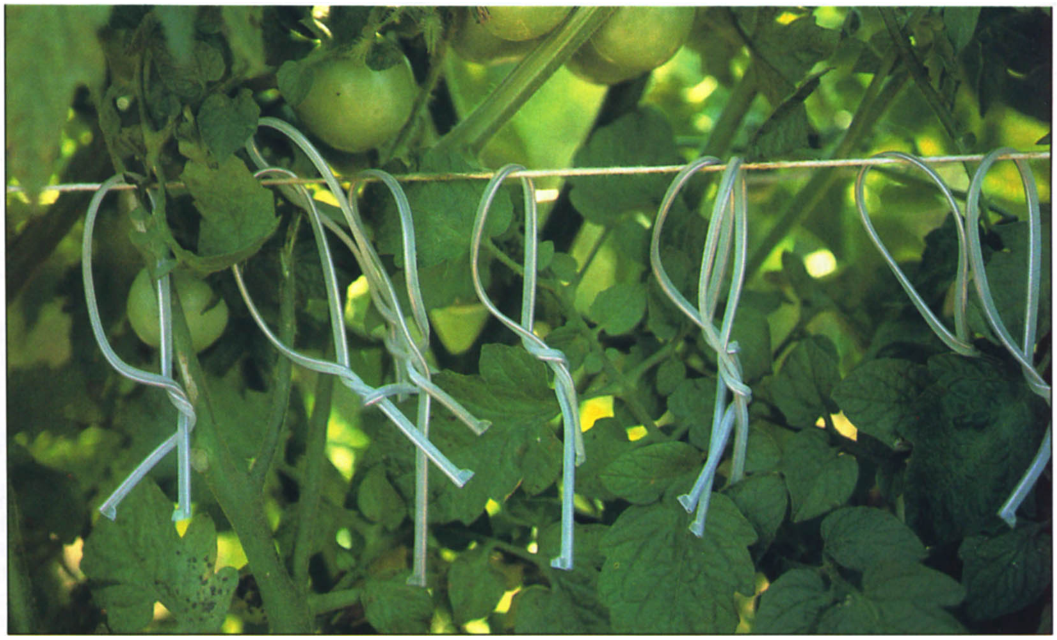

'PW larvae, feeding under the stem end of cherry toma- ɔes, where they are hard to detect (left), can cause dev- ıstating losses. Adult moths themselves (top left) cause ıo serious damage. Above, pheromone rope dispensers ɹsed in mating disruption trials.

Controlling tomato pinworm by mating disruption

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Tomato pinworm occurs principally in tropical tomato-growing areas where winters are mild, particularly Florida, the lower Rio Grande Valley in Texas, southern California, and Mexico. It is not an important pest of fresh market and processing tomatoes in California's major growing region of the central San Joaquin Valley, primarily because of the short production season and cold winters. But it has become a major pest of cherry tomatoes in that area, probably as a result of the long production season and cultural practices unique to this crop. Larvae of tomato pinworm (TPW), *Kieferia lycopersicella*, cause the most serious damage when they enter the fruit, although they also mine the foliage.

Two cherry tomato varieties are grown commercially in the Valley: FSU Dwarf and Basket Pak. FSU Dwarf, a short-season variety grown for an early market, is usually transplanted and hotcapped in February. The production season usually ends by August, although a few growers maintain plants for a second harvest in September and October. Basket Pak, a long-season variety, is normally transplanted in mid-March and harvested from late June until the first frost, which could be at the end of November. The cherry tomato season may therefore be from 6 to 9 months long, depending on the variety and market demand. An estimated six or seven tomato pinworm generations can occur during this season.

Unlike other tomatoes, cherry tomatoes are harvested and marketed with the calyx attached. TPW larvae feed mainly under the calyx, making it difficult to sort out infested fruit. Since growers cannot remove the calyx to detect injury, the tolerance for the pest is low. Losses due to the pinworm have been devastating, and many small-scale producers rely on heavy pesticide use for control. Eight to 12 insecticide applications per season are common, and some growers make as many as 16.

In spite of the repeated insecticide treatments, tomato pinworm continues to cause unacceptable levels of damage. Multiple treatments also lead to secondary outbreaks of the vegetable leafminer, *Lyriomyza sativa*, requiring additional insecticide treatment.

Monitoring study, 1981-83

We monitored adult TPW flight activity for 3 years in Tulare and Fresno counties using wing-style traps (Pherocon 1C) baited with TPW pheromone lures. Four to six fields, each containing at least two traps, were monitored annually beginning in April. Traps were inspected weekly, and twice a week when catches were high, to prevent trap saturation. Lures were replaced every 4 weeks.

Weekly fruit sampling began at the first sign of tomato pinworm mines, usually in mid-June. From 100 to 200 fruit were sampled from each field.

The combined observations showed that the first major TPW moth flight occurs in June. Mined foliage is visible in about mid-June to early July. Fruit infestation typically begins in July, reaching 5% damage by as early as the first week of August. Fields planted with cherry tomatoes for 3 years or more, or planted next to such fields, usually had more severe TPW problems than those with only 1 or 2 years of cherry tomatoes.

Mating disruption study

The same pheromones that have been used for several years as lures to monitor adult male TPW populations (96:4 mixture of [E]-4:[Z]-4-tridecen-1-yl acetate) have recently been used in large amounts for mating disruption. This technique provides control by saturating a field with TPW sex pheromone so that male moths cannot find and mate with females. We evaluated this approach in a 3-year project in Tulare and Fresno counties.

During August 1985, we obtained pheromone rope dispensers for testing in two 2-acre fields with high pinworm populations. The dispensers were hollow, 8-inch-long tubes containing 80 mg of TPW pheromone mix, bound to aluminum wire. We placed 400 dispensers in half of each field by tying them directly to

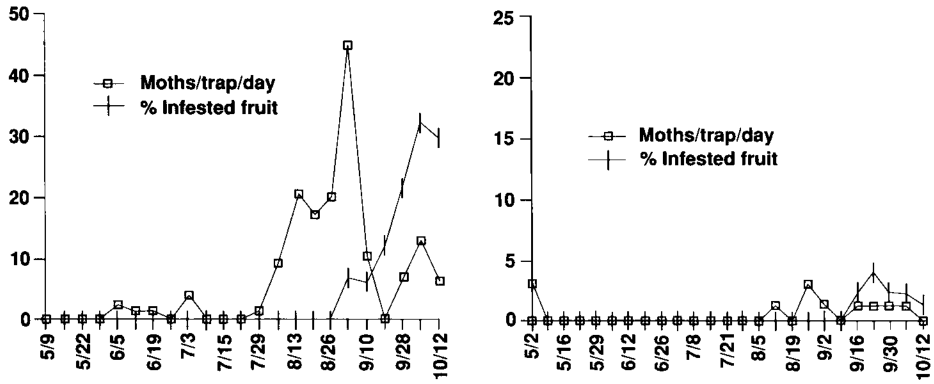

Fig. 1. Examples of 1986 TPW fruit infestation levels and moth trap counts in control (left) and pheromone-treated fields (right). Fruit infestation reached as high as 33% in the control. Fields treated with pheromone rope dispensers never had more than 5% infestation.

the tomato plant, support poles, or trellis string. Two wing traps with TPW pheromone lures plus one blank trap had previously been placed in each field. Trap counts and fruit infestation data were collected weekly.

There was a large reduction in moths trapped in the pheromone-treated sections of both fields compared with the untreated portions. No difference was seen in the level of pinworm fruit infestation, however, probably because the pheromone dispensers were placed in late August after larvae were abundant. Control by disruption was not achieved.

In 1986, the experiment began in mid-April. We chose fields that (1) had been planted to cherry tomatoes for 3 years or more or were adjacent to such fields, (2) had a history of high fruit damage by tomato pinworm, and (3) allowed a separation of at least a quarter of a mile between treated and untreated fields. Isolation was required to prevent mating disruption in control fields and to reduce migration from neighboring fields.

Of six such fields identified, ranging in size from 1 to 6 acres, we randomly selected three as controls. Three were treated with three applications of 400 pheromone rope dispensers per acre at 10-week intervals beginning the first week of May.

At least two wing traps (Pherocon 1C) with Scentry hollow fiber lures and one blank trap were placed in each field. Lures were replaced every four weeks. Trap counts were taken weekly and calculated as moths per trap per day.

Weekly fruit sampling from the top, middle, and lower part of the plant began at the first sign of leafmining, usually in early July. The percentage of tomato pinworm infestation was recorded.

Pheromone-treated fields were also monitored weekly for all "key" pests. Growers were asked to avoid unnecessary insecticide applications in treated fields and, when appropriate, to use more selective insecticides. Growers made their own pest management decisions on untreated control fields.

In 1987, field selection and monitoring were the same as in 1986. However, another pheromone dispenser treatment (Scentry Attract 'n Kill Tomato Pinworm fibers) was compared with the rope dispenser. Two fields received rope dispensers, and two received pheromone fiber applications.

TABLE 1. Insecticide application record of research plots, 1986-87

Year and field	Pheromone treatment	Insecticides used	Date of first appl.	No. of appl.	Peak fruit infestation
1986					%
A	None	Azinphos-methyl, methomyl, naled	5/28	14	33
B	None	Azinphos-methyl, methomyl, diazinon	6/15	12	14
C	None	Methomyl, *Bacillus thuringiensis*	6/27	6	23
D	Ropes	*Bacillus thuringiensis*	7/17	1	1
E	Ropes	None	—	0	5
F*	Ropes	—	—	—	—
1987					
G	None	Methomyl, diazinon	3/27	16	65
H	None	None	—	0	12
I	Fibers	None	—	0	4
J	Fibers	*Bacillus thuringiensis*	7/10	1	5
K	Ropes	*Bacillus thuringiensis*	7/2	1	4
L	Ropes	None	—	0	5

* Field was disced in June because of severe fusarium wilt.

Also during 1987, *Trichogramma pretiosum*, a biological control agent, was released in the pheromone-treated fields to reduce the need for insecticide applications to control tomato fruitworm (*Heliothis zea*). As in 1986, key pests were monitored in pheromone-treated fields, and growers were asked to avoid unnecessary insecticide applications. Growers followed their normal pest control strategies in the two control fields.

Results

In 1986, we found an average of 833 moths per trap in control fields and 63 moths per trap in pheromone-treated fields. In 1987, control fields averaged 950 moths per trap, while pheromone rope- and fiber-treated fields averaged 14 and 21 moths per trap, respectively. Although trap catches are not a direct indication of mating disruption, the pheromones apparently affected the ability of male moths to find baited traps.

In both 1986 and 1987, moth flights in control fields often reached 20 moths per trap per day by the August flight. Moth flights in pheromone-treated fields remained low from application through the entire season. These counts ranged from 0 to 3 moths per trap per day, except in one field, which had a count of 7.

In 1986, fruit infestation in control fields peaked at 33% in field A (fig. 1, left), 14% in field B, and 23% in field C. Fruit infestation in control fields in 1987 peaked at 65% in field G and 12% in field H. Fruit infestation levels in pheromone-treated fields never exceeded 5% (fig. 1, right).

Some fruit damage occurred in pheromone-treated fields, even though few moths were trapped. The damage probably resulted from the migration of mated females into treated fields. Also, some behavioral or physiological change may have occurred in the pinworm population in response to an environment altered by pheromone applications. Or some males may have found females visually.

The reduction of pesticide use to control tomato pinworm was the major objective of our project. During 1986, control fields had 14, 12, and 6 insecticide applications; both pheromone fields had only one (table 1). In 1987, one of the control fields had 16 insecticide applications and the other had none. The four pheromone-treated fields during 1987 totaled two insecticide applications.

Field I in 1987 was the same site as field A in 1986. As a control field in 1986, it received 14 pesticide applications. As a pheromone-treated field in 1987, it received no insecticides. Similarly, field K in 1987 was the same site as field B in 1986. As a control field in 1986, it had 12 insecticide applications. As a pheromone-treated field in 1987, it received one insecticide application. *Bacillus thuringiensis*, applied for hornworm and beet armyworm control, was the only insecticide used in any of the pheromone-treated fields.

Fruit damage resulting from other pests (principally armyworms) ranged from 4 to 9% during any one harvest in control fields compared with 1 to 5% damage in pheromone-treated fields. The lower damage in pheromone-treated fields may be attributed in part to more abundant parasite populations, principally *Hyposoter exigua* and *Trichogramma pretiosum*.

Conclusions

Our results suggest that pheromones can be integrated successfully into a TPW management program, as long as the cherry tomato field is isolated from other infested fields and the pheromones are applied before populations build up. Other helpful management practices include discing plant residues after the last harvest to reduce overwintering tomato pinworms and avoiding sites with a history of pinworm infestations.

One registered TPW pheromone is currently available, the Scentry "Attract 'n Kill" fibers. The fibers and adhesive cost about $28 per acre per application and take 0.5 to 1.5 hours to apply. The estimated cost for four applications is $124 to $128 per acre.

By comparison, insecticides cost from $8 to $12 per acre and labor ranges from 1 to 5 hours per application. Using 12 applications for comparison, it would cost $156 to $444 per acre for TPW control.

We conclude that, for the small-scale plantings (1 to 2 acres) that characterize the cherry tomato industry, the pheromone-disruption technique is an effective, economical alternative to chemical insecticide treatment.

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Spray coverage on strawberries

Carolyn Pickel ❑ Norman C. Welch

Complete underleaf spray coverage is essential for good control of several pest problems in strawberries. Two-spotted mites (*Tetranychus urticae*), for example, tend to build up on the undersides of the lowest leaves. Diseases such as common leafspot (*Ramularia tulasnii*) and powdery mildew (*Sphaerotheca humuli*) infect the underleaf and can develop into important sources of disease.

The growth pattern of strawberry plants—close to the ground and with middle and lower leaf tiers overlapping—make complete spray coverage difficult if not impossible with commonly used equipment. Most growers use homemade spray equipment, resulting in a wide variation of nozzle configuration, nozzle type and number, pressure, and spray boom height. Added to these problems is an increasing resistance of mites and leaf disease to currently registered chemicals.

We tested several growers' sprayers to see if any of them provided satisfactory coverage. We evaluated spray coverage on 1-inch-square dye cards stapled to upper and lower surfaces of strawberry leaves in the top, middle, and lower tiers of the plant. All tests were conducted on beds with 52-inch centers, each with two rows of strawberry plants spaced 14 inches apart.

Because most sprayers cover three beds, we used the middle bed for the coverage evaluation. Dye cards were attached to 12 leaves at each test site, starting from the furrow side of the row. This sampling approach allowed data collection from the inside and outside of the bed area. Evaluation was based on the card area covered with dye (red dye No. 40 at 8 oz./100 gal. spray solution): 1 indicated no dye; 2, less than 50% coverage; 3, spots; 4, more than 50% coverage; and 5, completely covered. Coverage rated 1 to 2 would be inadequate; 3 to 4, adequate; and 5, complete.

Equipment evaluations

Tests in 1984 and '85 evaluated grower-designed sprayers near Watsonville during July and August, when plant density was greater and coverage most difficult. We tested several sprayers again in 1985 to see if coverage had improved. In our analysis, we considered each grower in 1984 and 1985 as a treatment and the dye system rating as replicates. In the analysis of overall coverage, results corresponded to underleaf coverage found on the lowest tier. That is, when coverage was poor on the underleaf of the lowest tier, coverage from the entire plant sample was also poor. When data were analyzed from the whole plant, coverage also decreased in the lower tiers; ratings were 3.17 in the highest tier, 2.29 in mid-tier, and 1.70 in the lowest tier. Since underleaf coverage is the most important for control of straw-

TABLE 1. Evaluation of underleaf spray coverage of strawberry plants' bottom tier by growers' sprayers

	1984			1985		
Sprayer	Rate	Pressure	Rating*	Rate	Pressure	Rating*
	gpa	*psi*		*gpa*	*psi*	
1	200	200	3.3 c			
2	200	190	3.0 c			
3	200	250	2.5 bc	180	300	0.5 d
4	250	350	1.8 ab	200	250	2.0 b
5	300	200	1.7 ab	300	220	2.8 a
6	200	200	1.5 ab			
7	200	200	1.0 a			
8				250	160	2.8 a
9				100	280	1.8 b
9				100	280	.8 c

* Average coverage rating on scale of 1-5; 5 = best coverage. Means in each column followed by same letter are not significantly different (p = 0.05 DMRT).

TABLE 2. Underleaf coverage with and without air assist at different plant tier heights, three sprayers

	Rating*					
	Air assist on			Air assist off		
	Sprayer			Sprayer		
Tier	B	C	D	B	C	D
Top	4.3 a	3.8 a	3.9 a	3.8 c	3.2 b	3.3 a
Mid	4.2 ab	3.7 a	3.9 a	3.3 d	2.3 c	2.4 b
Low	3.9 bc	3.5 ab	3.8 a	2.4 e	1.8 d	1.4 c

* See table 1 footnote. P = 0.01 DMRT.