly complicates the management requirements for this pest group, and any decision to use mating disruption as a supplemental tactic will need to take this additional species into account. Although these tactics represent a substantial increased cost in a crop protectant program, they may be necessary for avoiding the higher price of having even a single load rejected by the fruit buyer. Ongoing work in this area will be directed at optimizing more farm-wide management strategies, in order to improve the effectiveness of both mating disruption and selective insecticide use and to diminish the potential for immigrating moths to overcome more localized control programs.

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