In the San Joaquin Valley . . .

Mating disruption of codling moth has mixed results

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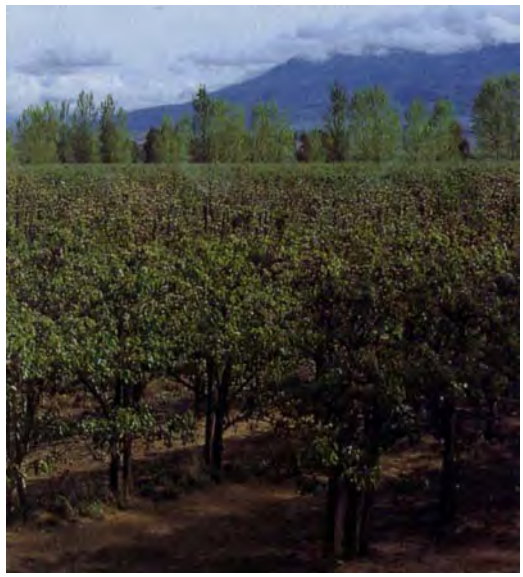

Pheromone confusion had to be augmented with insecticide sprays to control codling moth in the Sherrill orchard, which has a history of long moth flights and high infestation.

Pheromone confusion worked best in isolated orchards with low codling moth populations. In areas where codling moth developed three to four generations and apples were exposed to egg laying for each generation, mating disruption with pheromones was not consistently successful in suppressing codling moth populations. For an orchard with an established history of codling moth infestation, well-timed insecticide sprays had to be integrated with the confusion technique to obtain adequate control.

Codling moth, *Cydia pomonella* (Linnaeus), has been a serious pest of apples and other deciduous fruit in California since 1872. As fruit production moved into the San Joaquin Valley, so did codling moth. It still ranks as the key pest of apples.

Until recently, the only ways of reducing infestation were through synthetic insecticides (initially arsenicals, then chlorinated hydrocarbons, organophosphates and insect-growth regulators) or through cultural methods, such as sanitation and larvae-trapping. However this approach has led to problems with insect resistance and, in some instances, pesticide residues on fruit at harvest.

However, with the isolation of codlemone in 1971, the synthetic sex pheromone for codling moth, has come the development of mating disruption as a method of pest management. In trials to date, this technique has been more successful in some areas than others.

Probably the most challenging situation for mating disruption is the one in which codling moth can develop a maximum number of generations during a season. This is precisely the situation in the southern San Joaquin Valley. Based on an 11-year history of daily codling moth monitoring in the Sherrill orchard near Arvin, California, the total number of degree days (dd.) between first and last moth of the year has ranged from 3,405 (110 moths per trap per season in 1983) to 4,694 (394 moths per trap per season in 1992). A degree day is defined as 1 degree above the threshold temperature for 24 hours. This is using a base of 50° F and an upper threshold of 88° F. Monitoring traps were either Pherocon 1C (1983–1989)) or 1CP (1990–1993) traps baited with Trece 1 mg pheromone caps changed monthly. The earliest moth activity recorded was on March 7, 1986, and the latest moth trapped was on October 2, 1991. Codling moths are capable of laying eggs for as long as 7 months. In this area three full generations were present each year; most years had at least a partial fourth generation. A full fourth generation was possible in 1986 (3,981 dd.), 1990 (4,013 dd.), 1991 (4,220 dd.) and 1992 (4,694 dd.). This is based on an average of 1,060 dd. for the first generation and 1,220 dd. for the remaining generations (a total of 3,500 dd. would allow for four generations).

In addition to a climate that permits extended flight activity of codling moth, this area provides hosts for codling moth development throughout the spring and into the fall. The primary apple variety, Granny Smith, requires at least 180 days from full bloom to harvest. Another popular apple in the San Joaquin Valley, the Fuji cultivar, is harvested even later than Granny Smith.

This article reviews mating disruption trials performed at three locations in the southern San Joaquin Valley. The participating growers referred to below include the Sherrill orchard trial, the Bidart orchard trial, the second Sherrill orchard trial and the Met West trial. The work was done by the authors in collaboration with the growers and their pest control advisors.

The sites were chosen based on the history of infestation. Both the Sherrill orchard and the Met West orchard have a long history of high moth flights and infestation. The Bidart orchard is a relatively new planting with low numbers of moth flights and no damage. It should be pointed out that both the Sherrill and Met West orchards, where mating disruption was in place, were also treated with insecticides, but much less frequently than in the conventional grower-sprayed plots. This was not done at the Bidart location because we knew the moth population was low. The use of some

insecticide is necessary where moth populations are established and harvest of apples occurs in late August and September. The trial is a controlled trial that is intended to be analyzed statistically based on a number of years' research. In each trial, the pheromone disruption area was under control of the researchers, while the grower and pest control advisor made decisions in the conventional plot.

Sherrill orchard: the first trial

The first codling moth mating disruption trial established in Kern County in 1987 was not successful. It was performed on the original 18.4-acre Sherrill orchard, which was planted in 1981. The orchard has a density of 1,361 trees per acre (4-feet-by-8-feet spacing) and is irrigated by overhead sprinklers. The trees at the start of the season are approximately 6 feet high and at harvest are approximately 9 feet high. Other than pollinizers and a small planting of akane apples, a Japanese variety no longer grown in the orchard, Granny Smith was the only variety. To the west of the orchard is a 9-acre planting of apricots, which are harvested by mid-May. To the east is a 10-acre planting of peaches and nectarines, also harvested during May. No other hosts are within a mile of the orchard.

The pheromone-treated portion of the orchard was the east 11.5 acres; the standard insecticide comparison block was the west 6.9 acres. Following the manufacturer's instructions, Biolure LTD 6-month dispensers were placed in the 11.5-acre area at a rate of 100 per acre on March 23, 1987. By April 10 flight of winter moths was detected in the disruption block, only 12 days after moths were trapped in a non-pheromone-treated comparison block. This was a clear indication that mating disruption was failing. Fruit infestation was first detected on May 8; by June 12, 12% of the Granny Smith apples were infested in the pheromone-treated area. This was based on a small, randomly selected sample of 100 fruit from throughout the disruptant-treated area. Although two sprays were subsequently applied to the disruption block on June 20 (phosmet at 4 pounds active ingredient per acre in 200 gallons per acre) and July 31 (carbaryl at 3 pounds a.i. per acre in 200 GPA), infestation at harvest, on September 4 (first pick), averaged 17.5%. On September 22 (second pick) damage was 33%. Both of these infestation rates were computed using a random sample of 900 fruit taken from throughout the orchard. At that time an average of 62 moths per trap had been captured in the disruptant side (based on four Trece Pherocon 1C traps baited with the 1 mg codlemone-loaded rubber septa).

The standard insecticide comparison block was sprayed three times with azinphosmethyl on April 15, June 5 and June 20, at the rate of 1 pound a.i. per acre applied in 200 GPA. Carbaryl was applied once, on July 31, at the same time and rate that was used in the disruptant-treated area. Codling moth damage in the standard insecticide block averaged 3.7% on September 4. There were no fruit left after this date.

Bidart orchard trial

The three experiments were all designed with a minimum of 5 acres treated with the Checkmate. The grower standard plots were adjacent to the pheromone treatment and varied in size as indicated below. The varieties sampled were the same. Irrigation was by overhead sprinkler at the Bidart and Sherrill orchards and by ground misters at the Met West side.

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Codling moth damage

Overhead sprinklers reduce the effectiveness of insecticides and are a common method of irrigation in the southern San Joaquin Valley.

In 1992 and 1993 trials were attempted again at the Bidart Granny Smith orchard, the Sherrill orchard (for the second time), and the Met West orchard. These trials were part of a long-term study to evaluate mating disruption; to date they have met with varying success. The Met West orchard trial — where codlemone was used with least success — is difficult to evaluate, because the grower was late in placing disruptant in the field, contrary to manufacturer's instructions.

Greater success was obtained in the Bidart and Sherrill orchards, where the pheromone disruptant was placed in accordance with manufacturer's (Consep) instructions. Three applications of disruptant were applied at approximately 60-day intervals through the growing season in each of these locations. Even so, the success rate in these two orchards differed, possibly because they have quite different codling moth histories. The Bidart trial has been quite successful. Where sprays were integrated with the pheromone placement at Sherrill, it is also successful.

The Bidart Granny Smith orchard site has been the most successful example of mating disruption of the three orchards studied. It was observed in both 1992 and 1993. Except for the grower 32-acre standard comparison site, adjacent to the pheromone-treated 6 acres, this orchard is isolated from any other codling moth source and was in its second year of production in 1992. The total 38 acres is surrounded by a small manufacturing area, airport, and canal to the south and a canal and vineyards to the north and east. Open cotton land lies to the west. The orchard consists of 518 trees per acre on 6-foot-by-14-foot spacing. A modified Lincoln trellis system is used. Trees are irrigated with overhead sprinklers and are approximately 12 feet in height at harvest.

In 1992 two standard 1CP traps baited with 1 mg Trece caps were used to monitor moths in both the 6-acre

and a 10-acre portion of the 32-acre block. No codling moths were trapped and no sprays applied to the 6-acre disruptant portion of the orchard. The disruptant was applied on March 27, May 20 and July 23 at the rate of 120 Checkmate dispensers per acre. These contain 105 mg active codlemone per dispenser. The grower-standard comparison trapped only four moths all season. One spray was applied on April 3 to the 32-acre block using 1 pound a.i. of chlorpyrifos in 200 gpa. This treatment was aimed at both codling moth and oblique-banded leafroller. At harvest in the disruptant treatment, on August 10, only 0.15% (2,000-fruit sample) codling moth-damaged fruit was found; 0.6% was damaged by oblique-banded leafroller. Other pest damage was less than 0.5%. The grower standard had no codling moth damage and 0.15% oblique-banded leafroller damage.

This orchard was again evaluated in 1993, using the same guidelines as in 1992. The only difference in method was that codling moth was monitored with 10 mg Trece codling moth septa, changed monthly and placed inside the 1CP traps cleaned regularly. The Checkmate disruptant treatments were made on March 7, May 28 and July 30. No moths were trapped in the single trap placed in the disruptant side. Only six moths were trapped during August in the grower-standard treatment, which was treated on April 8 with chlorpyrifos (1 pound a.i. in 200 gpa) for both codling moth and oblique-banded leafroller. No damage was detected in a 500-fruit sample from each block on August 24, 1993.

Sherrill orchard trials

A more challenging site was the orchard described in the 1987 trials, the 18.4-acre Sherrill orchard. This site was only followed in 1993. The grower had planted an additional 10-acre orchard in 1988, to the east of the original Granny Smith planting. These two orchards were separated by a poplar windbreak. This new planting contained a mixture of Red Clapp and Bartlett pears and Gravenstein, Lady Williams, Mutsu and Gala apples. These fruit are all harvested by the end of July and exposed to only the overwintering, first generation and a portion of the second generation of codling moth.

The history of the older orchard area is of high codling moth populations, based both on moths trapped during the season and fruit infestation found at harvest. For example, in 1992 an average of 394 moths per trap per season (Trece caps and traps) were monitored from March 19 to September 19. Damage at harvest averaged 7% on August 19, even after five sprays had been applied. In 1990 and 1991, 206 and 259 moths per trap per season were found, respectively. This was also in spite of six sprays (1990) and five sprays (1991) applied for codling moth. Because of this high resident codling moth population, we were hesitant to use this orchard as a trial site in 1992.

However, in 1993 we felt that the integration of well-timed sprays aimed at first-generation worms and placement of Checkmate at 160 dispensers per acre might be effective in reducing damage at harvest. Eleven and a half acres of the older 18.4-acre block were treated with the 105 mg Checkmate disruptant at the rate of 160 dispensers per acre on March 24, June 2 and August 1. In addition, three azinphosmethyl (1 pound a.i. in 200 gpa) sprays were also applied to the overwintering flight and aimed at first-generation worms on April 4, April 29 and May 20. No other treatments were made after May 20 in the disruptant side of the orchard; three more were made on July 1 (azinphosmethyl at 1 pound a.i. in 200 gpa), August 3 and August 23 (both carbaryl at 2 pounds a.i. in 200 GPA) to the 6.9-acre grower standard side of the block. Infestation in both comparison blocks on July 28 was 2 to 3%. Fruit infestation increased dramatically by August 31. Based on a 1,000-fruit harvest sample, the grower standard, with six sprays, averaged 7.2% infestation from codling moth (no other damage) and 5.4% in the disruptant-treated portion of the orchard (stinkbug and oblique-banded leafroller were less than 1%). An average of 387 moths per trap per night were trapped in the grower-standard area and 54 moths per trap per season in the pheromone-treated area (43 in the overwintering flight based on the 10 mg trap loads in both blocks). Ideally no moths should be trapped in the disruptant treatment, even using 10 mg trap loads.

Met West

A third site (Met West) was followed in 1992 and 1993. The results observed at this site are difficult to evaluate because of the late placement of the disruptant. The orchard is near the oldest continuous planting of Granny Smith apples in the southern San Joaquin Valley. In both years the disruptant was placed considerably after the first moth was trapped. In 1992 the first moth was trapped on March 13 and disruptant placed on March 27. In 1993 disruptant was not applied until 19 days after the first moth was trapped on March 8. Two subsequent placements of disruptant were made each year at 60-day intervals and at the 120-trap-per-acre recommended rate. This Granny Smith orchard is irrigated with under-tree misters and contains 518 trees per acre (approximately 12 feet high). The orchard is surrounded by various varieties of apples, peaches and nectarines.

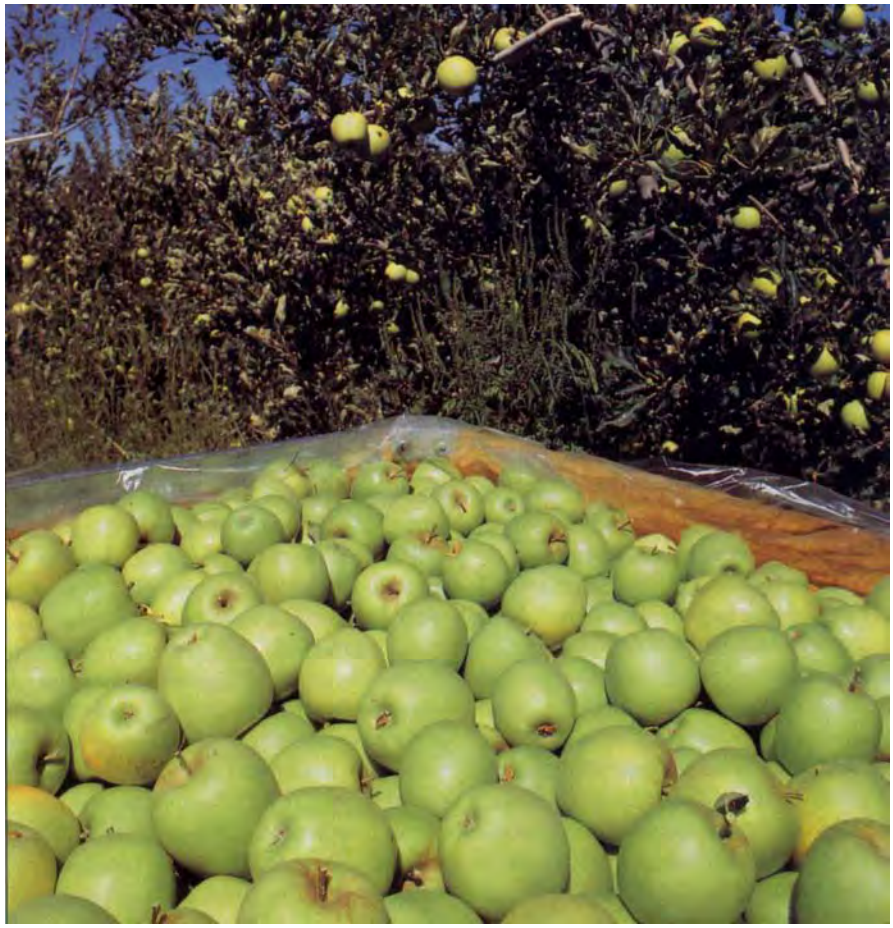
Observations were quite different in each of the 2 years at the Met West site. The 1992 trial (5 acres of disruptant-treated adjacent to insecticide treated) was quite successful, with only 2.2% codling moth damage at harvest (August 11) in the disruptant (Consep) treated 5 acres of Granny Smith. The grower insecticide-treated 5 acres had 0.1% damage. The disruptant was applied after a total of 23 moths had been trapped, and the area was therefore sprayed with 1.5 pounds of azinphosmethyl at 200 gpa on April 3, 1992. The grower-standard area also received this treatment plus 1.5 pounds a.i. of methyl parathion on May 2, 1992.

In 1993 the disruptant treatment at Met West failed, resulting in 48% fruit damage, in spite of the application of two sprays. These two sprays included 1 pound a.i. of azinphosmethyl on April 4, 1993 and 2 pounds a.i. of methyl parathion on August 12, 1993. Both treatments were in 200 gpa. The grower standard received six sprays, all applied in 200 gpa. These sprays in-

cluded 2.5 pounds a.i. of diazinon on April 6, 1 pound a.i. of azinphosmethyl on May 17, 1.5 pounds a.i. of azinphosmethyl on June 4, 0.75 pounds a.i. of methyl parathion on June 28, 3 pounds a.i. of phosmet on August 4 and 1 pound a.i. methyl parathion on August 14. Infestation in the grower check was 6.4% at harvest on August 23, 1993, also considerably higher than the previous year.

Best uses, limits of pheromone

Two extremes in codling moth infestation have been tested with pheromone disruption in the southern San Joaquin Valley. Where the orchard is young and the history of damage is quite low, pheromone confusion has worked alone and can possibly keep infestation from developing in the future (the Bidart orchard will be followed in the years to come). Where the history of infestation and moth populations is high, pheromone confusion must be supplemented with well-timed insecticide sprays, to be confident of reduced codling moth damage at harvest. Our experience has been that treatment of first-generation worms is the most successful approach. In spite of the insecticide treatments being required where codling moth populations are high, mating confusion has been observed to reduce the number of sprays necessary, particularly those applied near harvest, when chances of finding detectable levels of residues on fruit are highest. Mating confusion can also be used to reduce the exposure to multiple applications of organophosphates and thereby slow the development of resistance to them. Repeated use of pheromone mating disruption may eventually lead to a decline of codling moth populations in the orchard, unlike the increase seen during the last decade, in spite of increased insecticide treatments.



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In orchards where codling moth populations are high, mating disruption can reduce the number of insecticide sprays needed, particularly near harvest.

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The authors wish to express their thanks to Jim Eyherabide of Bidart Bros. Farming, Norm Reirmers, and Sam Perez of Met West Farming Corp. Also, we appreciate the financial and product support of Consep Corp. The research was funded through USDA Cooperative Agreement No. 91-COOP-1-6590.