Population Dynamics and Distribution of *Trialeurodes vaporariorum* and *Bemisia tabaci* (Homoptera: Aleyrodidae) on Poinsettia Following Applications of Three Chemical Insecticides[1]

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ABSTRACT The effects of three insecticides, bifenthrin, endosulfan and aldicarb, on the within- and between-plant distributions of both greenhouse whitefly (GHWF), *Trialeurodes vaporariorum* (Westwood), and sweetpotato whitefly (SPWF), *Bemisia tabaci* (Gennadius), were examined on greenhouse-grown poinsettia using Taylor's Power Law. Insecticide applications affected the spatial distribution of GHWF and SPWF. The populations of immatures of both species surviving an insecticide application on poinsettia were less aggregated within and between plants than untreated populations. Among the three insecticides, the efficacy against the two whiteflies was not significantly different at the end of the seventh week when multiple applications were conducted. Aldicarb caused higher mortality of immature stages than bifenthrin and endosulfan after four weeks following a single application. A single application of bifenthrin and endosulfan affected the distribution of all whitefly stages in the first and second weeks after treatment, whereas aldicarb did not affect the whitefly population until the third week. Insecticidal treatments had little effect on the stratification of whitefly stages within the plant.

KEY WORDS Insecta, chemical insecticides, greenhouse whitefly, sweetpotato whitefly, cotton whitefly, tobacco whitefly, insect distribution, poinsettia pests, *Trialeurodes vaporariorum, Bemisia tabaci.*

The greenhouse whitefly (GHWF), *Trialeurodes vaporariorum* (Westwood) and sweetpotato whitefly (SPWF), *Bemisia tabaci* (Gennadius), are important pest insects of agricultural crops including ornamental plants (Price et al. 1986). The nymphal stages and adults suck plant sap and excrete honeydew which cultures sooty mold. Adults transmit plant viral diseases.

Ornamental plants are high cash value crops and often receive extensive insecticide treatments to counter the damaging effects of a whitefly infestation. Insecticides are the most commonly used method to suppress whitefly infestations on greenhouse-grown ornamental plants (Dittrich et al. 1990). Current efforts to achieve acceptable control of the two whitefly species requires an efficient quantitative sampling system (Butler et al. 1986). However, previous studies on the within- and between-plant spatial distribution of GHWF and SPWF were conducted on untreated field and greenhouse-grown plants and on areas of unknown chemical insecticide treatment history (Noldus et al. 1986a,

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1986b; Ohnesorge et al. 1980; Xu et al. 1980; Xu 1985; Yano 1983). These studies reported that the spatial distributions of the two whitefly species were highly aggregated within and between plants. There was significant stratification with whitefly development on the host plant: the eggs and adults were mostly located on the youngest leaves, the young nymphs on more mature leaves, the old nymphs and pupae mostly on older leaves.

During a survey of greenhouses throughout Georgia, we observed that the distribution of the 2 whiteflies was probably affected by the application of chemical insecticides. Monitoring and sampling programs developed from data on untreated plants may not be applicable to populations influenced by chemical application, or vice versa (Trumble 1985). Data are needed on poinsettia treated with different chemical insecticides to develop integrated whitefly management programs in greenhouses. The objectives of this study was to determine if the application of chemical insecticides will affect the within- and between-plant distributions and the population dynamics of both whitefly species.

Materials and Methods

This study was conducted in the greenhouses and insect-rearing room at the Department of Entomology, Georgia Experiment Station, at Griffin, GA. Both GHWF and SPWF were cultured on poinsettia (*Euphorbia pulcherrima* Willd.) and chrysanthemum (*Dendranthema grandifolium* Tevyel) in the greenhouse. Poinsettia cuttings were potted individually in 15-cm plastic azalea pots with standard media, and then placed in a greenhouse containing poinsettias infested with whiteflies for about 5 weeks. Experiments were initiated when all developmental stages of whiteflies were present on the plants.

Three chemical insecticides were applied: bifenthrin (Talstar 10WP), endosulfan (Thiodan 50WP) and aldicarb (Temik 10G); water sprays served as a check. Price et al. (1986) reported that bifenthrin was effective on both adults and immatures, endosulfan was effective only on adults, and aldicarb only on immatures. The amounts used for each of the 3 insecticides were: bifenthrin, 1.1 g AI per liter of water; endosulfan, 1.2 g AI per liter of water; and aldicarb, 0.2 g AI per 15-cm pot.

Two tests were conducted in an insect culture room in which temperature and relative humidity were maintained at 25°C (± 3°C) and 75% (±5%), respectively, and photophase and scotophase were 12:12 hr. Treated plants were maintained in cages 56 × 60 × 60 cm high with 200 mesh screen on all sides and a clear plastic top.

Test I. Sixteen poinsettia plants were randomly assigned to 4 blocks with 4 plants per block and each block was placed in a screen cage. Treatments were replicated 4 times. Bifenthrin, endosulfan, and water (as a check) were sprayed once a week for 3 weeks. Aldicarb was applied twice, once on the first day of the test, and again 3 weeks later. Following each application of insecticides, a large number of additional adult whiteflies (ca. 200-300) of GHWF or SPWF were released on the plants inside the cage after the spray droplets on the plant foliage were dry. The test was terminated 3 weeks after the last insecticide application (i.e. the seventh week from the beginning of the experiment).

Test II. In this test, GHWF adults were released on the plants 5 weeks prior to the test, and all whitefly immature stages were present on the plants. The same insecticides were used in this test as those applied in Test I, but the insecticides were used only once, on the first day. The numbers of all immature stages on 4 plants from each treatment were sampled and counted 5 times: the first day just before the spray (pretreatment), and weekly for 4 weeks after the insecticide application. On the termination date, 15 leaves from each plant were collected, and numbers of all immatures were counted in the laboratory using a dissecting stereomicroscope.

The original counts were used in the population dynamics analysis, and then were transformed to $\sqrt{(\text{count} + 0.5)}$ for within- and between-plant distribution pattern analysis (Steele and Torrie 1960). Whitefly between-plant distribution patterns were based on single plant counts, and within-plant distribution patterns on single leaf counts which correspond to the "natural habitat units" for sampling as described by Patil and Stiteler (1974). Taylor's power law method (Taylor 1961) which is the widely used index of spatial distribution also was used to examine between- and within-plant dispersion patterns. Taylor's power law ($s^2 = am^b$) was calculated as the regression of log-transformed variance ($\log_{10} s^2$) on log-transformed mean ($\log_{10}$ m) in a linear model such that:

$$\log_{10} (s^2) = \log_{10} a + b \log_{10} (m)$$

where s^2 is variance, m is mean number of each immature stage of whiteflies per leaf (within-plant) or per plant (between-plant), a is largely a sampling factor related to sample unit size, and b is a measure of aggregation. In Taylor's power law method, $b > 1$, $b = 1$ and $b < 1$ were considered aggregated, random and uniform distribution, respectively. Student's *t*-test was used to test the hypothesis that $b = 1$, as well as for documenting if b values were significantly different between analyses (SAS Institute 1986).

Results and Discussion

Population densities of each immature stage for both whitefly species were greatest on the plants treated with water in both tests, and were reduced after the treatments of insecticides (Tables 1 and 2). In test I, all immature populations of the 2 whitefly species were significantly different from the water check at the end of the seventh week. Test I was similar to the situation in a commercial greenhouse where 3-4 insecticide applications are common when the whitefly population is large enough to cause foliar damage. The efficacies of bifenthrin, endosulfan, and aldicarb were similar and were not significantly different at the end of the seventh week. However, because only the data on the seventh week were collected, the progressive population changes in test I were not available.

In test II all immature populations in the bifenthrin treatment were reduced in the first week and the following weeks. In the endosulfan treatment, egg numbers decreased rapidly after the first week because the adult population was reduced, but other immatures were not significantly affected. However, the numbers of all immatures were reduced by week 2, resulting in a similar

Table 1. Numbers of immature stages of greenhouse whitefly and sweetpotato whitefly on poinsettia following four insecticide applications in Test. 1.

	Mean ± SD/Leaf				
		Post--treatment*			
Species & Stage	Pre-Treatment	Bifenthrin	Endosulfan	Aldicarb	Water
Greenhouse whitefly					
Eggs	35.5 ± 61.2	5.3 ± 11.9 b	5.7 ± 9.0 b	3.7 ± 3.1 b	29.8 ± 57.1 a
Nymph	21.1 ± 18.2	5.7 ± 5.9 b	11.9 ± 4.7 a	1.4 ± 1.3 b	14.3 ± 10.1 a
Pupa	61.1 ± 67.8	28.3 ± 5.4 b	25.9 ± 6.1 b	0.4 ± 0.8 c	53.5 ± 65.0 a
Sweetpotato whitefly					
Egg	123.2 ± 77.3	14.1 ± 56.5 b	10.3 ± 8.4 b	3.6 ± 4.2 b	153.8 ± 74.5 a
Nymph	567.4 ± 302.1	16.8 ± 26.9 b	18.3 ± 15.2 b	2.6 ± 3.3 b	223.5 ± 96.6 a
Pupa	89.5 ± 90.3	3.4 ± 8.8 b	0.7 ± 1.4 b	0.2 ± 0.6 b	100.4 ± 106.2 a

* Data were collected on the seventh week from the first day of the test. Means of each whitefly stage within the same row from post-treatment section followed by the same letter are not significantly different ($P = 0.05$, LSD).

effectiveness to bifenthrin at the end of the test. Aldicarb is a systemic insecticide and efficacy was slower than was observed with bifenthrin and endosulfan. The numbers of all immature stages in the first week were not significantly different from those of pre-treatment and water treatment. However, numbers of all immature stages were reduced significantly by aldicarb after the second week which resulted in a greater reduction in whiteflies than the other two insecticides (Table 2). Data from test II showed similar effectiveness of the 3 insecticides against different whitefly stages as reported by Price et al. (1986).

In Taylor's Power Law method, the b values were highly aggregated with b values significantly greater than one ($P < 0.05$) for whiteflies on plants prior to insecticide treatments or sprayed with water. All immatures of SPWF and GHWF in the tests were less aggregated for both within- and between-plant distributions from the insecticide-treated plants than on untreated plants (Tables 3-6). However, some immatures were still aggregated on some insecticide-treated plants (Table 5). Biologically these results were descriptive since the survivors of all immatures after insecticide treatments, and the new immigrating adult females could develop and reproduce rapidly, creating a situation where few leaves or plants had a great number of whiteflies, and most leaves and plants had few or none. Data from test I showed that the distribution patterns between the 2 whitefly species following insecticide applications were not significantly different (Tables 3 and 4), although SPWF had much higher population density before and after insecticide treatment than GHWF.

Table 2. Numbers of immature stages of greenhouse whitefly on poinsettia following one insecticide application in Test II.

Time Stage	Mean ± SD/Leaf			
	Bifenthrin	Endosulfan	Aldicarb	Water
Pre-treatment				
Eggs	19.9 ± 22.7 a	19.0 ± 33.8 a	29.7 ± 32.5 a	22.3 ± 24.8 a
Nymph	47.2 ± 64.9 a	54.6 ± 55.9 a	81.1 ± 92.0 a	57.6 ± 59.9 a
Pupa	11.7 ± 20.4 a	8.5 ± 10.1 a	13.9 ± 12.2 a	17.7 ± 35.6 a
First Week				
Egg	11.7 ± 14.9 b	14.2 ± 16.3 b	10.9 ± 3.4 b	20.4 ± 19.9 a
Nymph	38.3 ± 30.0 b	119.7 ± 108.7 a	22.6 ± 17.0 b	141.5 ± 115.5 a
Pupa	8.2 ± 10.6 a	15.5 ± 17.7 a	7.9 ± 17.7 a	12.2 ± 12.1 a
Second Week				
Egg	11.4 ± 12.9 b	2.1 ± 3.5 c	3.1 ± 3.2 c	20.7 ± 20.2 a
Nymph	48.5 ± 23.2 b	26.7 ± 27.2 b	18.1 ± 19.5 b	210.2 ± 132.1 a
Pupa	12.1 ± 13.3 b	7.7 ± 11.5 bc	6.7 ± 0.8 c	18.9 ± 18.8 a
Third Week				
Egg	6.7 ± 13.6 b	7.0 ± 10.9 b	4.6 ± 7.6 b	18.0 ± 22.1 a
Nymph	15.8 ± 11.3 bc	21.4 ± 26.5 b	2.3 ± 3.4 c	59.1 ± 43.9 a
Pupa	4.5 ± 5.1 bc	7.8 ± 11.3 b	0.9 ± 1.6 c	17.1 ± 13.6 a
Fourth Week				
Egg	2.0 ± 2.3 b	3.7 ± 7.1 b	0.8 ± 1.3 b	8.9 ± 9.0 a
Nymph	9.9 ± 8.1 b	16.4 ± 18.0 b	1.3 ± 2.1 c	57.2 ± 36.9 a
Pupa	10.3 ± 13.5 bc	18.1 ± 12.9 b	2.7 ± 2.9 c	36.6 ± 33.0 a

* Means (n = 60) in the same row followed by the same letter are not significantly different (P = 0.05, LSD).

The efficacy of the 3 insecticides also was associated with changes in the distribution of both whitefly species. The more effective insecticides resulted in greater changes in distribution. In test II, for instance, bifenthrin and endosulfan reduced the GHWF aggregation on treated plants shortly after their application, but the eventual reduction in population and aggregation were not as large as with aldicarb. Meanwhile aldicarb did not reduce whitefly population density and did not significantly affect the aggregation until the third week, but it produced the lowest whitefly densities and smallest b values at the end of the test.

In summary, the application of 3 insecticides on poinsettia caused substantial mortality of all immatures for both whitefly species, and the application of aldicarb resulted in higher mortality (greater than 90%) in test I, and a relatively high mortality in the test II. Analyses of the distribution patterns based on Taylor's power law method indicated that all immatures of

Table 3. Distributions of immature stages of greenhouse whitefly on poinsettia before and after multiple insecticide applications as measured by Taylor's power law method in Test I.

	Within-plant distribution				Between-plant distribution			
	Pretreatment		Posttreatment		Pretreatment		Posttreatment	
	b	r^2	b	r^2	b	r^2	b	r^2
Bifenthrin (Talstar)								
Egg	1.78*	0.86	1.23	0.79	2.12*	0.93	1.37	0.81
Nymph	1.88*	0.95	1.31	0.67	3.01*	0.89	1.30	0.78
Pupa	–		–		1.99*	0.87	1.19	0.86
Endosulfan (Thiodan)								
Egg	1.98*	0.91	1.34	0.78	2.82*	0.79	1.12	0.76
Nymph	2.45*	0.74	1.29	0.81	1.56*	0.75	1.21	0.79
Pupa	–		–		1.49*	0.84	1.17	0.69
Aldicarb (Temik)								
Egg	2.03*	0.90	1.44	0.77	1.67*	0.83	1.33	0.84
Nymph	1.79*	0.83	1.03	0.78	2.76*	0.81	1.16	0.76
Pupa	–		–		1.65*	0.79	1.08	0.86
Water (check)								
Egg	2.12*	0.92	1.88*	0.87	1.79*	0.89	1.86*	0.91
Nymph	2.45*	0.85	1.97*	0.91	2.98*	0.90	2.09*	0.79
Pupa	1.67*	0.93	1.57*	0.87	3.08*	0.93	2.87*	0.87

* The b values followed by a "*" were significantly larger than 1 (Student's *t*-test). Data were collected seven weeks after the initial application.

both whitefly species on untreated plants were highly aggregated initially, and were less aggregated on insecticide treated plants than on untreated and water-treated plants. The population dynamics and distributions of the two whitefly species were similar following insecticide applications (in Test I).

Table 4. Distributions of immature stages of sweetpotato whitefly on poinsettia before and after multiple insecticide applications as measured by Taylor's power law method in Test I.

	Within-plant distribution				Between-plant distribution			
	Pretreatment		Posttreatment		Pretreatment		Posttreatment	
	b	r^2	b	r^2	b	r^2	b	r^2
Bifenthrin (Talstar)								
Egg	1.59*	0.76	1.41	0.81	2.51*	0.91	1.28	0.78
Nymph	1.53*	0.88	1.18	0.70	1.98*	0.88	1.40	0.84
Pupa	–		–		2.32*	0.82	1.25	0.87
Endosulfan (Thiodan)								
Egg	1.87*	0.94	1.23	0.83	3.01*	0.93	1.14	0.79
Nymph	2.03*	0.82	1.31	0.77	1.74*	0.79	1.16	0.89
Pupa	–		–		1.96*	0.82	1.26	0.86
Aldicarb (Temik)								
Egg	2.12*	0.94	1.27	0.81	2.07*	0.84	1.18	0.67
Nymph	1.68*	0.82	1.11	0.69	2.07*	0.84	1.18	0.67
Pupa	–		–		1.98*	0.93	1.36	0.85
Water (check)								
Egg	1.65*	0.89	1.69*	0.89	2.09*	0.90	2.87*	0.90
Nymph	2.06*	0.93	1.77*	0.87	1.79*	0.89	2.15*	0.92
Pupa	1.69*	0.77	1.58*	0.86	1.74*	0.91	1.99*	0.83

* The b values followed by a "*" were significantly larger than 1 (Student's *t*-test). Data were collected seven weeks after the initial application.

Table 5. Within-plant distributions of immature stages of greenhouse whitefly on poinsettia following one insecticide application as measured using Taylor's power law method.

	Pre-treatment		Post-treatment							
			1 week		2 week		3 week		4 week	
Stage	b	r^2	b	r^2	b	r^2	b	r^2	b	r^2
Bifenthrin (Talstar)										
Egg	1.92*	0.81	1.76*	0.91	1.42	0.75	1.22	0.74	1.31	0.85
Nymph	2.32*	0.91	1.87*	0.83	1.32	0.76	1.61*	0.65	1.13	0.67
Endosulfan (Thiodan)										
Egg	3.41*	0.96	2.18*	0.71	1.29	0.90	1.27	0.78	1.32	0.65
Nymph	2.87*	0.88	1.85*	0.79	1.72*	0.68	1.59*	0.81	1.54*	0.66
Aldicarb (Temik)										
Egg	3.09*	0.80	2.18*	0.92	1.86*	0.66	1.29	0.87	1.26	0.86
Nymph	2.11*	0.82	2.02*	0.84	1.33	0.76	1.15	0.76	1.11	0.78
Water (check)										
Egg	2.15*	0.90	1.89*	0.92	1.69*	0.87	2.57*	0.89	1.92*	0.92
Nymph	4.12*	0.82	2.12*	0.90	3.17*	0.74	2.87*	0.91	1.88*	0.78

* The b values followed by a "*" were significantly larger than 1 (Student's t-test).

Table 6. Between-plant distributions of immature stages of greenhouse whitefly on poinsettia following one insecticide application as measured using Taylor's power law method.

	Pre-treatment		Post-treatment							
			1 week		2 week		3 week		4 week	
Stage	b	r^2	b	r^2	b	r^2	b	r^2	b	r^2
Bifenthrin (Talstar)										
Egg	2.35*	0.84	1.68*	0.86	1.57	0.82	1.36	0.77	1.17	0.79
Nymph	2.09*	0.88	1.72*	0.81	1.44	0.73	1.51	0.71	1.32	0.91
Pupa	1.87*	0.94	1.91*	0.76	1.61*	0.88	1.29	0.86	1.19	0.65
Endosulfan (Thiodan)										
Egg	2.73*	0.93	2.13*	0.89	1.38	0.70	1.24	0.83	1.15	0.72
Nymph	2.10*	0.96	2.71*	0.91	1.67*	0.71	1.43	0.89	1.32	0.89
Pupa	1.84*	0.91	1.68*	0.90	1.76*	0.87	1.39	0.66	1.21	0.83
Aldicarb (Temik)										
Egg	2.01*	0.86	1.89*	0.82	1.55*	0.91	1.56	0.72	1.09	0.80
Nymph	2.27*	0.88	2.15*	0.87	1.41	0.79	1.32	0.91	1.18	0.65
Pupa	1.67*	0.85	1.77*	0.81	1.64*	0.83	1.21	0.81	1.23	0.71
Water (check)										
Egg	3.82*	0.87	2.10*	0.89	2.75*	0.86	1.62*	0.79	1.78*	0.87
Nymph	2.19*	0.90	1.56*	0.91	1.81*	0.91	1.53*	0.82	1.56*	0.81
Pupa	1.89*	0.94	2.85*	0.76	1.89*	0.85	1.72*	0.84	1.73*	0.78

* The b values followed by a "*" were significantly larger than 1 (Student's t-test).

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