Effect of Horticultural Oil, Insecticidal Soap, and Film-Forming Products on the Western Flower Thrips and the Tomato Spotted Wilt Virus

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ABSTRACT

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Horticultural oil, insecticidal soap, and film-forming products were tested for their efficacy in reducing transmission of the tomato spotted wilt virus (lettuce serotype) and feeding and reproduction of the western flower thrips (*Frankliniella occidentalis*). Wilt-Pruf, oil, and Dow Corning 36 products reduced virus transmission by 73, 57, and 46%; and feeding activity by 40, 4, and 41%, respectively. Only Dow Corning 36 significantly reduced (66%) reproduction.

Control of the western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), and the tomato spotted wilt virus (TSWV) which it transmits, requires frequent and thorough application of pesticides. Even though population densities of the thrips can be reduced by spraying so that feeding damage is below economic thresholds for a given crop, sufficient numbers of viruliferous thrips can survive to initiate a significant number of new infections (4). Moreover, there is evidence that an increase in virus incidence can result from pesticide application (15), presumably because viruliferous thrips are dispersed during spraying and transmit before being affected.

Horticultural oil and insecticidal soap have been shown to interfere with both mechanical and insect transmission of viruses (12,23), as well as controlling aphids, leaf miners, mealybugs, mites, scales, and whiteflies (3,9,11,20,22). Oil has not been effective in controlling the WFT (17,18) but has controlled certain fungal diseases (8).

Film-forming products, such as antidesiccants, also have been effective in controlling fungal diseases on various crops (13,24). Although these products apparently have not been tested for their potential to inhibit virus transmission by insects, the major ingredient (β-pinene) in one product (Wilt-Pruf, Wilt-Pruf Products, Inc., Essex, CT) acts as a feeding deterrent for certain insects of the orders Coleoptera and Orthoptera (21).

It was of interest, therefore, to determine if the WFT–TSWV complex would be affected by these classes of low-toxicity (biorational) chemicals, either by directly interfering with the establishment of the virus in plant cells or by altering the feeding or reproductive behavior of the thrips. Evaluations were performed in large growth rooms and repeated in a greenhouse with petunia as the test plant. Petunia was chosen because it is a highly preferred host of the WFT and is very susceptible to the TSWV (2). Feeding scars appear as white or silvery sunken spots. Viral lesions, which are visible within 2–3 days and remain localized, appear as dark brown to black spots which are easily counted. A preliminary report of these studies has been made (1).

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MATERIALS AND METHODS

Test plants and conditions, virus isolates, and thrips. Experiments were conducted with potted, approximately 4-wk-old petunia (*Petunia* × *hybrida* Hort. Vilm.-Andr. 'Calypso') plants that had been grown free of side shoots. Prior to testing, the stem and young leaves of each plant were removed leaving six to eight fully expanded basal leaves in a rosette.

Growth rooms were fitted with a single bench (approximately 5.5 × 1.7 m) illuminated with both sodium-vapor and metal-halide lamps (200 $\mu E \cdot m^{-2} \cdot s^{-1}$, at test-plant height). The rooms were programmed to give 55% RH, 27 C, and 16 hr of light daily.

Potted nonflowering chrysanthemum (*Dendranthema grandiflora* Tzvelev 'Palisade') plants, systemically infected with the TSWV (lettuce serotype), were placed in the experimental growth rooms to serve both as a source of virus and as hosts for the WFT. Weekly, each plant received approximately 50 WFT nymphs collected from a laboratory culture maintained on healthy flowering chrysanthemum. The chrysanthemum source plants, which were placed in a double row at a density of 16 plants per linear meter of row, occupied a central position over the length of each bench. The petunia test plants were placed on both sides of the chrysanthemum plants and arranged in rows perpendicular to the long axis of the bench. Each row of petunia contained four pots, and the row centers were 25 cm apart.

In initial studies, two experimental designs (A and B) were compared. In design A, test (T) and check (C) plants were arranged in separate alternating rows perpendicular to the long axis of the bench. All adjacent test and check plants along each of the four rows that paralleled the long axis of the bench were used as pairs; e.g., in row 1, T^a vs. C^a, C^a vs. T^b, T^b vs. C^b, etc. Design B alternated the position of test and check plants in the perpendicular rows to partially randomize treatments and to equalize left vs. right positioning. For example, the first parallel row ran T, C, C, T, T, C, etc.; and the second ran C, T, T, C, C, T, etc. Comparisons of treatments, as in design A, were made along each of the four rows that paralleled the long axis of the bench; e.g., in row 1, T^a vs. C^a, C^b vs. T^b, T^c vs. C^c, etc.

Both designs accommodated variations in thrips activity across the rooms. Treatments effects and levels of significance were closely similar when the designs were compared concurrently on opposite sides of a bench. Design A was selected for continued use because a greater number of paired comparisons was generated with fewer plants. Tests with each product were replicated at least three times in a growth room, and a single test with each product was conducted in a glass research greenhouse equipped with supplemental lighting and temperature control. Mean numbers of virus lesions, feeding scars, and nymphs per leaf per plant were determined 6–8 days after initial exposure to thrips. Data were transformed ($\log_{10}[1 + x]$) and analyzed with a paired t test (2-tail) (StatView II, Abacus Concepts, Inc., Berkeley, CA).

Treatment. The following materials were prepared in water as suggested by the manufacturer to give the concentrations indicated on a v/v (product:water) basis unless otherwise indicated: Clear Spray (1:40, acrylic emulsion; W. A. Clearly Chemical Corp., Somerset, NJ), Dow Corning 36 (1:6, polydimethyl siloxane emulsion; Dow Corning Canada, Inc., Mississauga, ON), Folicote (1:6, hydrocarbon wax emulsion; Aquatrols, Pennsauken, NJ), Plantco antidesiccant (1:4, acrylic emulsion; Plant Products

Table 1. Effect of products on virus transmission and on the feeding and reproductive activity of the western flower thrips in growth room tests

Treatment (test/check)	Viral lesions				Feeding scars				Nymphs			
	Pairs (no.)	X ± SE[w]	Control (%)[x]	P[y]	Pairs (no.)	X ± SE	Control (%)	P	Pairs (no.)	X ± SE	Control (%)	P
1% Oil/ Nonsprayed	32	0.77 ± 0.21/ 2.02 ± 0.41	62	0.0002	32	4.24 ± 0.33/ 4.70 ± 0.42	10	0.2424	32	0.13 ± 0.03/ 0.16 ± 0.03	19	0.4220
1% Oil/ Nonsprayed	32	0.95 ± 0.29/ 1.97 ± 0.35	52	0.0050	32	2.81 ± 0.19/ 2.70 ± 0.20	−4	0.8761	32	0.08 ± 0.03/ 0.10 ± 0.02	20	0.3688
1% Oil/ Nonsprayed	32	1.54 ± 0.27/ 3.49 ± 0.49	56	0.0001	32	4.01 ± 0.47/ 4.40 ± 0.46	9	0.6685	32	0.94 ± 0.15/ 1.03 ± 0.13	9	0.5591
2% Oil/ Nonsprayed	32	1.73 ± 0.22/ 3.56 ± 0.53	51	0.0124	32	13.77 ± 1.11/ 13.22 ± 0.75	−4	0.6716		NT[z]		
2% Oil/ Nonsprayed	32	1.48 ± 0.21/ 3.79 ± 0.69	61	0.0117	32	16.89 ± 1.20/ 18.68 ± 1.22	10	0.1905		NT		
2% Oil/ Nonsprayed	32	0.61 ± 0.15/ 1.50 ± 0.41	59	0.0105	32	12.56 ± 0.79/ 12.67 ± 0.90	1	0.9771		NT		
2% Oil/ 1% Oil	28	1.24 ± 0.23/ 1.59 ± 0.29	22	0.2231	28	5.26 ± 0.30/ 6.32 ± 0.46	17	0.0397		NT		
2% Oil/ 1% Oil	28	4.32 ± 0.41/ 4.54 ± 0.52	5	0.8909	28	4.47 ± 0.40/ 4.79 ± 0.52	7	0.7260		NT		
2% Oil/ 1% Oil	28	6.98 ± 0.61/ 8.55 ± 0.83	18	0.0223	28	6.04 ± 0.76/ 6.76 ± 1.03	11	0.6514		NT		
Safer's soap/ Nonsprayed	32	1.01 ± 0.22/ 1.13 ± 0.21	11	0.2559	32	4.36 ± 0.41/ 8.62 ± 0.84	49	0.0001	32	1.03 ± 0.10/ 0.83 ± 0.11	−24	0.0730
Safer's soap/ Nonsprayed	32	1.29 ± 0.38/ 1.19 ± 0.20	−8	0.8102	32	7.06 ± 0.53/ 11.36 ± 0.93	38	0.0005	32	2.14 ± 0.33/ 1.59 ± 0.20	−35	0.1042
Safer's soap/ Nonsprayed	32	0.94 ± 0.23/ 0.83 ± 0.20	−13	0.5009	32	7.66 ± 0.75/ 12.30 ± 1.03	38	0.0019	32	0.47 ± 0.04/ 0.33 ± 0.05	−42	0.0206
Wilt-Pruf Nonsprayed	32	0.52 ± 0.08/ 2.84 ± 0.49	82	0.0001	28	6.40 ± 0.57/ 11.78 ± 1.14	46	0.0001	32	1.49 ± 0.21/ 1.57 ± 0.24	5	0.9415
Wilt-Pruf/ Nonsprayed	32	2.93 ± 0.45/ 7.66 ± 0.84	62	0.0001	28	8.81 ± 0.81/ 13.90 ± 0.93	37	0.0001	32	2.27 ± 0.25/ 2.15 ± 0.20	−6	0.6317
Wilt-Pruf/ Nonsprayed	32	1.30 ± 0.22/ 4.96 ± 0.75	74	0.0001	28	7.58 ± 0.89/ 12.31 ± 0.91	38	0.0001	32	2.47 ± 0.25/ 2.44 ± 0.23	−1	0.9090
Wilt-Pruf/ 2% Oil	32	2.25 ± 0.34/ 3.27 ± 0.61	31	0.3602	28	6.51 ± 0.52/ 7.88 ± 0.52	17	0.0210		NT		
Wilt-Pruf/ 2% Oil	32	1.34 ± 0.31/ 2.68 ± 0.60	50	0.1336	28	4.57 ± 0.54/ 8.25 ± 0.78	45	0.0006		NT		
Wilt-Pruf/ 2% Oil	32	0.42 ± 0.21/ 0.79 ± 0.24	47	0.0913	28	5.62 ± 0.52/ 8.15 ± 0.77	31	0.0058		NT		
Dow 36/ Nonsprayed	32	3.08 ± 0.37/ 5.72 ± 1.09	46	0.0394	28	5.83 ± 0.91/ 9.90 ± 1.58	41	0.0005	32	0.17 ± 0.04/ 0.54 ± 0.08	69	0.0001
Dow 36/ Nonsprayed	32	0.15 ± 0.10/ 0.32 ± 0.10	53	0.0496	28	9.26 ± 0.86/ 16.06 ± 1.60	42	0.0010	32	0.14 ± 0.02/ 0.59 ± 0.07	76	0.0001
Dow 36/ Nonsprayed	32	0.48 ± 0.23/ 0.79 ± 0.15	39	0.0198	28	2.93 ± 0.41/ 4.99 ± 0.63	41	0.0050	32	0.44 ± 0.06/ 0.96 ± 0.17	54	0.0040
Folicote/ Nonsprayed	32	1.18 ± 0.23/ 1.78 ± 0.38	34	0.1112	28	7.56 ± 0.65/ 6.80 ± 0.43	−11	0.5567	28	1.43 ± 0.29/ 0.75 ± 0.11	−91	0.0218
Folicote/ Nonsprayed	32	1.00 ± 0.25/ 2.19 ± 0.55	54	0.0571	28	7.29 ± 0.53/ 7.11 ± 0.52	−3	0.7175	28	0.90 ± 0.28/ 0.72 ± 0.09	−25	0.8226
Folicote/ Nonsprayed	32	0.44 ± 0.14/ 1.01 ± 0.36	56	0.1444	28	7.61 ± 0.58/ 9.71 ± 0.85	22	0.1264	28	0.46 ± 0.07/ 0.51 ± 0.11	10	0.2598
Rhoplex/ Nonsprayed	32	0.75 ± 0.17/ 0.92 ± 0.27	18	0.6212	32	6.00 ± 0.64/ 7.89 ± 0.75	24	0.0296	32	0.35 ± 0.04/ 0.30 ± 0.04	−17	0.7460
Rhoplex/ Nonsprayed	32	0.66 ± 0.26/ 0.90 ± 0.24	27	0.3895	32	8.96 ± 0.65/ 12.57 ± 1.19	29	0.0010	32	1.15 ± 0.77/ 0.95 ± 0.17	−21	0.2524
Rhoplex/ Nonsprayed	32	1.05 ± 0.28/ 1.81 ± 0.50	42	0.1986	32	10.64 ± 0.68/ 15.57 ± 1.06	32	0.0001	32	1.02 ± 0.13/ 0.77 ± 0.10	−32	0.0847

[w] Mean lesions, scars, or nymphs per leaf followed by the standard error of the mean.
[x] Percent control = (check − test)/check × 100.
[y] Probability calculated by paired (2-tail) *t* test.
[z] Not tested.

Co., Ltd., Bramalea, ON), Rhoplex AC-33 (1:6, acrylic resin emulsion; Rohm and Haas Co., Philadelphia, PA), Wilt-Pruf (1:6, β-pinene emulsion; Wilt-Pruf Products, Inc., Essex, CT), Dormant Oil (1:99 and 1:49, emulsion of SunSpray 6E oil; Plant Products Co., Ltd., Bramalea, ON), and Safer's Insecticidal Soap (1:49, emulsion of potassium salts of selected fatty acids; Safer, Ltd., Scarborough, ON). All leaves were sprayed on the upper surface to runoff with a hand-pressurized 300-ml sprayer. Plants were allowed to dry thoroughly before exposure to thrips.

RESULTS

The efficacy tests indicated that only Wilt-Pruf (73%), oil (57%), and Dow Corning 36 (46%) significantly reduced transmission of TSWV by thrips, although Folicote also tended to reduce transmission (Table 1). In paired comparisons, 2% oil tended to be slightly more effective than 1% oil, and Wilt-Pruf tended to be superior to 2% oil. Dilutions of Wilt-Pruf and Dow Corning 36 as high as 1:19 were effective. The acrylic emulsions, Clear Spray and Plantco (*data not included*) and Rhoplex, gave similar but ineffective virus control. Safer's soap was the least effective product.

Apparent feeding activity was reduced significantly by Safer's soap, Wilt-Pruf, Dow Corning 36, and Rhoplex (Table 1). However, oil had no effect. Again, the results for Clear Spray and Plantco (*data not included*) were similar to those for Rhoplex. The results with oil and Safer's soap appeared unrelated to respective levels of virus transmission. Reductions in virus transmission with oil, Wilt-Pruf, and Folicote were disproportionately greater than reductions in feeding damage.

Dow Corning 36 was the only product that significantly reduced the number of nymphs (Table 1). By contrast, Safer's soap and the acrylics, Clear Spray and Plantco (*data not included*) and Rhoplex tended to increase the number of nymphs. The effect of the latter products on reproduction, therefore, tended to be inversely related to their effect on feeding activity.

Similar results (*data not presented*) to the mean effects of these products on feeding and reproductive activity and on virus transmission were obtained in the research greenhouse.

DISCUSSION

The average percent reduction in transmission of the TSWV by 1 or 2% horticultural oil was similar to that reported for oils used to control aphid- and whitefly-transmitted viruses in vegetable crops (16). The reduction in transmission of the TSWV was achieved without an apparent reduction in feeding activity. The mechanisms that may explain how oil reduces virus transmission have been reviewed by Sastry (16). However, most of these hypotheses have been developed from results with aphid-transmitted viruses.

There is little indication that inhibition of virus transmission by oil is associated with virus shape or size, or that the action of oil is specific to the vector (16). It is of interest, moreover, that inhibition of virus transmission by oil is generally effective with non- and semipersistent viruses, but not with persistent viruses such as TSWV (16). Whether the mode of inhibition for TSWV transmission is similar to that occurring with aphid-borne viruses is not known. However, in regard to the effect of oil on vectored and nonvectored viruses, tests in our laboratory suggest that the mode of action may be similar or the same. In tests (W. R. Allen, *unpublished*) with the TSWV and *Nicotiana glutinosa* L. (a local lesion host), in which the experimental design and treatments were the same as those of Peters and Lebbink (12) with tobacco mosaic virus (TMV) and the same host, transmission of TSWV was substantially reduced to leaf-halves sprayed with oil either before or after mechanical inoculation. Lesion numbers on leaf-halves sprayed before inoculation decreased over a 6-hr period as the interval between spraying and inoculating decreased. Lesion numbers on leaf-halves sprayed at intervals after inoculation were minimal at 15 min (lower than at time zero) and then increased over the following 4–6 hr on leaf-halves sprayed at progressively later intervals after inoculation. The results with these two viruses and TMV-RNA were nearly identical. Peters and Lebbink (12) have interpreted their data to indicate that oil does not directly inactivate the virus or its RNA, but interferes in the progression of infection at an early stage, but later than uncoating. We have no data on the postinoculation effect of oil on thrips transmission of TSWV, but results with aphid-borne viruses indicate that post-inoculation oil sprays are not effective (16).

With the current emphasis on decreasing the use of conventional pesticides, horticultural oils are receiving renewed attention; consequently, lower impurity, less phytotoxic formulations are being developed (22). Also, information is increasing on factors that contribute to phytotoxicity and on cultivar susceptibilities to oil (7,8,10). It is noteworthy that horticultural oils are compatible with some biological control agents which are susceptible to conventional pesticides (8). Further, increasing attention is being given to the control of fungal diseases with oil, in particular the mildews (8,13).

Although insecticidal soap has been shown to reduce mechanical transmission of tobacco mosaic and tobacco ringspot viruses (23), the product had no significant effect on transmission of the TSWV by thrips (Table 1). These results were surprising because the soap significantly reduced apparent feeding damage by as much as 49%. These reductions in apparent feeding damage without reductions in virus transmission indicate that the type of feeding associated with virus transmission is different from that which results in the highly visible feeding scars recorded in the present study. Further indication of a lack of association may be the disproportionately greater reduction in virus transmission than in feeding damage afforded with Wilt-Pruf and Folicote. In this regard, other workers (6) have suggested that virus transmission may occur more readily during brief and shallow probing which is associated with salivation and discharge of virus. This type of probing leaves minute or nonobservable feeding scars, and cell damage is usually not lethal. By contrast, probing associated with ingestion of cell contents occurs largely without salivation and virus discharge, and cell death results in the development of highly visible, sunken, silvery scars. If these presumptions are correct, an assessment of the potential of a product to reduce virus transmission based solely on changes in visible feeding damage may be misleading.

The only products which gave significant reductions in both virus transmission and apparent feeding damage were Wilt-Pruf and Dow Corning 36. β-Pinene, the active ingredient in Wilt-Pruf, is reported to be a feeding deterrent to beetles (species not specified), *Dendrolimnus pini* L., and *Locusta migratoria migratorioides* (Reiche & Fairmaire) (21). Additionally, research at this station has shown that Wilt-Pruf is a strong deterrent to feeding and oviposition by the chrysanthemum leaf miner, *Liriomyza trifolii* (Burgess) (B. Tehrani, A. B. Broadbent, and W. R. Allen, *unpublished data*). This product is manufactured as an antitranspirant which is slowly polymerized by sunlight into a persistent, clear, colorless, and flexible film. Wilt-Pruf does not require registration in the United States with the Environmental Protection Agency and meets specifications of the Food and Drug Administration for use on all edible crops. The product consists entirely of carbon and hydrogen, is biodegradable, and is relatively nontoxic to mammals ($LD_{50} > 20,000$). Toxicity was not reported by the manufacturer in tests on certain food crops, trees, shrubs, or ornamentals; and it was nontoxic in the present studies.

Dow Corning 36 was the only product that significantly reduced both the number of nymphs and the amount of feeding damage. Surprisingly, Safer's soap, Folicote, and the acrylic emulsions, Rhoplex, Clear Spray, and Plantco, tended to increase nymph numbers,

although feeding damage was reduced. As mentioned, the variable results regarding the effects of the individual products on feeding, reproduction, and virus transmission indicate that the potential of a product to reduce virus transmission or reproduction cannot be accurately predicted on the basis of its effect on visible feeding damage. Other chemicals that have reduced feeding or oviposition, or both, by other insects have been identified (14).

Concerns associated with the use of oil and antidesiccants relate perhaps less to worker and environmental safety than to phytoxicity, especially after prolonged use. However, considerable information is available on the relative susceptibility of ornamental and vegetable crops to some of these materials and the conditions under which damage may occur (5,7,9,13,19,22,24). If prolonged use of any of these products is detrimental to the production of some crops, they could be used judiciously as supplements to pesticide programs.

Rapid control of TSWV epiphytotics requires an unusually efficient reduction in the number of viruliferous adult thrips and thorough eradication of sources of the virus and accompanying viruliferous immature thrips. Conventional pesticide programs generally do not provided the required levels of efficiency, especially during the summer months in greenhouses when thrips populations are high. In commercial greenhouses, eradication of sources of the virus is economically feasible only if infected plants express symptoms. Large-scale testing of production stock to eliminate latent infections is not practical. Products that can reduce virus acquisition or transmission by altering feeding activity, or that can directly interfere with the establishment of the virus in plant cells, would have a faster and presumably greater effect on epiphytotics than insecticides alone. Such products would be useful substitutes or supplements for conventional pesticides if 1) they are toxicologically and environmentally safe; 2) their use does not significantly limit opportunities for the use of biological agents for control of target and associated insects; and 3) they provide an aspect of thrips control that has a long-lasting effect on population dynamics, such as reduced oviposition, slower maturation, greater mortality, or an increased susceptibility to pesticides, perhaps because of impaired health associated with altered feeding behavior.

In the past two decades, there has been increasing interest in identifying biologically active, natural or synthetic compounds that in some way change the behavior, development, or reproduction of pests, including insects, pathogens, and weeds. These bioregulators, used in conjunction with genetic resistance, biological control agents, and modified cultural practices, are alternatives or supplements that can reduce reliance on conventional pesticides. However, the use of these alternatives or substitutes requires an intimate understanding of their impact on pest–plant interactions and the related ecosystem.

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