Impact of Pesticides for Tomato Fruitworm (Lepidoptera: Noctuidae) Suppression on Photosynthesis, Yield, and Nontarget Arthropods in Strawberries

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ABSTRACT Effects of several chemicals registered or considered for *Heliothis zea* (Boddie) suppression on strawberries were evaluated for impact on plant physiology, yield, and nontarget arthropods. During a period when *Tetranychus urticae* Koch populations had not reached damaging levels, bifenthrin significantly increased photosynthesis rates and significantly reduced stomatal resistance compared with the untreated control. Bifenthrin treatments produced significantly heavier fruit than controls on 3 of 8 dates in 1985 and 5 of 11 dates in 1986. Foliage and fruit treated with naled at 1.12 or 1.68 kg (AI)/ha on alternate weeks developed visual symptoms of phytotoxicity, but plants did not produce significantly lighter fruit compared with control plants or exhibit a trend toward reduced photosynthesis. However, application of naled (1.68 kg [AI]/ha) showed a strong trend of fewer fruit in 1985 compared with controls. Repeated applications of methomyl, carbaryl, and permethrin produced only transient effects on photosynthetic activity. Although all chemicals tested provided acceptable levels of aphid control, only bifenthrin and avermectin b_1 reduced *T. urticae* populations to below economic injury levels. The incorporation and use of these chemicals in an integrated control program on strawberries are discussed.

KEY WORDS Insecta, Acari, insect control, photosynthesis

STRAWBERRIES, *Fragaria ananassa* (L.), are an important agricultural commodity in California, with annual values exceeding $200 million since 1980 (McGregor 1981). This crop is attacked by a complex of economically important pests, which includes the twospotted spider mite, *Tetranychus urticae* Koch, the strawberry aphid, *Chaetosiphon fragaefolii* (Cockerell), the potato aphid, *Macrosiphum euphorbiae* (Thomas), the melon aphid, *Aphis gossypii* Glover, and the green peach aphid, *Myzus persicae* (Sulzer) (Oatman & Platner 1972, Trumble & Oatman 1984). In 1969, the first infestation of the tomato fruitworm, *Heliothis zea* (Boddie), was reported for strawberries (Oatman 1969). The larvae cause damage by boring into the ripe fruit, rendering the strawberries unmarketable for the fresh market and downgrading the fruit to "juice" quality for the processing industry. This results in substantial losses to growers because the fresh market price is usually much higher than the processing price and the value of berries for juice is typically 2.5–3.5¢/kg versus 9.5–10.5¢/kg for jam or freezer grades.

Unfortunately, applications of insecticides registered for the control of *H. zea* may cause resurgence by other pest species or reduce yields through adverse effects on plant growth. Carbaryl, per-

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Table 1. Photosynthesis (Pn) rates and stomatal resistance (Rs) of strawberry plants at 1, 4, and 13 d after treatment with selected pesticides in 1985

Treatment and kg (AI)/ha	Days after treatment[a]					
	1		4		13	
	Pn	Rs	Pn	Rs	Pn	Rs
Control	0.82a	1.95b	1.06a	1.05b	0.87a	1.25a
Carbaryl 1.68	0.69abc	1.93b	1.09a	1.12b	0.89a	1.28a
Methomyl 1.01	0.68abc	2.18ab	0.97ab	1.14b	0.81a	1.43a
Permethrin 0.22	0.60bc	2.33ab	1.01ab	1.12b	0.93a	1.31a
Naled 1.68	0.54c	2.63a	0.84b	1.73a	0.82a	1.48a
Bifenthrin 0.11	0.74ab	1.91b	0.99ab	1.11b	0.85a	1.34a

In columns, means followed by the same letter are not significantly different ($P \le 0.05$; Duncan's multiple range test [SAS Institute 1985]).

[a] Data collected 13 d after the first pesticide application, 4 d after the second application, and 1 d after the third application. Rs units are in $s \cdot cm^{-1}$; Pn units are in mg CO_2 assimilated$\cdot m^{-2} \cdot s^{-1}$.

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methrin, and methomyl have been implicated in causing outbreaks of phytophagous mites and other pests in many crops (van de Vrie et al. 1972, Dittrich et al. 1974, Oatman & Kennedy 1976). For many years, researchers have reported that some pesticides affect plant physiology and photosynthetic activity, thereby reducing yields (McIlwrath 1950, Toscano et al. 1982, Jones et al. 1986). Therefore, before recommendations can be made for the use of a pesticide for the control of *H. zea* on strawberries, an understanding of the physiological effects on the plants, as well as information on the potential for causing secondary pest outbreaks, is required.

The primary purpose of our research was to generate information necessary for planning chemical use against *H. zea* in strawberries. Specifically, we wished to determine whether any new or currently registered compounds could cause outbreaks of nontarget pests so that additional pesticides would have to be used, or could lower plant productivity through reductions in photosynthesis and yield.

Materials and Methods

Field trials were conducted at the University of California South Coast Field Station in Santa Ana, Calif., on strawberry in 1985 ('Parker') and 1986 ('Parker' × 'Chandler'). The experimental plantings consisted of 6 and 10 treatments, each including a control, in 1985 and 1986, respectively. Each treatment was replicated four times in a randomized complete block design. Replicates consisted of two-row beds 9.15 m long. To reduce edge effects, buffer areas of four rows surrounded the experimental plantings. Pesticides were applied on alternate weeks from 29 March through 20 June in 1985 (seven applications), and from 5 March through 28 May in 1986 (seven applications). Repeated applications were evaluated because *H. zea* can oviposit directly on the fruit and the first instars can penetrate the berry immediately (Wiesenborn & Trumble, unpublished). Thus, multiple treatments with pesticides may be required to provide economic levels of control. A single application of cyhexatin at 0.84 kg (AI)/ha was applied in both years during the last week in January; this application prevented *T. urticae* populations from accumulating damaging levels of mite-days per leaflet before early May in 1985 and late April in 1986. Cyhexatin reportedly has no effect on photosynthesis and stomatal conductance in strawberry (LaPre et al. 1982).

Chemicals were applied through hoses from a tractor-mounted sprayer. As plant height and foliage density increased, we increased the number of nozzles from two to four per row. The carrier (water) was applied at 935 liters/ha unless specified. All treatments except avermectin b_1 (Merck & Company, Rahway, N.J.) included 0.04% spreader-sticker (Leaf Act 80A). Carbaryl (Union Carbide, New York, N.Y.), methomyl (Shell Development, Modesto, Calif.), permethrin (FMC,

Table 2. Effects of pesticides on photosynthesis (Pn) and stomatal resistance (Rs) in strawberries during 1986

Treatment and kg (AI)/ha	Mean photosynthesis rate and stomatal resistance per sample[a]															
	20 Mar.		10 Apr.		17 Apr.		24 Apr.		1 May		8 May		16 May		22 May	
	Pn	Rs	Pn	Rs	Pn	Rs	Pn	Rs	Pn	Rs	Pn	Rs	Pn	Rs	Pn	Rs
Control	0.36a	2.04a	0.41c	2.15a	0.39c	2.33a	0.50bc	2.38a	0.33c	2.09a	0.48bc	1.91a	0.58ab	1.48ab	0.62c	2.03a
Methomyl 1.01	0.38a	2.05a	0.62b	1.73b	0.47bc	2.04ab	0.47c	2.35a	0.50bc	1.93ab	0.35c	2.05a	0.59ab	1.34bc	0.62c	2.03a
Naled 1.12	0.44a	1.95a	0.65b	1.29cd	0.50bc	2.06ab	0.68b	1.91b	0.45c	1.73b	0.41c	2.02a	0.53b	1.61a	0.60c	1.88ab
Carbaryl 1.68	0.36a	1.86a	0.67b	1.47bc	0.54b	1.93bc	0.57bc	1.91b	0.40c	1.80b	0.40c	1.84a	0.67a	1.26c	0.61c	1.85abc
Permethrin 0.22	0.42a	1.87a	0.65b	1.41bcd	0.69a	1.71cd	0.93a	1.47c	0.65ab	1.47c	0.59ab	1.39b	0.61ab	1.28c	0.73ab	1.70bc
Bifenthrin 0.11	0.47a	1.89a	0.88a	1.10d	0.76a	1.57d	0.98a	1.38c	0.77a	1.32c	0.70a	1.44b	0.70a	1.30bc	0.79a	1.66c

In columns, means within each category followed by the same letter are not significantly different ($P < 0.05$; Duncan's multiple range test [SAS Institute 1985]).

[a] Rs units are in $s \cdot cm^{-1}$; Pn units are in mg CO_2 assimilated $\cdot m^{-2} \cdot s^{-1}$.

Table 3. Effects of pesticides on number of strawberry fruit produced in 1985

Treatment and kg (AI)/ha	Mean no. strawberry fruit per replicate[a]							
	25 Mar.	8 Apr.	22 Apr.	6 May	20 May	8 June	17 June	25 June
Control	44.5a	89.8a	163.8b	206.0a	65.0bc	85.8a	163.8a	298.5ab
Carbaryl 1.68	33.3ab	75.5a	279.0a	153.8bc	73.5abc	63.5ab	139.5a	212.8b
Methomyl 1.01	30.3b	81.0a	210.5ab	201.8ab	107.0a	64.8ab	151.0a	263.5b
Permethrin 0.22	37.0ab	67.8a	189.0b	157.5abc	85.5abc	70.3ab	170.3a	294.3ab
Naled 1.68	40.3ab	73.8a	40.3c	145.3c	56.8c	48.3b	—	258.5b
Bifenthrin 0.11	39.5ab	84.0a	184.3b	178.3abc	92.0ab	75.5a	186.5a	358.5a

In columns, means followed by the same letter are not significantly different ($P \leq 0.05$; Duncan's multiple range test [SAS Institute 1985]).
[a] Based on four replicates of 34 plants per treatment; —, data unavailable.

Middleport, N.Y.), bifenthrin (FMC), and naled (Chevron Chemical, Richmond, Calif.) were applied during both years. Avermectin b_1 0.02 and 0.02 + 0.1% oil were added during the second season as interest in registering this compound in strawberries increased. Application rates are shown in Tables 1–5.

Evaluation of Physiological and Yield Effects of Pesticides. In 1985, phytotoxicity was evaluated by measuring photosynthesis (mg CO_2 assimilated $\cdot s^{-1} \cdot m^{-2}$) and stomatal resistance ($cm \cdot s^{-1}$) with the Li-Cor 6000 (Li-Cor Inc., Lincoln, Nebr.) on 10, 15, and 26 April (13 d after the first treatment, 4 d after the second treatment, and 1 d after the third treatment, respectively). Because *T. urticae* populations were low, this approach allowed evaluation of pesticide-induced phytotoxicity at selected intervals after treatment. In 1986, phytotoxicity data were collected weekly from 20 March through 22 May. This procedure provided information on pesticide-induced phytotoxicity early in the season, as well as combined phytotoxicity caused by pesticides and *T. urticae* late in the season. Because of a calibration error in the LI-Cor 6000, data from 27 March were not included in the analyses. Because pesticides were applied on alternate weeks in 1986, data were collected at 1 or 7 d following treatment.

Photosynthesis measurements were taken between 1000 and 1400 hours (PST) when sunlight exceeded 1,000 $\mu E \cdot s^{-1} \cdot m^{-2}$. Due to these time constraints, only those chemical treatments evaluated during the 1985 season were included in the 1986 photosynthesis tests. In both seasons, five central leaflets from mature trifoliates that were fully exposed to sunlight were examined per replicate on each sampling date.

Yields were evaluated by counting and weighing all ripe strawberries in each replicate each week from 25 March through 25 June and 24 March through 2 June in 1985 and 1986, respectively.

Evaluation of Pesticidal Impact on Nontarget Arthropods. Evaluation of pesticidal impact on *T. urticae* populations was based on percentage of plants infested on the highest trifoliate on each plant for 10 plants per replicate every week from 24 March through 25 June and 11 March through 2 June (40 plants per treatment per week) in 1985 and 1986, respectively. This sampling technique was selected on the basis of previously published sampling programs (Trumble 1985). Aphid counts were collected at the same times as the *T. urticae* data. Percentage of plants infested was based on the presence or absence of aphids on the oldest trifoliate of 10 randomly selected plants per replicate (Trumble et al. 1983a,b). Pesticidal effects on beneficial insects were evaluated by monitoring numbers of aphid mummies, chrysopid larvae, and chrysopid eggs on all leaves examined for aphids and *T. urticae*. These were the only natural enemies observed during the study.

Data were analyzed with the Proc GLM procedure and Duncan's multiple range test ($P < 0.05$) from Statistical Analysis Systems (SAS Institute 1985). Percentage data were transformed with an arcsine transformation before analysis.

Table 4. Effects of pesticides on average fruit weight in 1985

Treatment and kg (AI)/ha	Mean weight of individual fruit[a]							
	25 Mar.	8 Apr.	22 Apr.	6 May	20 May	8 June	17 June	25 June
Control	30.1a	25.2a	18.6ab	15.4b	13.2b	14.4ab	11.2c	9.9ab
Carbaryl 1.68	30.4a	24.2a	15.2b	20.1a	15.3ab	13.1b	12.9bc	7.9c
Methomyl 1.01	30.3a	24.4a	18.3ab	18.2ab	15.9ab	15.3ab	15.0ab	10.3ab
Permethrin 0.22	29.6a	25.0a	19.0ab	18.6a	16.5a	14.4ab	12.9bc	9.4bc
Naled 1.68	29.0a	23.8a	20.4a	18.4ab	13.5b	14.1b	—	9.1bc
Bifenthrin 0.11	29.5a	23.2a	19.2ab	19.8a	18.2a	16.7a	15.6a	11.1a

In columns, means followed by the same letter are not significantly different ($P \leq 0.05$; Duncan's multiple range test [SAS Institute 1985]).
[a] Calculated by dividing fruit weight per replicate by no. of fruit per replicate; —, signifies no data available.

Table 5. Effects of pesticides on number of strawberry fruit produced in 1986

Treatment and kg (AI)/ha	Mean no. strawberry fruit produced										
	24 Mar.	31 Mar.	7 Apr.	14 Apr.	22 Apr.	28 Apr.	5 May	12 May	19 May	27 May	2 June
Control	42.5a	90.8ab	81.3c	67.3de	78.8ab	67.5bc	38.8cd	34.0cd	17.8c	27.0b	32.5b
Methomyl 1.01	30.8a	83.0b	79.5c	63.3e	71.5b	67.5bc	37.5d	37.0cd	20.3c	29.3b	26.5b
Naled 1.12	36.5a	94.8ab	91.0bc	64.3e	75.3b	56.3c	46.0bcd	42.8bcd	20.0c	40.5b	46.3b
Carbaryl 1.68	35.5a	88.3ab	74.8c	69.8cde	78.3ab	62.8bc	37.8d	24.8d	17.3c	36.5b	29.8b
Permethrin 0.22	40.8a	93.0ab	91.0bc	76.0bcde	90.3ab	81.3abc	56.5abcd	51.8abcd	29.3bc	55.8b	52.8b
Avermectin 0.02	42.3a	98.0ab	112.5a	81.8abcde	105.3ab	94.8abc	58.5abcd	64.5abc	39.8abc	84.5a	89.8a
Avermectin + 0.1% oil	32.8a	111.3a	106.0ab	96.0ab	100.8ab	113.8a	78.3a	67.0abc	45.5ab	91.5a	90.8a
Avermectin in 436 liters/ha	43.3a	99.3ab	116.5a	89.5abc	106.5ab	99.8ab	59.5abcd	67.0abc	47.8ab	99.0a	100.3a
Bifenthrin 0.06	32.8a	105.3ab	120.3a	101.0a	106.5ab	104.8ab	67.3abc	71.5ab	37.8abc	84.0a	99.5a
Bifenthrin 0.11	32.3a	110.0a	116.5a	86.5abcd	117.0a	101.0ab	69.0ab	83.0a	54.0a	102.0a	95.5a

In columns, means followed by the same letter are not significantly different ($P < 0.05$; Duncan's multiple range test [SAS Institute 1985]).

Table 6. Effects of pesticides on average weight of strawberry fruit produced during 1986

Treatment	Mean wt (g) per strawberry fruit[a]										
	24 Mar.	31 Mar.	7 Apr.	14 Apr.	22 Apr.	28 Apr.	5 May	12 May	19 May	27 May	2 June
Control	24.4ab	27.5abc	25.3a	19.9a	13.4a	14.8b	13.0ab	12.3cd	15.5bc	12.1c	13.2c
Methomyl	24.5ab	29.8a	20.9ab	18.6a	15.4a	15.8ab	12.9ab	13.7cd	13.3c	13.3bc	14.1bc
Naled	23.9ab	26.3abc	20.5b	18.6a	14.5a	16.4ab	15.1ab	12.3cd	13.4c	13.5bc	13.3c
Carbaryl	22.3ab	25.4bc	22.5ab	24.1a	14.2a	13.1b	11.4b	11.5d	13.5c	11.9c	13.1c
Permethrin	22.1ab	24.7c	20.7ab	18.8a	16.0a	16.1ab	12.5ab	13.3bcd	16.5abc	14.3b	15.7abc
Avermectin	21.6b	29.0ab	19.7b	19.9a	14.3a	17.2ab	16.4a	15.7abc	16.9ab	16.4a	16.5ab
Avermectin + 0.1% oil	23.2ab	26.3abc	21.4ab	19.3a	15.9a	17.5ab	15.9a	13.8bcd	17.7ab	16.8a	16.6ab
Avermectin in 436 liters/ha	22.8ab	29.0ab	21.3ab	20.0a	16.1a	17.4ab	16.5a	17.6a	16.0abc	16.2a	16.9a
Bifenthrin	23.7ab	28.8ab	20.6ab	18.9a	15.7a	17.2ab	16.6a	15.9abc	18.8a	17.4a	18.0a
Bifenthrin	27.1a	28.4abc	22.0ab	19.3a	15.0a	19.5a	15.8a	16.0ab	19.9a	17.1a	17.3a

In columns, means followed by the same letter are not significantly different ($P < 0.05$; Duncan's multiple range test [SAS Institute 1985]).
[a] Application rates as in Table 5.

Table 7. Effects of pesticides on *T. urticae* in strawberries during 1985

Treatment and kg (AI)/ha	Mean % plants infested on highest trifoliate							
	25 Mar.	8 Apr.	22 Apr.	6 May	20 May	8 June	17 June	25 June
Control	0.0b	2.5a	7.5a	47.5a	82.5a	92.5a	100.0a	97.5a
Carbaryl 1.68	0.0b	2.5a	10.0a	72.5a	82.5a	100.0a	100.0a	100.0a
Methomy 1.01	5.0a	0.0a	17.5a	52.5ab	90.0a	95.0a	100.0a	100.0a
Permethrin 0.22	0.0b	0.0a	2.5a	47.5ab	72.5a	95.0a	100.0a	95.0a
Naled 1.68	2.5ab	0.0a	5.0a	27.5bc	62.5a	90.0a	100.0a	100.0a
Bifenthrin 0.11	0.0b	0.0a	0.0a	0.0c	5.0b	10.0b	45.0b	42.5b

In columns, means followed by the same letter are not significantly different ($P \leq 0.05$; Duncan's multiple range test [SAS Institute 1985]; analysis on data before conversion to percentages).

Results and Discussion

Evaluation of Physiological and Yield Effects of Pesticides. In 1985, only naled and permethrin significantly affected photosynthetic activity of strawberries. The impact of naled on photosynthetic rates and stomatal resistance could not be detected at 13 d after the first pesticide treatment, but was evident for at least 4 d after the second application (Table 1). Permethrin treatments reduced photosynthesis significantly at 1 d after application, but the response was transient (no differences were detected at 4 d after treatment). This response time differs from that of lettuce, where the photosynthesis rate continued to decrease for several weeks following application (Toscano et al. 1982). The stimulation of photosynthesis rates by carbaryl reported by Ayers & Barden (1975) on apples was not evident during either season in our experiments.

In 1986, bifenthrin treatments generally resulted in the highest photosynthetic rates and lowest stomatal resistances (Table 2), followed closely by replicates treated with permethrin. Photosynthetically damaging levels of 2,000 to 7,000 mite-days per leaflet (Sances et al. 1981, Oatman et al. 1982), as conservatively estimated from spider mite dispersions after treatment (Trumble 1985), did not accumulate until late April of the 1986 season. Thus, use of bifenthrin significantly increased photosynthetic rates and decreased stomatal resistances during this portion of the season. From late April until termination of the study, photosynthetic rates, stomatal resistances, and yields were influenced by the cumulative impact of spider mite feeding (Sances et al. 1979, 1981) and pesticide effects. Variable photosynthesis rate and stomatal resistance from week to week within a treatment were expected to occur as environmental conditions changed.

Bronzing of both leaves and fruit were observed in both years only in the naled treatments. Therefore, we conclude that reduced photosynthesis and increased stomatal resistance may be caused by an inhibition in mesophyll conductance and a wound-induced closure of the stomata similar to that reported by LaPre et al. (1982) for propargite and formetanate hydrochloride applications in strawberries.

In 1985, naled treatments generally produced fewer (Table 3) and lighter (Table 4) fruit. Similar results were found in 1986 (Tables 5 and 6). However, the yield from plants treated with naled was not significantly different from the controls on most sampling dates. Thus, undesirable photosynthetic effects observed in the naled treatments did not definitively affect fruit numbers or weight adversely. However, visually evident phytotoxicity on the fruit would probably result in additional economic losses.

The phytotoxicity in the naled treatments was expected because use above 27°C, a temperature which was reached within 4 h of nearly every application, is not recommended by the manufacturer. Although registered for *H. zea* control on strawberries, naled may not be suitable for general use against this pest because of high temperatures that occur during late spring and early summer in southern California strawberry growing areas. Evening applications on cool nights might avoid this effect, but additional research should document such results before the pesticide is recommended.

Numbers of fruit from plants treated with bifenthrin at 0.11 kg (AI)/ha and avermectin b_1 at 0.02 kg (AI)/ha + 0.1% oil were significantly greater than from control plants on 7 of 11 sampling dates in 1986, respectively (Table 5). In addition, the mean weight of individual fruit was significantly greater in avermectin b_1 and bifenthrin treatments on two of five dates. Replicates treated with lower rates of bifenthrin or avermectin b_1 without oil in 468 liters/ha had fewer fruit, but still had significantly more than controls on at least 5 of 11 sampling dates. The trend toward more fruit in bifenthrin treatments was not evident in 1985, but the fruit was significantly heavier on three of eight dates (Table 4).

Evaluation of Pesticidal Impact on Nontarget Arthropods. Although a trend toward larger *T. urticae* populations was observed in both years for methomyl and carbaryl treatments, no significant increases over control populations were found for any of the pesticides evaluated (Tables 7 and 8). Thus, pesticide-induced hormoligosis effects (Lucky 1968), or higher populations because of improvements in plant nutritional quality reported by van de Vrie et al. (1972), were not detected in our study.

All pesticides reduced the percentage of highest trifoliates infested with aphids to 0–5% by 8 April in 1985 and by 24 March in 1986. Treatments in alternate weeks kept aphid populations below the economic injury level of 30% infestation (Trumble et al. 1983b) through the remainder of both seasons (controls exceeded threshold levels on seven dates in 1985 and two dates in 1986). Thus, use of any of these compounds for the control of *H. zea* would minimize the need for additional aphicide applications.

Unfortunately, the density of beneficial insects, ranging from 0.0 to 1.0 parasitized aphids per 40 trifoliates per treatment and from 0.0 to 0.8 immature green lacewings per 40 trifoliates per treatment, was low in both seasons. No other predators were observed. Low populations of natural enemies did not permit statistical separations between treatments and made definitive conclusions regarding potential impact of these pesticides on beneficial insects impossible.

In managing *H. zea* populations on strawberries, use of egg parasites such as *Trichogramma* spp. would be ideal, but cost of inundative releases to allow less than 0.1% USDA infestation allowance would be prohibitive. Repellent or ovicidal chemicals may offer practical alternative control strategies. Unfortunately, because the fruit develop to a harvestable stage in 2 wk, these approaches will require repeated applications. This requirement for multiple treatments during the harvest period not only increases the pesticide costs but increases the potential for human health and environmental problems as well.

Methomyl, carbaryl, and naled do not appear to be promising for use against *H. zea* in southern California strawberries. Although methomyl has excellent ovicidal activity against *H. zea* (Wiesenborn et al. 1987), the usefulness of this chemical would be reduced by limitations placed on growers by processors who claim an undesirable flavor results when methomyl-treated fruit are processed. Unfortunately, carbaryl and naled provide <80% control of eggs (Wiesenborn et al. 1987).

In our tests, bifenthrin appeared to be the most useful because this compound provided suppression of *T. urticae* and aphids without damaging photosynthetic processes. However, repeated applications of this pyrethroid for spider mite control would increase the potential for the development of resistance, which is a major problem in the strawberry ecosystem (Croft et al. 1984). Thus, restricting late season applications on *H. zea* infestations from May through June, and using these materials on an as-needed basis as determined by scouting, would minimize the number of applications and thereby reduce the pressure for resistance development by *T. urticae*.

In addition, considerable potential exists for breeding pyrethroid-resistant strains of predatory mites (Croft & Wagner 1981). These predators could slow resistance development by reducing survi-

Table 8. Effects of pesticides on *T. urticae* in strawberries during 1986

Treatment	Mean % plants infested on highest trifoliate[a]												
	11 Mar.	17 Mar.	24 Mar.	31 Mar.	7 Apr.	14 Apr.	22 Apr.	28 Apr.	5 May	12 May	19 May	27 May	2 June
Control	50abc	80ab	94a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a
Methomyl	70ab	90a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a	100a
Naled	50abc	70abc	95a	100a	90ab	100a	100a	100a	100a	100a	100a	100a	100a
Carbaryl	75a	85ab	100a	95a	95a	100a	100a	100a	100a	100a	100a	100a	90ab
Permethrin	45abc	75ab	80ab	100a	95a	100a	100a	100a	90ab	100a	100a	100a	85ab
Avermectin	35bcd	40bcd	40cd	100a	75abc	100a	95a	95ab	85ab	55b	65bc	70b	40cd
Avermectin + 0.1% oil	15cd	30cd	65bc	80a	65bc	65b	80a	75bc	50c	60b	70b	55b	80ab
Avermectin in 436 liters/ha	35bcd	20d	60bc	100a	90ab	85ab	95a	65c	75b	75b	50cd	50b	10d
Bifenthrin	50d	65abc	60bc	90a	55c	80b	60b	95ab	20d	60b	45d	70b	60bc
Bifenthrin	15cd	20d	15d	55b	15d	35c	25c	60c	20d	20c	90a	45b	15d

In columns, means followed by the same letter are not significantly different ($P < 0.05$; Duncan's multiple range test [SAS Institute 1985]; analysis before conversion to percentages).

[a] Application rates as in Table 5.

vorship of *T. urticae* in strawberry plantings, thereby inhibiting migration of large numbers of resistant genotypes between fields and allowing potential dilution of resistance through immigration of susceptible mites. Similar studies evaluating avermectin b_1 with and without oil suggest that predatory mites may be selectively less affected than *T. urticae*, allowing use of this chemical in an integrated program (Hoy & Cave 1985). However, additional experiments evaluating the effects of the formulations and additives on strawberry physiology and yield will be necessary before avermectin b_1 and permethrin can be incorporated into the pest management system.

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