Effects of Insecticides Applied in the Field on Incidence of Aphid-borne Viruses in Cultivated Strawberry

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ABSTRACT

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Four pyrethroid insecticides and oxydemetonmethyl were evaluated in field spray application tests for ability to reduce the incidence of aphids and aphid-borne viruses in a field plot of Totem strawberry plants over a 2-yr period at Corvallis, OR. Ninety-four percent of the virus infection occurred during the second year of the test. Three pyrethroids (cypermethrin, permethrin, and fenvalerate) and oxydemetonmethyl significantly reduced aphid-borne virus incidence to 44–63% of the adjoining unsprayed plots at the end of the second growing season, whereas the pyrethroid bifenthrin gave a virus incidence that was not significantly different from that of the unsprayed treatment. Strawberry mild yellow-edge (SMYEV), a luteovirus, was present in 97% of the virus-infected strawberry plants and was the only virus detected in 88% of those plants. All insecticides caused a highly significant reduction of populations of the SMYEV vector aphid, *Chaetosiphon fragaefolii*, compared with the unsprayed plots in the second growing season. There was no significant association between efficacy of insecticides in reducing aphid populations and virus incidence, however, suggesting that properties of these insecticides other than aphid kill may have influenced virus incidence.

Viruses transmitted by aphids, particularly *Chaetosiphon fragaefolii* (Ckll.), are widespread and damaging to the commercial strawberry (*Fragaria* × *ananassa* Duch.) crop in California, Oregon, and Washington (11,12,16,17,19). The control of these aphid-borne strawberry viruses by insecticides has been generally regarded as difficult because of the rapidity of the inoculation process (1). In western Oregon, alate *C. fragaefolii* generally reach peak numbers during May–June and develop a lesser peak population in early autumn (R. H. Converse, *unpublished*). Recently Shanks (18) stated that "because aphids flying from infected fields can inoculate sprayed plants faster than the insecticides can kill them . . . it is a waste of money to spray one field for strawberry aphid control if *unsprayed* virus-infected fields are nearby." Recent papers (8,9), however, have noted a reduction in infection by persistent, semipersistent, and nonpersistent aphid-borne viruses in certain other crops after the application of pyrethroid insecticides. This subject has recently been briefly reviewed (13). A report from Japan (10) indicates that in greenhouse tests, spraying with a mixture of fenvalerate (a pyrethroid) and malathion (an organophosphate) was effective in reducing aphid-borne virus infection in cultivated strawberries. The present study was undertaken to compare the incidence of aphid-borne viruses in field-grown, cultivated strawberry after the application of synthetic pyrethroids with the incidence after the application of a standard organophosphate insecticide or no insecticide. None of the pyrethroid insecticides is currently approved for commercial application on strawberry in the Pacific Northwest, but we expect some to be available in the near future. An abstract (4) described part of this work.

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MATERIALS AND METHODS

Registered Totem strawberry plants were obtained from California in March 1985. Thirty-five plants taken at random from the shipment were grown in the greenhouse and indexed for virus content on *F. vesca* L. 'UC-4' (6), according to standard leaflet insert grafting methods for detecting most of the known strawberry viruses present singly and in complex (2,3). No viruses were detected by this procedure, and 826 of these Totem plants were planted in a field at the Oregon State University Plant Pathology farm at Corvallis on 19 March 1985, 80 m downwind from a 4-yr-old unsprayed, aphid-infested planting of Hood and Totem strawberries. Sixty-seven percent of this planting was infected with a mixture of aphid-borne viruses—6% with strawberry mottle virus (StMV) alone, 28% with strawberry mild yellow-edge virus (SMYEV) (3) alone, and 33% with StMV, SMYEV, and strawberry crinkle virus (SCV) (3) in various combinations—and 33% was not infected with aphid-borne viruses, as determined by standard leaflet-graft indexing into UC-4 plants in the greenhouse.

In the test planting, plants were spaced 7 cm apart in rows spaced 19 cm apart. Seven rows were planted, two as guard rows and five containing a randomized block test, each row comprising a block of experimental plants having six treatments, usually 12 plants per treatment, separated by two- to four-plant buffers. The plots were managed according to standard local horticultural procedures, except that runner plants were removed and no insecticides were applied other than those used experimentally. The plants were grown in this field for 2 yr.

Four pyrethroid insecticides were used at indicated grams-per-hectare active ingredient per application: bifenthrin (Capture, Brigade), 56 g; cypermethrin (Ammo), 67 g; fenvalerate (Pydrin), 112 g; and permethrin (Pounce), 112 g. Oxydemetonmethyl (Metasystox-R), 840 g, an organophosphate insecticide currently recommended for strawberry aphid control in the Pacific Northwest (18), and unsprayed check plots were included as experimental treatments. Six spray applications were made each growing season—on 5 May, 12 June, 10 July, 2 and 27 August, and 18 September in 1985 and on 17 April, 19 May, 26 June, 24 July, 12 August, and 3 September in 1986.

Five plants per treatment replicate were indexed on 8 July and 1 October 1985 and on 4 June and 30 September 1986. Young, fully expanded leaves were selected, usually from plants 1, 3, 5, 7, and 9 in each treatment replicate in each of the five blocks, for grafting in the greenhouse into UC-4 indicator plants. When source plants were missing, adjoining plants or higher odd-numbered plants were indexed. Only indicator plants in which graft survival was good were evaluated for characteristic virus symptom development (3) three times a week for 6 wk. Repeat grafts were made when graft survival was not good. Once an aphid-borne virus was detected in a field plant, that plant was assumed to have been infected by aphid vectors before indexing and was so classified at subsequent indexings. All 10 self-grafted UC-4 plants remained symptomless during each graft run. Percentages (p) of plants per plot infected with aphid-borne viruses were converted to arcsin p/100 for analysis of variance and mean separation using LSD ($P \leqslant 0.05$) to compare virus incidence in sprayed vs. unsprayed treatments.

Aphids (both alate and apterous) were counted in the field plots at approximately 3-wk intervals on 17 June, 2 and 18 July, 1 and 20 August, 5 and 26 September, and 10 October in 1985 and on 3 and 25 April, 13 May, 6 and 25 June, and 23 July in 1986. All strawberry plants in each replicate were examined and all aphids counted on three leaves per sampled plant. Aphids were divided into two groups. Those with capitate setae were placed in group 1 and classified as *C. fragaefolii* (5,16) and those lacking capitate setae were placed in group 2 and referred to as "other" aphids. The percent infestation by each aphid group was calculated for each treatment at each observation date. The percent infestation by a given aphid group at a specified observation date for a given treatment replicate was defined as 100 times the number of three-leaf samples from all plants in that treatment replicate that were infested with one or more aphids of the specified group divided by the total number of plants in that replicate (usually 12). After arcsin transformation, percent aphid infestation data were subjected to analysis of variance and mean separation (LSD, $P \leqslant 0.05$) compared with the unsprayed treatment at each observation date.

RESULTS

Virus incidence in 1985 was very low in the test plots (Table 1), reflecting the low percent infestation of *C. fragaefolii*. The number of plants virus-positive was one of 150 indexed in July and four of 150 indexed in October. Most of the plants were infected only with SMYEV, and one was infected with both strawberry vein banding virus (SVBV) (3) and SMYEV. These four virus-infected plants were scattered among unsprayed and two pyrethroid treatments.

When sampled in June 1986 (Table 1), 24 of 150 Totem plants indexed were virus-infected, and there were no significant differences in virus incidence among treatments. Single infections by SMYEV occurred in 22 of 24 cases, with single instances of double infection by SMYEV and SCV and SMYEV and SVBV. No other viruses were detected. Virus indexing on 30 September 1986 (Table 2) showed that all insecticides except bifenthrin significantly ($P \leqslant 0.05$) reduced the incidence of aphid-borne viruses compared with the unsprayed treatment. Of 150 Totem plants indexed 30 September 1986, 89 were virus-infected—78 with SMYEV alone, three with StMV alone, two with StMV plus SMYEV, five with SCV plus SMYEV, and one with SVBV plus SMYEV. No other viruses were detected (Table 1).

During the 1985 season, percent infestations with group 1 and group 2 aphids remained low (0–12.0 and 0–20.7, respectively; data not shown). During the 1986 season, *C. fragaefolii* infestations

Table 1. Cumulative occurrence of aphid-borne viruses[a] in 150 Totem strawberry plants receiving various insecticide spray treatments (six applications per growing season) during 1985 and 1986 at Corvallis, OR

	Cumulative number of plants		Cumulative number of plants infected with:			
Virus testing date	**Infected**	**Healthy**	**SMYEV**	**StMV**	**SCV**	**SVBV**
8 July 1985	1	149	1	0	0	0
1 October 1985	4	146	4	0	0	1
4 June 1986	24	126	24	0	1	1
30 September 1986	89	61	86	5	5	1

[a]SMYEV = strawberry mild yellow-edge virus, StMV = strawberry mottle virus, SCV = strawberry crinkle virus, and SVBV = strawberry vein banding virus. Occurrence of each virus is recorded separately, even though StMV (with three exceptions), SCV, and SVBV were found in mixed infection with SMYEV.

Table 2. Cumulative percentage of Totem strawberry plants[a] infected with aphid-borne viruses in field plots given various insecticide spray treatments (six applications per growing season) during 1985 and 1986 at Corvallis, OR

		Percent virus-infected plants on:			
Treatment	**Dosage (g a.i./ha)**	**8 July 1985**	**1 Oct. 1985**	**4 June 1986**	**30 Sept. 1986**
Cypermethrin	67	0	0	8	40*[b]
Oxydemetonmethyl	840	0	0	8	52*
Permethrin	112	4	4	28	56*
Fenvalerate	112	0	4	12	57*
Bifenthrin	56	0	0	20	73
Unsprayed	···	0	8	24	90

[a]Five plants tested per 12-plant plot, five plots per treatment.
[b]* = Significantly different ($P \leqslant 0.05$) from the unsprayed treatment mean (30 September 1986) after analysis of variance following arcsin transformation ($LSD_{0.05}$ for arcsin transformed means = 20.5). F not significant (NS, $P \geqslant 0.05$) in analyses of variances of similarly transformed data from the three previous test dates.

Table 3. Percent aphid infestation of leaves sampled (April–July 1986) from Totem strawberry plants receiving various insecticide spray treatments (six applications from 17 April to 3 September) at Corvallis, OR

		Percent aphid infestation[a] on:											
		3 April		25 April		13 May		6 June		25 June		23 July	
Treatment	**Dosage (g a.i./ha)**	***C.f.***	**Other**	***C.f.***	**Other**	***C.f.***	**Other**	***C.f.***	**Other**	***C.f.***	**Other**	***C.f.***	**Other**
Bifenthrin	56	4.7	7.4	0*[b]	0*	0*	0	1.3*	1.5	0*	1.5	6.4	4.9
Fenvalerate	112	3.2	3.2	0*	1.8*	0*	0	5.3*	1.8	8.3*	7.7	8.1	0
Cypermethrin	67	0	5.4	1.3*	1.7*	1.3*	6.1	4.3*	0	21.6*	10.5	8.2	1.3
Permethrin	112	4.6	10.4	0*	1.5*	1.5*	10.2	10.1*	0	17.2*	10.0	8.7	0
Oxydemetonmethyl	840	7.8	13.5	0*	0*	1.5*	0	7.1*	0	19.4*	5.6	0	2.2
Unsprayed	···	8.0	6.1	17.9	14.6	34.6	3.6	37.6	11.6	85.1	5.5	NT	NT

[a]Percent infestation = [no. individual plant samples (three leaves per plant) infested with one or more aphids per treatment replicate divided by total no. plants per replicate (usually 12)] × 100. NT = not tested. *C.f.* = *Chaetosiphon fragaefolii*, the major aphid vector of viruses in cultivated strawberry; other = all aphids other than *C. fragaefolii*.
[b]* = Significantly different ($P \leqslant 0.05$) from the unsprayed treatment value in the same column.

among the six treatments ranged from 0 to 85.1% (Table 3). These percent infestations reached a maximum on 25 June, the last day such data were taken in the unsprayed plots. The percent infestation in unsprayed plots was significantly greater ($P \leq 0.05$) than those in sprayed plots, except on 3 April, 2 wk before the 1986 spray applications were begun. Because of an oversight, infestation in unsprayed plots was not measured on 23 July.

The presence (A+) or absence (A−) of *C. fragaefolii* at various sampling dates in 1986 and the presence (V+) or absence (V−) of aphid-borne viruses in each plot of the four pyrethroid spray treatments were evaluated for independence by chi-square analysis. The tabular value for chi-square for independence at $P_{0.05}$ with 1 df is 3.841. Similar calculations were performed for the presence or absence of group 2 (non-*Chaetosiphon*) aphids vs. aphid-borne virus presence or absence in the same plots over the same period. All aphid infestation determinations made prior to 4 June 1986 were related to the virus indexing on that date, and all subsequent aphid infestation determinations were related to the virus indexing done 30 September 1986. For *C. fragaefolii,* all chi-square values were nonsignificant (chi-square range 0–0.980), indicating that virus incidence was independent of percent *C. fragaefolii* infestation throughout the 1986 observation period. For group 2 aphids, the 4 June virus incidence was not independent of the 3 April aphid infestation data (chi-square = 4.040), but all subsequent chi-square values were nonsignificant (chi-square range 0.008–2.494), indicating that virus incidence was independent of percent infestation by non-*Chaetosiphon* aphids from 25 April to 23 July.

Percent infestation of group 2 aphids in 1986 remained relatively low (Table 3), ranging from 0 to 14.6% and peaking 3 April and 25 June (Table 3). Percent infestations by group 2 aphids were significantly greater in unsprayed than in sprayed plots only on 25 April. On 13 May, percent aphid infestations in plots treated with cypermethrin and permethrin, although higher, were not significantly different from percent infestation in unsprayed plots.

DISCUSSION

All pyrethroids except bifenthrin significantly reduced virus incidence in September 1986 to 44–63% of the unsprayed level. Because 97% of the virus-infected Totem strawberry plants tested in September 1986 were carrying SMYEV, the results can be interpreted in terms of SMYEV alone, a luteovirus (20). The organophosphate oxydemetonmethyl caused a significant reduction in virus incidence to 58% of that of the unsprayed plants at the end of the test and did not differ significantly in virus control from three of the pyrethroids already mentioned. This observation contrasts with those of Johnstone (9), who found that the pyrethroid deltamethrin gave significantly more control of the luteovirus subterranean clover red leaf than the organophosphate demeton-S-methyl, and Highwood (8), who found that cypermethrin and fenvalerate gave significantly more control of the luteovirus barley yellow dwarf than the organophosphates dimethoate and methamidophos. The insecticides we used in the present trial, however, were different from those reported earlier (8,9).

Several investigators (7,14,15) have noted that the effectiveness of some pyrethroids in reducing virus incidence in treated plant hosts exposed to viruliferous aphid vectors may in part be attributed to their very rapid action in causing intoxication, the first symptom of which is inhibition of feeding of aphids encountering the toxicant. We note with interest that although the pyrethroid bifenthrin allowed the lowest seasonal mean percent infestation of *C. fragaefolii* on treated Totem strawberry plants in 1986 in our studies, it did not significantly reduce virus incidence measured in September 1986 below that of unsprayed plants. With the exception of 3 April data for group 2 aphids, chi-square tests for independence showed no significant association between the presence or absence of aphids (*C. fragaefolii* sensu lato [5] or group 2 aphids) and the presence or absence of aphid-borne viruses in the pyrethroid-sprayed plots on 4 June or 30 September 1986. This suggests that factors other than aphid kill (7) may have been operating to reduce virus infection by some of these insecticides. Insecticide-induced aphid behavior may have played an important role in reducing virus disease incidence in our tests.

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