Esfenvalerate Residues on Pepper and Pumpkin Following Application for Control of Cucumber Beetles (Coleoptera: Chrysomelidae)[1]

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J. Entomol. Sci. 29(4): 441-449 (October 1994)

ABSTRACT Esfenvalerate was sprayed on green pepper and pumpkin plants at 7.0 g (AI)/ha to control adult striped cucumber beetle, *Acalymma vittatum* (Fabricius), and spotted cucumber beetle, *Diabrotica undecimpunctata howardi* (Barber). Following spraying, residues of esfenvalerate on the two crops were determined and adult insects were swept and counted. Esfenvalerate was extracted using n-hexane from representative plant samples collected at different time intervals following spaying for residue analysis. Determination of residues using gas chromatography (GC-ECD) indicated initial deposits of 3.34 and 1.18 ppm on pumpkin and pepper leaves, respectively. Only trace levels were detected on pepper fruits on day 21 (0.0001 ppm). Half-life values were 1.11 and 2.79 d on pumpkin and pepper fruits, respectively, whereas the values were 1.92 and 3.38 d on pumpkin and pepper leaves, respectively. Periodic sweep-net collections from treated and untreated plots revealed mean beetle reductions of nearly 100% 1 h post-treatment and > 60% 2 wk after treatment on both crops. Results obtained may be useful for developing IPM strategies to reduce pesticide residues on produce.

KEY WORDS *Acalymma vittatum, Diabrotica undecimpunctata,* Pepper, Pumpkin, esfenvalerate residues.

The spotted cucumber beetle (SPCB), *Diabrotica undecimpunctata howardi* Barber, is a serious pest of cucurbits. It severely damages emerging or newly-transplanted plants, may damage reproducing plants by feeding on pollen, and causes economic damage by feeding directly on mature cucurbit fruits. The striped cucumber beetle (STCB), *Acalymma vittatum* (F.), a close relative of SPCB, is also an economic pest of cucurbit crops throughout the United States, damaging cucumber, watermelon, cantaloupe, squash and pumpkin (Reed et al. 1986, Necibi et al. 1992). In addition, both beetles are carriers of the causal organism of bacterial wilt of cucurbits, *Erwinia tracheiphila* Smith (Whitaker and Davis 1962, Reed and Reed 1986), which can cause more damage than feeding by beetles. Because of their ability to transmit *E. tracheiphila,* small populations of beetles may vector economically disastrous effects. Recently,

[1] Accepted for publication 07 June 1994.

many synthetic pyrethroids have been developed and evaluated for insecticidal efficiency. Among these, some α-cyano-3-phenoxybenzyl esters exhibit a particularly high biological activity; the potential of these compounds for agricultural use is being evaluated. Esfenvalerate, [(s)-cyano (3-phenoxyphenyl) methyl (s)-4-chloro-α-(1-methyl ethyl) benzene acetate], is the S isomer of the pyrethroid fenvalerate (70% or more active isomer of fenvalerate). It has the highest insecticidal activity of the four fenvalerate isomers (Oouchi 1985). Limited data are available on dissipation of esfenvalerate on vegetable crops (Lim and Meister 1991). The current study was designed to determine persistence of esfenvalerate residues on pepper and pumpkin foliage and fruit and to evaluate its efficacy against SPCB and STCB on two types of crops (viney and vertical): on pumpkin, known as a host of cucumber beetles, and on pepper when beetles were present, incidentally.

Materials and Methods

Field plots were located on the Kentucky State University Research Farm, Franklin County, KY. Field plots (22.0 × 3.7 m, n = 16) were arranged on a 10% grade in a randomized complete block design and were planted with green bell pepper (*Capsicum annuum*) 'Lady Bell' transplants on 13 June, while Pumpkin (*Cucurbita pepo*) 'Big Moon' was seeded on 21 June 1991. Pepper transplant and pumpkin seeding rates were 10 plants and 2 seeds per 3.7 m of row, respectively. Plots contained 10 rows oriented along the contour of the slope.

Esfenvalerate analytical standard grade (82%) and its formulation, Asana XL (8.4% Emulsifiable Concentrate), were obtained from Du Pont Ag Products, Wilmington, DE. Asana XL was sprayed using a portable backpack sprayer on pumpkin and pepper plants at 14 d intervals at the rate of 7.0 g (AI) in a total volume of 157.5 l of water/ha. On 1 October 1991 (one month before harvest), a final spraying was made. Triplicate leaf samples (100 g each) from each plot were collected randomly from mid canopy of plants 1 h prior to the 1 October spraying, and 1 h to 28 d post-treatment. A leaf punch (2.2 cm diameter) was used to take 100 randomly selected leaf discs per sample weighing about 9.5 and 11.5 g for pumpkin and pepper leaves, respectively. This sampling procedure provided the same total surface area (760 cm^2) used for residue analysis for each type of foliage. Samples of pepper fruits (1-2 kg) and three pumpkin fruits (12-15 kg each) were collected at random from experimental plots for residue analysis of esfenvalerate at the different time intervals of 1 h to 28 d post-treatment. Insect collections were made with a sweep-net (38-cm diameter). Ten random sweeps per 10 rows were collected by a single person through the vegetation at a height of 15-20 cm. Insects were counted 1 h before spraying and 1 h and 1, 3, 7, 10 and 14 d after spraying. All sweeps were begun at 8:00 AM, because beetle counts often decline after early morning sampling (Weinzierl et al. 1986). Mean daily temperature during the study period was 15°C (average maximum and minimum of 21.1 and 8.9°C, respectively). Mean relative humidity (RH) was 70.5% (average maximum and minimum of 95 and 46%, respectively). Field count data of insects collected from treated versus untreated plots were evaluated by calculating percent reduction using Abbott's (1925) formula. Values of percent reduction were transformed to their arcsin

square root and analyzed using analysis of variance (SAS Institute 1991). Means were separated using Fisher's protected least significant difference (LSD) test ($P < 0.05$) (Snedecor and Cochran 1967).

Analytical Procedure. One hundred randomly-selected leaf discs were blended with 100 ml of n-hexane. Unwashed fruits were quartered, a subsample from the two opposite quarters from each fruit was homogenized. One hundred grams of homogenate were blended with 300 ml of n-hexane for 3 min at high speed. Four replicates from each treatment were obtained. Extraction of esfenvalerate residues was carried out using the procedures described by Antonious (1982) for cypermethrin and flucythrinate extraction from plant tissues. Concentrated hexane extracts were transferred to glass chromatographic columns (2.2 i.d. × 35 cm) containing 12 g of 3% deactivated Florisil (Lee et al. 1978). The residue was reconstituted in 2 ml iso-octane for GC injections. Extraction and clean-up methods were verified using laboratory-spiked samples at different levels (0.001-1 ppm), and the efficiencies were determined. Gas chromatographic analysis of esfenvalerate was performed on a Hewlett-Packard Model 5890A Series II gas chromatograph (Hewlett Packard Co., Avondale, PA), equipped with a ^{63}Ni electron capture detector and a column (5 m × 0.5 mm i.d.) of 100% polydimethylsiloxane (HP-1 column). Operating temperatures were 225, 230, and 325°C for injector, oven, and detector, respectively. Peak areas were determined on a Hewlett Packard Model 3396 Series II integrator. Average area units (based on 2 injections per sample) were compared to an external standard that was used for quantification. Under these conditions, two peaks with retention times of 5.67 and 6.14 min were obtained corresponding to the two enantiometric pairs of pyrethroids designated as RS, SR and, RR, SS. The first peak (Rt = 5.67 min) consists of the RS and SR isomers; the second (Rt = 6.14 min) consists of SS and RR isomers. Because esfenvalerate is the SS isomer, only the second peak was used for esfenvalerate quantitation (Heinis and Knuth 1992). The chromatograms obtained indicate that plant pigments cause no interference in esfenvalerate quantitation. Standards of esfenvalerate (0.025, 0.05, 0.1, 0.2 ng/ul) were prepared in iso-octane, and the unit areas were obtained using 1-ul injections. Linearity over the range of concentrations was determined using regression analysis. Recoveries of fortified samples averaged 85.8-88.2% for pepper and 90.0-93.2% for pumpkin. Detectability limits were 4.2×10^{-7} and 5×10^{-6} ppm for pepper and pumpkin leaves respectively; 5×10^{-7} and 2.5×10^{-7} ppm for pepper and pumpkin fruits, respectively. Residue data were used to calculate regression slopes. Slopes were analyzed using analysis of variance (ANOVA) (SAS Institute 1991); Fisher's LSD was used to compare means (Snedecor and Cochran 1967). Esfenvalerate residues detected on vegetation were plotted against their corresponding post-treatment sampling time, and were used to calculate half-lives by conducting linear regression of $\log_e$ residue values versus time (Anderson 1986).

Results and Discussion

The persistence of esfenvalerate on treated pepper and pumpkin was evaluated on the basis of half-life values. Residue analysis of fruit samples by means of gas chromatography revealed that the initial deposits of esfenvalerate on

pepper fruit were 0.014 ppm but dropped to 0.008 ppm by day 3, indicating that 42.06% of the initial deposits were dissipated. Residue levels on pumpkin foliage were significantly higher than on pepper foliage ($P < 0.05$, Fisher's protected LSD test) for days 0-7. On day 10, differences were not significant, and on days 14-20 more residue was present on pepper foliage.

The calculated half-life ($t_{1/2}$) was 2.79 and 1.11 d on pepper and pumpkin fruits, respectively (Fig. 1). $T_{1/2}$ values were 3.38 and 1.92 d on pepper and pumpkin leaves, respectively (Fig. 2). Initial deposits were higher on pumpkin leaves (3.34 ppm) than pepper leaves (1.18 ppm), but dissipation rate on pumpkin was higher than that on pepper.

Reduction of both beetle species was 100% immediately after spraying and decreased proportionally as time elapsed. Significant differences in insect reduction on the two crops and at the different time intervals following spraying were observed. Mean estimates of SPCB density on untreated foliage during the experimental period ranged from 58.5 to 69.8 and from 13.3 to 20.5 beetles per 10 sweeps on pumpkin and pepper leaves, respectively (Table 1). In contrast, STCB population counts averaged only 4 to 14.8 and 1 to 7.7 beetles per 10

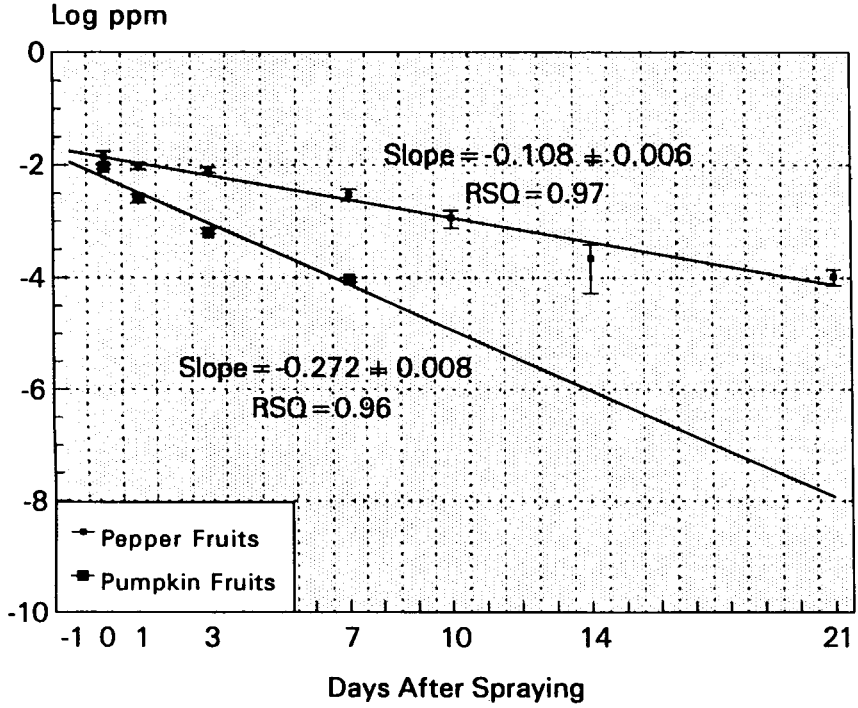

Fig. 1. Dissipation of esfenvalerate residues on pepper and pumpkin fruits at different time intervals following spraying of 7.0 g AI/ha. Vertical bars indicate ± standard error; where no bar is shown, it is less than the size of the symbol. Slopes ± (SE) are significantly different ($P < 0.05$; Duncan's multiple range test [SAS Institute 1991]).

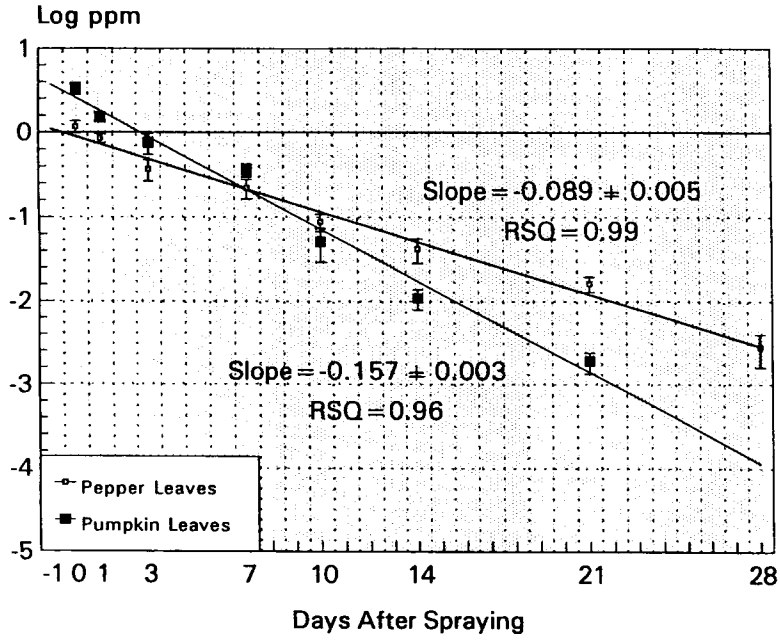

Fig. 2. Dissipation of esfenvalerate residues on pepper and pumpkin leaves at different time intervals following spraying of 7.0 g AI/ha. Vertical bars indicate ± standard error; where no bar is shown, it is less than the size of the symbol. Slopes ± (SE) are significantly different ($P < 0.05$; Duncan's multiple range test [SAS Institute 1991]).

sweeps on pumpkin and pepper leaves, respectively (Table 2). Generally, low concentrations of esfenvalerate were detected on fruits of both pepper (vertical corp) and pumpkin (viney crop). Studies of esfenvalerate against SPCB indicated that 3.34 ug esfenvalerate per g pumpkin leaves, which is equivalent to 0.021 ug/cm^2 leaf area, was extremely toxic to SPCB on that viney crop and that considerable reduction, 100% and 90.3% occurred 1 h and 1 d following spraying, respectively (Table 1). Two wk after esfenvalerate spraying, the residue levels were 0.01 ppm, which still reduced SPCB population by 69.5%.

Weather patterns influence the performance of pyrethroids as contact insecticides in a number of ways under field conditions. Volatility after application can result in significant loss of residues from treated surfaces with the rate of volatilization directly related to sun exposure. Guillebeau et al. (1989) found that the control of boll weevil damage by esfenvalerate (0.03-0.04 kg [AI]/ha) gradually decreased during hot periods. Dissipation pathways in this system include photodegradation, expansion of leaves, microbial degradation, and volatilization. Volatilization likely occurs but at rates less than for photodegradation, due to the low vapor pressure of esfenvalerate (2.8×10^{-7} mmHg, 25°C). Photodegradation pathways as a function of exposure are listed by Aizawa (1989). The observed

Table 1. Population density and percent reduction of spotted cucumber beetle on pepper and pumpkin foliage following esfenvalerate application.

Sampling Time in Days	Pepper		Reduction** in Counts (%)	Pumpkin		Reduction** in Counts (%)
	Untreated*	Treated*		Untreated*	Treated*	
0†	13.3 ± 3.8	0.0 ± 0.0	100.00 a	58.5 ± 22.3	0.0 ± 0.0	100.00 a
1	16.0 ± 4.6	0.5 ± 1.0	96.88 ab	62.0 ± 28.3	6.0 ± 3.4	90.32 b
3	19.8 ± 9.4	2.3 ± 2.2	88.38 bc	69.5 ± 13.5	11.5 ± 7.7	83.45 bc
7	22.5 ± 2.1	3.5 ± 1.0	84.44 bc	64.3 ± 18.8	13.0 ± 5.7	79.78 cd
10	20.3 ± 5.3	3.5 ± 4.4	82.72 c	67.5 ± 12.6	18.3 ± 5.6	72.89 cd
14	20.5 ± 4.7	3.8 ± 1.7	81.46 c	69.8 ± 17.3	21.3 ± 4.8	69.48 d

* Average of beetles ± SE/10 sweeps.

** Percentages of reduction calculated by Abbott's (1925) formula after esfenvalerate application. Values in a column having different letters are significantly different from each other, using Fisher's protected LSD ($P < 0.05$).

† 1 hr after spraying.

Table 2. Population density and percent reduction of striped cucumber beetle on pepper and pumpkin foliage following esfenvalerate application.

Sampling Time in Days	Pepper		Reduction** in Counts (%)	Pumpkin		Reduction** in Counts (%)
	Untreated*	Treated*		Untreated*	Treated*	
0†	1.0 ± 1.2	0.00 ± 0.0	100.0 a	4.0 ± 0.0	0.0 ± 0.0	100.0 a
1	2.0 ± 0.8	0.00 ± 0.0	100.0 a	6.8 ± 1.5	0.5 ± 1.0	92.6 a
3	3.0 ± 0.8	0.25 ± 0.5	91.7 ab	6.3 ± 1.3	0.8 ± 1.0	87.3 ab
7	4.5 ± 1.3	0.50 ± 1.0	88.9 ab	9.0 ± 5.7	2.0 ± 1.3	77.8 bc
10	4.5 ± 1.8	0.75 ± 1.4	83.3 ab	11.5 ± 3.9	3.0 ± 1.4	73.9 c
14	7.7 ± 3.0	2.25 ± 1.2	70.8 b	14.8 ± 4.0	5.8 ± 1.7	60.8 c

* Average of beetles ± SE/10 sweeps.

** Percentage of reduction calculated by Abbott's (1925) formula after esfenvalerate application. Values in a column having different letters are significantly different from each other, using Fisher's protected LSD ($P < 0.05$).

† 1 hr after spraying.

variation in esfenvalerate dissipation on the two crops studied here is likely due to differences in leaf orientation. Pumpkin leaves are oriented in a monolayer, approaching a leaf area index (LAI) of 1. They are minimally shaded, but do lose turgor on hot days and tend to wilt. The orientation of pepper leaves on a stalk causes partial shading during each diurnal cycle. Esfenvalerate efficiency in reducing population densities of SPCB and STCB is affected by crop type; control is more effective on pepper (vertical crop) than on pumpkin (viney crop). This may partially be due to the faster growth rate of pumpkin plants than pepper, causing dilution of esfenvalerate residues. In addition, because esfenvalerate is not systemic, newly-expanded pumpkin leaves have no insecticide residues.

Broader implications of data obtained may help Integrated Pest Management and crop-pesticide residue reduction programs for the following reasons: First, esfenvalerate has a strong activity against cucumber beetles on pumpkin, a viney crop, at an application rate of only 7 g (AI)/157.5 liters of water/ha. Second, pyrethroids are toxic to beneficial insects (Mizell and Schiffhauer 1990); but low rates of esfenvalerate application may reduce detrimental effects to beneficials while still controlling cucumber beetles. Finally, esfenvalerate residue concentrations on the fruit were low. One day following spraying, residues were 0.009 and 0.002 ppm on pepper and pumpkin fruits, respectively. These low residues are encouraging because risk of exposure to the consumer is low. Concern for consumer safety challenges vegetable production personnel to minimize pesticide residues without increasing production risks.

Acknowledgment

We thank D. L. Dahlman (University of Kentucky, Entomology Dept.) for his valuable guidance and for reviewing the manuscript. This investigation was supported by a grant from the USDA/CSRS to Kentucky State University under agreements KYX-10-90-16P and KYX-9101791.

References Cited

Abbott, W. S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

Aizawa, H. 1989. Metabolic maps of pesticides: volume II. Academic Press. San Diego, CA.

Anderson, A. C. 1986. Calculating biodegradation rates. J. Environ. Sci. Health, B 21: 41-56.

Antonious, G. F. 1982. Studies on the residues of some pesticides in relation to their effect on the quality of certain crops. Ph.D. Thesis, College of Agriculture, University of Alexandria, Egypt.

Guillebeau, L. P., J. N. All and A. M. Javid. 1989. Influence of weather on efficacy of pyrethroid insecticides for boll weevil (Coleoptera: Curculionidae) and bollworm (Lepidoptera: Noctuidae) in cotton. J. Econ. Entomol. 82: 291-297.

Heinis, L. J. and M. L. Knuth. 1992. The mixing, distribution and persistence of esfenvalerate within Littoral enclosures. Envir. Toxicol. Chem. 11: 11-25.

Lee, Y. W., N. D. Westcott and R. A. Reichle. 1978. Gas-liquid chromatographic determination of pydrin, a synthetic pyrethoid, in cabbage and lettuce. J. Assoc. Off. Anal. Chem. 61: 869-871.

Lim, L. O. and C. W. Meister. 1991. Deposition of esfenvalerate on brassica vegetables. Bull. Environ. Contam. Toxicol. 46: 810-814.

Mizell, R. F. and Schiffhauer D. E. 1990. Effects of pesticides on pecan aphid predators *Chrysoperla rufilabris* (Neuroptera: Chrysopidae), *Hippodamia convergens*, Cycloneda sanguinea, *Olla v-nigrum* (Coleoptera: Coccinellidae), and *Aphelinus perpallidus* (Hymenoptera: Encyrtidae). J. Econ. Entomol. 83: 1806-1812.

Necibi, S., B. A. Barrett and J. W. Johnson. 1992. Effects of a black plastic mulch and plant dispersal on cucumber beetles, J. Agric. Entomol. 9: 129-135.

Oouchi, H. 1985. Sumi-alpha (esfenvalerate) Jpn. Pestic. Inf. 46: 21-24 Pesticide Analytical Manual, vol II, sec. 180.379. Food and Drug Administration.

Reed, K. R. and G. L. Reed. 1986. Activity of Avermectin B_1 against striped cucumber beetle (Coleoptera: Chrysomelidae). J. Econ. Entomol. 79: 943-947.

Reed, D. K., G. L. Reed and C. S. Creighton. 1986. Introduction of entomogenous nematodes into trickle irrigation systems to control striped cucumber beetle. J. Econ. Entomol. 79: 1330-1333.

SAS Institute. 1991. SAS/STAT Guide, Release 6.03 Edition. SAS Institute Inc., SAS Campus Drive, Cary, NC.

Snedecor, F. W. and W. G. Cochran. 1967. Statistical methods. 6th ed. Iowa State University Press, Ames, Iowa.

Weinzierl, R. A., R. E. Berry and G. C. Fisher. 1986. Sweep-net sampling for western spotted cucumber beetle (Coleoptera: Chrysomelidae) in snap beans. J. Econ. Entomol. 79: 1100-1105.

Whitaker, T. W. and G. N. Davis. 1962. Cucurbits: botany, cultivation, and utilization. Interscience Pub. Co., NY.