Quote: Mating disruption for codling moth is well established as an IPM tactic in Washington orchards.

Codling Moth Mating Disruption and Its Role in Washington Orchard Pest Management Programs

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Mating disruption technology for codling moth control was first registered by the EPA in 1991 and was used on no more than 2000 acres (809 ha) that year in North America. The acreage increased to an estimated 45,000 acres (18,212 ha) in 1997, almost entirely located in Washington, Oregon and California. Its use has increased most dramatically in Washington, with about 15,000 acres (6,071 ha) treated in 1995 and close to 27,000 acres (10,927 ha) in 1997 (about 15% of the Washington bearing acreage of pome fruits). We can expect to have more than 35,000 acres (14,165 ha) treated in 1998 in our state (Figure 1). What factors have led to the rapidly increasing use in Washington, and why is so much of the use concentrated in our state?

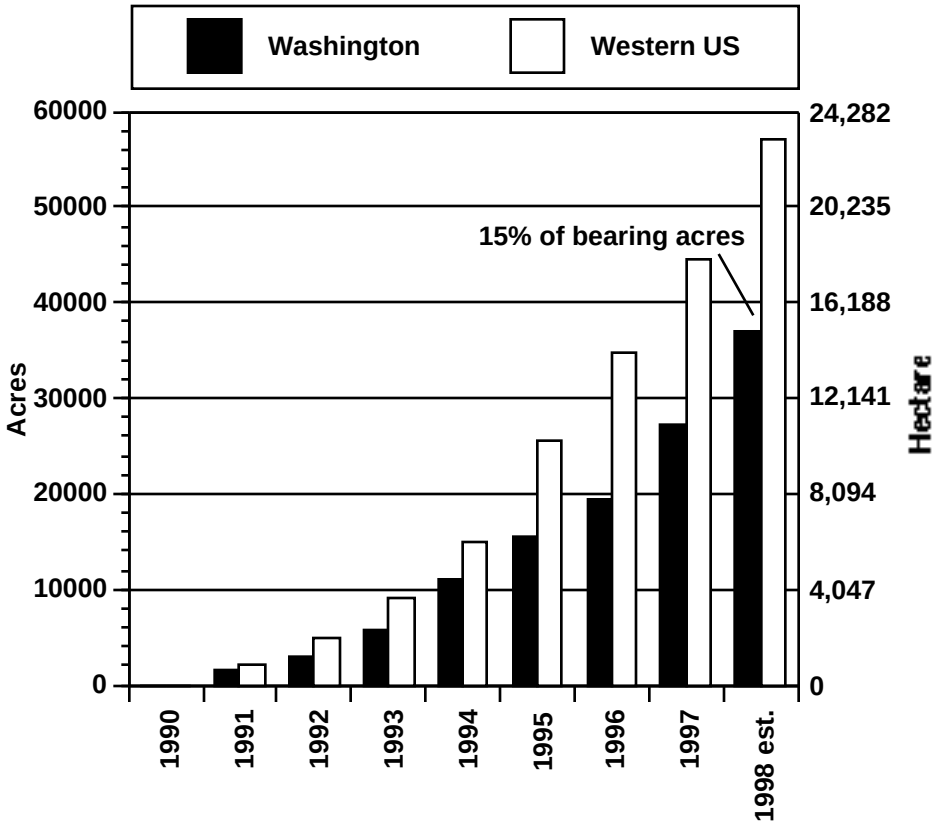

Figure 1. Pome fruit acreage treated with codling moth mating disruption.

Codling moth is the "key" pest for most Washington apple growers, the one around which most of our post-bloom cover sprays revolve. Unlike our midwestern and eastern counterparts, we do not have other obligate direct fruit pests, like the plum curculio and apple maggot. With our dry climate we spray relatively little, if at all, for fungal diseases such as apple scab, cedar apple rust and sooty blotch. The use of codling moth mating disruption can allow Washington growers to greatly reduce or, in some cases, even eliminate broad-spectrum insecticide use after bloom. The result can be a reduction of control costs for codling moth and sometimes for secondary pests. Many growers have experienced improved biological control of a number of pests, including aphids, leafminers, mites and pear psylla, when broad-spectrum insecticide use is reduced or eliminated.

Codling moth is well adapted to the warm, dry climate of central Washington, most years completing two full generations and in some years a partial third. In contrast, California growers

must control three or four generations of this pest and levels of resistance to organophosphate insecticides in some locations are very high. Because of this high pest pressure, and with the very high temperatures encountered in the California Central Valley apple districts, codling moth mating disruption has been less effective than in Washington. California growers have routinely had to supplement mating disruption with more insecticide applications than Washington orchardists to get adequate control and, therefore, its use has not been as cost effective.

The impact of the Food Quality Protection Act (FQPA) of 1996 is now looming large, with the likely loss of most of the organophosphate and carbamate insecticides we have relied upon for much of our orchard insect control. New insecticides, such as the insect growth regulators fenoxycarb (Comply®) and tebufenozide (Confirm®), can provide good control of codling moth and some other pests when and if they are registered for use on apples (see in this volume J. Brunner, "Integration of Multiple Tactics in Pest Management—Novel Chemicals and Biological Control"). However, they do not provide the same degree of control we have become accustomed to with insecticides like azinphosmethyl or phosmet. They will benefit from being supplemented with mating disruption, just as mating disruption itself will often need some help.

Growers cite other reasons for using mating disruption in Washington orchards. Many value the reduced time spent spraying, with its attendant hassles and discomfort, and the reduced exposure to insecticides, lessening the risk faced by their families, their employees and themselves. The use of organophosphates like azinphosmethyl requires reentry intervals of 72 hours in Washington orchards; eliminating those sprays simplifies labor management by not interfering with the increasingly labor intensive practices used in high density plantings. Others use mating disruption, in part because “it is the right thing to do,” demonstrating to the non-farming public that growers are responding to concerns about pesticide use and residues.

Mating disruption works by maintaining sufficient levels of the females’ sex pheromone in the orchard atmosphere to limit and delay the amount of mating that takes place. Pheromone dispensers are applied high in the tree canopy by bloom time, prior to the beginning of codling moth flight. Early on we recognized the importance of conditions that helped maintain adequate pheromone levels in the orchard. These include flat terrain, uniform and dense canopies, minimal wind, large treated areas, and square rather than elongate blocks to minimize the area of border relative to the interior. Realistically, few Washington orchards met most of these criteria. We also soon realized that mating disruption was not a simple substitute for cover sprays; too often, after pheromone dispensers were installed, the grower stopped any sprays for codling moth and sometimes suffered too much damage as a result. Many growers and consultants in the early

1990s were therefore skeptical of this technique. They believed that either mating disruption did not work or that it was suitable only in orchards with low codling moth pressure, where the cost of mating disruption, close to $140/acre at that time, far exceeded the cost of one or two cover sprays. Three developments have served to change these perceptions and increase the use of mating disruption.

First, the pheromone dispensers themselves are now much improved when compared with the initial versions. There have been two principal dispensers used in Washington. Isomate C+ (Pacific Biocontrol, Inc.) is applied once per season at up to 400 dispensers/acre. Checkmate CM (Consep, Inc.) is a two-application product, using 160 dispensers/acre applied by bloom and again about 70 days later. Both products have been improved from the original dispensers when there were problems with inconsistent pheromone release and inadequate longevity. In fact, the Isomate C+ dispenser, which was used on well over 80% of the Washington acreage treated in 1997, now releases codling moth pheromone into the early summer of the *next* year following application.

Second, we have learned that mating disruption needs to be supplemented periodically with insecticide applications to keep codling moth populations at low levels. The need for supplemental sprays varies with the block conditions and the codling moth pressure in the area. Large treated areas may, in time, require only a single first generation cover spray every 2, 3 or more years or, with a thorough monitoring program, just periodic sprays to hot spots or borders. Smaller blocks with more pressure may require one or two supplemental covers each year or a complete cover every other year with border sprays in intervening years. Mating disruption and cover sprays, to this point mostly insecticides like azinphosmethyl and phosmet, have almost a synergistic effect when used together. This combination has allowed mating disruption use to shift to higher codling moth pressure orchards, where cover sprays can be reduced from four, five or more annually to but one or two sprays within 2 years.

Third, there has been an increase in the use of the Isomate C+ dispenser at less than the full rate of 400 dispensers/acre. Close to 50% of the acreage treated with this dispenser in 1997 was at a rate of 200-300 dispensers/acre, resulting in cost savings of up to $55-60/acre. We have learned that with the application of one or more cover sprays there is little additional benefit in the use of 400 versus 200 dispensers. Many orchards that began with the use of the full rate have, over the course of 2 to 3 years, reduced the amount of Isomate C+ per acre. In the past few years, many orchardists using mating disruption for the first time have begun with the use of a half-rate, sometimes lowering codling moth control costs even in the first year and reducing fruit damage

from this pest. Table 1 provides representative scenarios of mating disruption use in two Washington orchards. Table 2 shows the use of mating disruption over time in what was a high codling moth pressure orchard.

Mating disruption for codling moth is not without its problems. Even with the use of a half-rate of dispensers, many growers still find it cheaper to control codling moth with the application of one to three cover sprays. With minimal applications of organophosphate insecticides, many Washington growers already have good biological control of secondary orchard pests, including spider mites, leafminers and most aphid species.

Codling moths are monitored in most Washington orchards with the use of pheromone traps. In mating disruption blocks, this approach is complicated by the high levels of pheromone present throughout the orchard atmosphere. We have found that the traps need to be placed much higher in the trees and used at a higher density and that visual monitoring of fruit damage becomes more important, all practices that take more time and increase management costs. Another concern has been the increase in leafroller populations in many orchards where mating disruption is used. Cover sprays for codling moth control, even though not targeted specifically for leafrollers, have the effect of suppressing populations of this pest. When these cover sprays are reduced or eliminated in mating disruption orchards, leafroller problems have increased. As a result, some growers have had to include additional insecticides for leafrollers in their control programs, most often formulations of *Bacillus thuringiensis* (Bt).

The **C**odling moth **A**reawide **M**anagement **P**rogram, or **CAMP**, is a program funded by the USDA-Agricultural Research Service in which codling moth mating disruption has been used as the central control tactic on sites throughout Washington, as well as in Oregon and California. The intent of this program is to demonstrate the use of codling moth mating disruption on an areawide basis, with neighboring growers working together to share extensive pest monitoring information and treat large contiguous areas with pheromone. Five sites began with the CAMP in 1995, involving about 3,100 acres. The program expanded in 1997 to include ten sites (seven in Washington) and 9,400 acres, and 1998 will see the addition of seven new sites (six in Washington and one in western Colorado). This program will be funded through 1999, with five or more new sites funded that year.

After three seasons of mating disruption, certain trends are clear in the three original Washington CAMP sites:

- codling moth populations are **down**, over 90% in many cases, from Year 1.

- cover sprays for codling moth control are **down**, averaging less than one per year per acre at all sites.
- codling moth fruit damage is **down**, 80% or more from pre-CAMP levels.

In addition, many growers reduced the rate of Isomate C+ dispensers per acre in Year 3 (1997). Further reductions in dispenser rates and cover sprays are planned in 1998, in light of the very low codling moth populations that are present.

There are several new developments involving mating disruption and pheromones for orchard pest management.

THE "DUAL" DISPENSER

Pacific Biocontrol has registered for 1998 a "dual" dispenser, called Isomate CM/LR, that contains both codling moth and leafroller pheromones. This dispenser has run out of both pheromones by late July or early August, a limitation that the company hopes to overcome in future years. Nonetheless, the users of this product in over 30 trials in Washington in 1997 reported generally positive results for the control of both pests, particularly when supplemented with other leafroller controls. The extent of its use will depend in large part on its price and whether it can be used effectively at less than 400 dispensers/acre, like the Isomate C+ dispenser.

"PUFFERS" OR "MISTERS"

These are mechanical devices that, in concept very similar to the fragrance dispensers found mounted on rest room walls, instead of spewing out perfume, spray a mist containing pheromone. Several models are under development. They have several potential advantages over "conventional" dispensers. Because they deliver much more pheromone at a single release event ("puff"), far fewer dispensers may be needed per acre; some trials have used one per acre or less. The cost per acre for the devices, pheromone and installation may be less than for other dispensing systems. Pheromone blends can be put in the canisters, allowing several different pests to be targeted with one device. The pheromones are contained within a metal canister, protecting them from breakdown by UV light. A timer can be incorporated into the device, allowing the pheromone to be dispensed at selected times when the target insects are active.

To this point, I am unaware of any trials, in Washington State or elsewhere, that have successfully demonstrated the effectiveness of "puffers" or "misters" in providing mating disruption of codling moth. Several trials have been derailed by mechanical problems with the devices themselves: stuck valves, degraded gaskets, congealed pheromone and more. Other tests either had very low

codling moth populations and provided no real test, or were well sprayed with insecticides to control codling moth. With rigorous testing in 1998, and the resolution of mechanical problems, "puffer"-type dispenser systems may yet prove the equal or superior to mating disruption systems used presently.

SPRAYABLE PHEROMONE

For many years there have been investigations of the application of pheromones for mating disruption with spray equipment. This approach has several potential advantages when compared with the hand-applied dispenser systems used today. The high initial investment of installing dispensers by bloom could be reduced if pheromone is sprayed on the trees only prior to periods of peak flight, or after the need is determined. The amount of pheromone and number of applications could be varied to reflect the pest pressure, and conventional application equipment could be used.

Progress with this approach has been limited by the ability to formulate the pheromone in a manner allowing it to be released for an extended period. In general, there is a large initial "burst" of pheromone released following application, after which levels drop precipitously. For some pests, like codling moth and leafrollers, levels of pheromone effective for mating disruption may last only a week or two. Key to the advancement of sprayable pheromones has been the process of microencapsulation, termed "MEC" as developed by the 3M Corporation. Pheromone is placed within microcapsules with diameters of only 20 to 40 microns. These capsules are contained in a formulation that can be mixed with water and sprayed onto foliage. The pheromone is then released from the microcapsules over time.

Significant success has been achieved with Oriental fruit moth and peach tree borer. Results of tests with the leafroller product in Washington have been only fair, but may improve with better timing and adjustments of the rates used. A MEC leafroller product received full registration in 1997 and we will gain more experience with it in 1998. A codling moth sprayable pheromone product has met with even less success so far, providing pheromone trap shutdown for only very short periods.

"ATTRACT AND KILL": SIRENE CMâ

Sirene CM provides a new twist on mating disruption in that the males are not just confused, they are killed. Small plot trials with Sirene CM were conducted in the Pacific Northwest in 1995 and again in 1997 in Washington. Sirene has been developed over the past decade by the Swiss chemical company Ciba-Geigy (now part of Novartis). This product is formulated as a thick, sticky substance, black and tar-like in appearance, that contains codling moth pheromone

(codlemone) and permethrin, a fast-acting, synthetic pyrethroid insecticide. Using hand applicators, the material is placed in trees as small droplets to branches or scaffold limbs.

Sirene droplets act as a sort of pseudo-female, luring in males with the release of codlemone. Attracted to the droplet, the male attempts to mate and contacts the insecticide, in the process picking up a lethal dose of permethrin. A Sirene application is effective for at least 5 to 6 weeks. Sirene may be more effective than mating disruption in small blocks of less than 10 acres and should be less affected by conditions such as steep slopes, uneven canopies, irregularly shaped blocks or windy conditions, all of which can limit the success of mating disruption. Sirene could be used as a supplement for mating disruption, with applications being made to orchard borders, hot spots and/or just prior to peak moth flight. This product does have the disadvantages of requiring significant labor for multiple applications and of leaving in the tree a persistent black material that marks clothing and skin when contacted by thinners, pickers and others working in the trees. Extensive field trials are planned for 1998 and full registration by the EPA is expected this year.

SUMMARY

Mating disruption for codling moth is well established as an IPM tactic in Washington orchards, and recent developments, particularly with the FQPA, indicate that its use will continue to increase. It is not a stand-alone product for codling moth control or one that can clean up a messy situation, in contrast to materials such as azinphosmethyl and phosmet that we have relied upon for many years. Growers will need to take their management skills up a notch or two to use mating disruption, let alone adapt to the many changes in fruit production in general that they face. Mating disruption is sure to be a key part of the increasingly integrated and complex orchard pest management programs of Washington apple and pear growers in the coming years.

ADDITIONAL READING

Brunner, J. F. 1998. Integration of multiple tactics in pest management—novel chemicals and biological control. Compact Fruit Tree, this volume.

Table 1. A representative scenario with high and low codling moth pressure.

	Year 0		Year 1		Year 2		Year 3		***OR***	Year 3	
	No.	$	No.	$	No.	$	No.	$		No.	$
High codling moth pressure:											
Covers (@$25/ac/app)	6	150	3	75	1.5	38	1	25	***OR***	0	0
Isomate C+ (per acre)	0	0	200	55	200	55	200	55		400	110
Total cost:		$150		$130		$93		$80			$110

	Year 0		Year 1		Year 2		Year 3		Year 4	
	No.	$	No.	$	No.	$	No.	$	No.	$
Low codling moth pressure:										
Covers (@$25/ac/app)	3	75	1	25	0.5	13	0	0	0.5	13
Isomate C+ (per acre)	0	0	200	55	200	55	200	55	200	55
Total cost:		$75		$80		$68		$55		$68

Table 2. Example of codling moth control scenario for an actual block with high codling moth pressure (and damage) near Orondo, WA.

	Year				
	1993	1994	1995	1996	1997
Dispenser	none	Isomate C+	Isomate C+	Isomate C+	Isomate C+
Rate/acre (avg.)	0	400	400	200	200
No. of covers[z]	4	1	1	1	0
% CM damage	3 to 5%	0%	0%	0%	0%
Cost per acre	$100	$135	$135	$80	$55

[z] It appears from blocks that have used MD for over 3 years that a supplemental cover spray will be needed every 2 or 3 years, at least to hot spots and borders, to reliably maintain CM populations low.