Regional and Temporal Variation in Susceptibility to λ-Cyhalothrin in Onion Thrips, *Thrips tabaci* (Thysanoptera: Thripidae), in Onion Fields in New York

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J. Econ. Entomol. 96(6): 1843–1848 (2003)

ABSTRACT Populations of onion thrips, *Thrips tabaci* Lindeman, from commercial onion fields in New York were evaluated for their susceptibility to the commonly used pyrethroid, λ-cyhalothrin (Warrior T), using a novel system called the Thrips Insecticide Bioassay System (TIBS). To use TIBS, thrips are collected directly from the plant into an insecticide-treated 0.5-ml microcentrifuge tube that has a flexible plastic cap with a small well into which 0.08 ml of a 10% sugar-water solution with food colorant is deposited. The solution is sealed into the well with a small piece of stretched parafilm through which the thrips can feed on the solution. Thrips mortality is assessed after 24 h with the help of a dissecting stereoscope. In 2001, onion thrips populations were collected from 16 different sites and resistance ratios were >1,000 in five populations. Percent mortality at 100 ppm, a recommended field rate, varied from 9 to 100%, indicating high levels of variation in susceptibility. Particular instances of resistance appeared to be the result of practices within an individual field rather than a regional phenomenon. In 2002, we also observed large differences in onion thrips susceptibility, not only between individual fields but also between thrips collected in a single field at mid season and late season, again suggesting that insecticide-use practices within an individual field caused differences in susceptibility. Additional tests indicated no differences in susceptibility between adult and larval onion thrips populations and only relatively minor differences between populations collected from different parts of the same field. Using TIBS, several populations of onion thrips with different susceptibilities to λ-cyhalothrin were identified and then subjected to λ-cyhalothrin-treated onion plants. There was a highly significant positive relationship between percent mortality of thrips from TIBS and percent mortality from the treated onion plants, indicating that results from TIBS could be used to predict spray performance. These data suggest that use of TIBS for evaluating susceptibility to particular insecticides could be instrumental for developing a resistance management strategy for onion thrips.

KEY WORDS *Thrips tabaci*, onion thrips, pyrethroid, resistance, onion

ONION THRIPS, *Thrips tabaci* Lindeman, is a key insect pest of onion and other *Allium* species in many parts of the world (Lewis 1997), including New York (Hoffmann et al. 1996), where during many years it is considered the most damaging pest. Onion thrips is the only thrips pest of onion in New York, unlike regions in Georgia and Texas where western flower thrips, *Frankliniella occidemtalis* (Pergande), also may attack onion. Onion thrips feed on leaves and can kill young plants, but most often their injury results in reduced onion yield and bulb size. If onion thrips are not controlled, onion yield reductions can reach levels from 34% to nearly 50% (Fournier et al. 1995, Stivers 1999). In New York, 100% of the onion fields may become infested with onion thrips and growers are encouraged to sample fields and spray only when the action threshold of three thrips per green leaf is reached (Reiners et al. 2003). However, the current control strategy for onion thrips in New York is the frequent use of insecticides and growers may apply treatments weekly, resulting in upwards of 12 applications per crop (Stivers 1999). Such frequent spraying may indicate lack of confidence in the threshold or lack of efficacy of available insecticides at the currently recommended action threshold. Protection of the onion crop from onion thrips is intensive, primarily because of the crop's high value. In 2002 in New York, onions were planted on 5,000 ha and grossed $28 million (NYASS 2003).

Changes in field performance of some insecticides against onion thrips in the field have been reported in Colorado (Cranshaw 1989), Michigan (Henry et al. 1989, Davis et al. 1995), and New York (Gangloff 1999). However, field performance may be affected by environmental factors and poor coverage of the crop, therefore, additional assessments are needed, usually involving laboratory assays. A common approach for conducting insecticide-resistance assays for thrips is to

0022-0493/03/1843–1848$04.00/0

culture the insect populations until sufficient numbers are available for testing; however, this approach presents several problems (Rueda and Shelton 2003). Thrips are difficult to contain in cages because of their small size (<2 mm) and they can contaminate and be contaminated by other colonies within the greenhouse and laboratory. Additionally, plant material used to cultivate thrips can already be contaminated. Finally, because resistance may change over time, there should be concern about collecting a field sample of insects, rearing them for multiple generations to obtain sufficient numbers of test insects, and then conducting a bioassay on later generations. Because the level of insecticide resistance in onion thrips populations may decline in the absence of selection in the laboratory (A.M.S., unpublished data), levels of susceptibility in later generations are not likely to reflect those in the field populations. A common bioassay procedure for plant feeding insects is a leaf-dip assay, and this has been used in at least one study for onion thrips (Gangloff 1999). This assay requires collecting and rearing sufficient numbers of thrips and then conducting the bioassay. For the reasons mentioned previously, this approach is not likely to provide the grower with the reliable and timely knowledge needed to make an informed decision on using an insecticide. To overcome these concerns, we developed and field-tested a procedure for assaying susceptibility to some insecticides commonly used against onion thrips. This system is the Thrips Insecticide Bioassay System (TIBS), and was evaluated in commercial onion fields in Honduras and Nicaragua (Rueda and Shelton 2003).

The objectives of the current study were to use TIBS to evaluate the susceptibility of onion thrips populations in commercial fields in New York to the most commonly used insecticide, λ-cyhalothrin (Warrior T), determine whether susceptibility changed over time, and determine whether the results from TIBS could be used to predict the level of control achieved by foliar applications of λ-cyhalothrin.

Materials and Methods

Thrips Insecticide Bioassay System. For the collections in 2001 and 2002, we used TIBS, a method developed by Rueda and Shelton (2003). This system allows thrips to be collected directly from onion plants into a plastic 0.5-ml microcentrifuge tube (Laboratory Product Sales, Rochester, NY) previously treated with an insecticide. Thrips mortality is assessed after 24 h with the help of a dissecting stereoscope. The tube has a flexible plastic cap and on the inside of the cap is a small well into which 0.08 ml of a 10% sugar-water solution with food colorant is deposited. The solution is sealed into the well with a small piece of stretched parafilm through which the thrips can feed on the solution. The 10% sugar solution is used as the food source for thrips and it greatly prolongs thrips survival (Rueda 2000), whereas the food colorant is added to the solution to facilitate determining whether the parafilm membrane became broken and the solution contaminated the tube when the assay was read. The flexible cap only serves as a container for the solution and to seal the tube. The tube, but not the cap, is treated with an insecticide by filling the tube to its top with 0.75 ml of the insecticide solution (although the microcentrifuge tube is listed as a 0.50-ml tube, it can hold 0.75 ml if filled to the top). After 4 h, the insecticide is poured out and the tube is allowed to dry overnight. A small opening at the small end of the tube is then made using a heated sewing pin. It is through this opening that thrips are collected into the tube using a suction device. Once the thrips are collected, this opening is sealed with a small piece of parafilm.

In the experiments reported herein, we used the basic TIBS (Rueda and Shelton 2003) with the following modifications. Yellow dye (FD&C#5) was used as the food coloring. Rather than collecting thrips from the plants in the field, the plants were removed from the field and placed into a container for transport back to the laboratory where the thrips were aspirated into the tubes using a standard electric vacuum pump. This change allowed samples of onion plants to be collected quickly from several fields (or sites within a single field) and then the more time consuming steps in the assay could be conducted in the comfort of the laboratory. In some situations, the thrips-infested onions could also be stored in a cooler until needed. For all trials, we used the pyrethroid insecticide Warrior T, a commercial formulation of λ-cyhalothrin (Syngenta Crop Protection, Inc., Greensboro, NC), diluted with water. Bond spreader/sticker (Loveland Industry, Loveland, CO) was added at 2% to all test concentrations and to the water control. For all trials, except as noted below, we used second instars. Control mortality in our tests was very low (<2%).

2001 Tests. During the 2001 growing season, thrips populations were collected from 15 commercial fields encompassing the major onion growing areas of New York, and from an untreated planting of onions at the New York State Agricultural Experiment Station (NYSAES) in Geneva, NY (=standard colony designated as ST). Unlike the thrips populations collected from commercial onion fields grown continuously in onions for many years, the standard colony was collected from a new planting of onions and was suspected to be susceptible to insecticides. Collections were made during the middle part of the growing season (July through mid August) by removing the second (last) larval stage from the plants at >10 sites in the field to obtain an overall field assessment. Because of the aggregated nature of thrips on plants, we collected no more than 10 thrips on any one plant and at least 10 plants per site to ensure a reasonable estimate of the susceptibility of the overall field population to the insecticide.

In addition to the survey of 16 fields, two other experiments were performed. In two fields, separate collections of adult and second instars were made to test whether there were differences in susceptibility between these stages. In another field, collections of second instars were made at two different corners of a 10-ha onion field to determine whether susceptibil-

Table 1. Survey of susceptibility of *T. tabaci* larvae to λ-cyhalothrin in New York in 2001

Population[a]	*N*	Slope (SE)	LC_{50} (ppm)	95% CL	χ^2 (df)[b]	RR[c]	% Mortality (SE)[d]
ST	400	1.40 (0.15)	0.22	0.05–0.45	7.60 (2)	1.0	100 (0.00)a
EL-1	696	–	>1000[e]	–	–	>4545	9.0 (3.7)f
EL-2	400	1.41 (0.14)	486.94	203.37–1300	3.15 (2)*	2213.4	19.0 (3.7)ef
EL-4[f]	300	0.73 (0.21)	0.16	0.01–0.83	1.31 (3)*	0.7	98.3 (1.7)a
GV-1	383	2.38 (0.42)	1.09	–	6.93 (2)	5.0	94.0 (2.9)a
GV-5	850	0.54 (0.05)	116.79	50.66–357.33	5.97 (4)*	530.9	55.6 (8.7)bed
OR-1	382	0.98 (0.12)	25.87	6.61–74.49	3.00 (2)*	117.6	69.8 (9.7)abc
OR-3	403	0.73 (0.07)	10.62	2.22–132.57	6.65 (5)*	48.3	74.7 (10.5)abc
OR-4	600	0.86 (0.07)	278.88	130.19–673.45	12.4 (4)	1267.6	23.0 (7.5)ef
OS-1	540	0.93 (0.09)	66.59	26.53–161.37	14.5 (4)	302.7	61.0 (8.4)bcd
OS-2	405	1.11 (0.13)	9.54	6.78–12.68	1.27 (2)*	43.4	87.0 (4.6)ab
PO-1	430	0.94 (0.13)	245.05	168.04–358.00	0.46 (2)*	1113.9	37.0 (6.8)def
PO-3	500	1.21 (0.10)	84.53	50.41–136.73	4.16 (3)*	384.2	51.0 (5.3)cde
PO-4	593	1.60 (0.19)	197.49	43.47–374.58	6.62 (3)*	897.7	18.1 (2.8)f
WA-1	722	1.87 (0.23)	194.44	125.34–267.22	6.65 (5)*	883.8	29.0 (4.6)def
WA-2	408	1.13 (0.10)	458.21	343.53–616.52	1.96 (2)*	2082.8	20.0 (7.9)ef

[a] Population collected from: ST, standard population from NYSAES; EL, Elba; GV, Geneva; OR, Orange Co; OS, Oswego Co.; PO, Potter; WA, Wayne Co.; numbers refer to specific fields within a region. Field numbers within a region are not necessarily consecutive, but conform only to our reporting system. All fields in which thrips were collected during 2001 are reported.

[b] The χ^2 (df) values followed by "*" indicate good fit of the data to the probit model ($P > 0.05$).

[c] RR resistance ratio = LC_{50} of field colony/LC_{50} of ST.

[d] Percent mortality at a field concentration of 100 ppm. Values within a column followed by same letters are not significantly different (Tukey-Kramer; $P > 0.05$).

[e] 31% mortality at 1000 ppm.

[f] EL-4: onion thrips collected from organically grown onions with no pyrethroid use.

ity varied within a single field. The collection sites in this field were >400 m apart.

For tests with TIBS, we selected six to seven doses that we assumed, based on preliminary studies, would encompass a mortality range of ≈10–90%, plus an untreated control. We used five replicates of each dose with 20 thrips per replicate (tube). A dose of 100 ppm was always included because this is equivalent to a recommended field rate.

The POLO program was used for probit analysis of dose–response data (Russell et al. 1977, LeOra Software 1997). Differences in susceptibility were considered significant when the 95% CL of LC_{50} values did not overlap. The resistance ratio (RR) was calculated by dividing the LC_{50} of a field population by the corresponding LC_{50} of the standard colony (ST). Percent mortality data were transformed to arcsine square-root values before being subjected to analysis of variance (ANOVA) using the SuperANOVA program and means were compared using the Tukey-Kramer test at $P < 0.05$ (Gangon et al. 1991).

2002 Tests. In 2002, populations were collected from nine different sites during two different time periods, mid season (July through mid August) and late season (mid August through October). Collections and assays were done as in 2001. The reason for the two collections was to determine whether there were changes in thrips susceptibility to λ-cyhalothrin over time. For each collection, we only tested the populations against a single dose of λ-cyhalothrin, a recommended field dose of 100 ppm. This decision was based on evidence collected in 2001 that fields in which it was difficult to control thrips with λ-cyhalothrin had LC_{50} values >100 ppm. Percent mortality data were transformed to arcsine square-root values before being subjected to ANOVA using the SuperANOVA program and means were compared using the Tukey-Kramer test at $P < 0.05$ (Gangon et al. 1991).

Greenhouse Trials. From our collections of onion thrips in 2002, we selected four populations that varied significantly in their susceptibility to λ-cyhalothrin based on using TIBS. Onion sets, 'Stuttgarter', were planted in pots (7.6 cm diameter) then placed in cages that consisted of a Plexiglas tube (23 cm high × 13 cm diameter). The tube was capped at one end with a solid plug, whereas the other end had thrips-proof screening that allowed proper ventilation. When plants had 5–6 leaves, the cage was removed and the plants were treated with a recommended rate of λ-cyhalothrin (100 ppm) using a CO_2 backpack sprayer with a boom having a single overhead nozzle and two side nozzles (TXVS-8 hollow cone tips, R & D Sprayers, Opelousas, LA). Immediately after the spray, the cage was replaced and the insecticide was allowed to dry for 24 h. Twenty second-instar onion thrips were then introduced into each cage, allowed to feed, and then mortality was assessed after 5 d. There were eight cages (replicates) for each of the four populations of onion thrips used. The relationship between percent mortality using TIBS at a dose of 100 ppm and the percent mortality based on spraying the plants at 100 ppm was described using linear regression analysis, PROC REG (SAS Institute 1999). Mortality was corrected using Abbott's formula (Abbott 1925) for each colony.

Results and Discussion

2001 Tests. There were large differences in susceptibility between onion thrips populations, with RR values >1,000 in five populations (Table 1). Additionally, the percent mortality at the 100-ppm field rate

Table 2. Susceptibility of *T. tabaci* larvae and adults to λ-cyhalothrin in New York in 2001

Population[a]	Stage	*N*	Slope (SE)	LC_{50} (ppm)	95% CL	χ^2 (df)[b]	% Mortality (SE)[c]
ST	adult	600	3.00 (0.24)	0.17	0.07–0.29	20.2 (3)	100 (0.0)a
ST	larva	400	1.40 (0.15)	0.22	0.05–0.45	7.60 (2)	100 (0.0)a
PO	adult	411	1.09 (0.13)	176.00	129.94–237.04	0.39 (2)*	39.0 (6.2)b
PO	larva	430	0.94 (0.13)	245.05	168.04–358.00	0.46 (2)*	37.0 (6.8)b

[a] Population collected from: ST, standard colony from NYSAES; PO-1, Potter, NY.
[b] The χ^2 (df) values followed by "*" indicate good fit of the data of the probit model ($P < 0.05$).
[c] Percent mortality at a field concentration of 100 ppm. Values within a column followed by same letters are not significantly different (Tukey-Kramer; $P > 0.05$).

varied from 9 to 100%, with significant differences between several populations. The standard colony, collected from unsprayed onions at NYSAES, had a similar LC_{50} value to a population collected from an organic farm near Elba, NY (EL-4), suggesting that our standard population was representative of a pyrethroid-unchallenged population and, therefore, was a reasonable standard. Of the 16 populations of larvae examined, eight had LC_{50} values greater than the field dose of 100 ppm, indicating a potential for poor field performance. In Table 1, the fields are grouped by region (e.g., we surveyed three fields in Orange County denoted by OR 1–3), and there was no difference in mean percent mortality at 100 ppm of onion thrips populations among regions ($F = 0.93$; df = 5, 9; $P = 0.5053$), indicating that resistance to λ-cyhalothrin was not region-specific. There was considerable variation within each region, with some fields having populations of onion thrips with LC_{50} values much higher or lower than the field rate of 100 ppm. This suggests that individual grower practices in a field probably dictated the development of resistance. Unfortunately, we were unable to obtain reliable spray records to explore this hypothesis further.

A comparison of susceptibility of larval and adult populations is presented in Table 2. The overlap in the 95% CL of the LC_{50} values and the lack of significant differences in percent mortality at 100 ppm indicate there was no significant difference in susceptibility between the two stages in either field, although the populations in each field differed. In the only other previous report using TIBS (Rueda and Shelton 2003), there were some relatively minor differences in susceptibility between the adult and larval stages, but the differences varied by insecticide class and λ-cyhalothrin was not used in that trial. Because the larval stage is usually more abundant and easier to collect and because we did not see significant differences between the stages when using λ-cyhalothrin, we believe this suggests our continued use of the larval stage for TIBS assays with λ-cyhalothrin is justified.

In the field in which two collections were made in different parts of the field and analyzed separately, there was a significant difference in susceptibility at 100 ppm (Table 3). However, this amounted to a 3.3-fold difference in LC_{50} values, a relatively small amount compared with the between-field variation seen in Table 1. Despite this small difference, the data do suggest that multiple sites within an individual onion field should be sampled to adequately assess the susceptibility of an onion thrips population to an insecticide. More extensive tests should be performed to develop a more thorough understanding of the spatial and temporal development of resistance within an individual field, and TIBS could be an important tool in such studies.

2002 Tests. As in 2001, we observed large differences in susceptibility between fields (Table 4). An identical range in variation in mortality (9- 100%) at 100 ppm was observed in 2001 and 2002. In 2002, variation was observed not only between fields but also within a field at different collection times. For the first collection (mid season), there was considerable variation in percent control, with five populations having >50% mortality at 100 ppm. For the late-season collection, there was again considerable variation in percent control, with four of the nine populations having >50% mortality at 100 ppm. However, only one of the populations that was susceptible (>50% mortality at 100 ppm) in the first collection was susceptible in the second collection (i.e., OR-4). We suspect that patterns in insecticide use are largely responsible for these changes, but the growers' records provided to us were unreliable so this hypothesis could not be examined. An alternative hypothesis is that changes in the population's susceptibility to λ-cyhalothrin could be partially attributed to immigration of onion thrips into fields from nearby onion fields, as well as from

Table 3. Within-field comparison of the susceptibility of *T. tabaci* larvae to λ-cyhalothrin in New York in 2001

Population[a]	N	Slope (SE)	LC_{50} (ppm)	95% CL	χ^2 (df)[b]	% Mortality (SE)[c]
PO-3	500	1.21 (0.10)	84.53	50.41–136.73	4.16 (3)*	51.0 (5.3)a
PO-4	593	1.60 (0.19)	197.49	43.47–374.58	6.62 (3)*	18.1 (2.8)b

[a] Population collected from: PO, Potter; numbers refer to a specific area in the field.
[b] The χ^2 (df) values followed by "*" indicate good fit of the data to the probit model ($P > 0.05$).
[c] Values within a column followed by same letters are not significantly different (Tukey-Kramer; $P > 0.05$).

Table 4. Percent mortality of *T. tabaci* larvae to λ-cyhalothrin (rate of 100 ppm) at two periods during the growing season in New York in 2002. Mid season was July through mid August and late season was mid August through October ($N = 100$)

Population[a]	%Mortality (SE)[b]	
	Mid season	Late season
EL-3	11.2 (4.3)e	77.0 (6.8)ab
EL-6	70.0 (6.1)ab	17.0 (3.0)e
OR-2	100 (0.0)a	30.0 (3.5)de
OR-4	81.0 (5.3)ab	87.0 (5.8)ab
OS-1	15.0 (4.2)e	76.0 (10.2)ab
PO-5	9.0 ((3.3)e	18.0 (4.1)e
PR-1	63.0 (10.2)bc	36.0 (5.8)cde
WA-3	13.0 (3.7)e	59.0 (12.2)bcd
WA-4	53.7 (11.4)bcd	16.0 (2.9)e

[a] Population collected from: EL, Elba; OR, Orange Co.; OS, Oswego Co.; PO, Potter; PR, Prattsburg; WA, Wayne Co.; numbers refer to specific fields within a region. Field numbers within a region are not necessarily consecutive, but conform only to our reporting system. All fields in which thrips were collected during 2002 are reported.

[b] Percent mortality at a field concentration of 100 ppm. Values within a column followed by the same letters are not significantly different (Tukey-Kramer; $P < 0.05$).

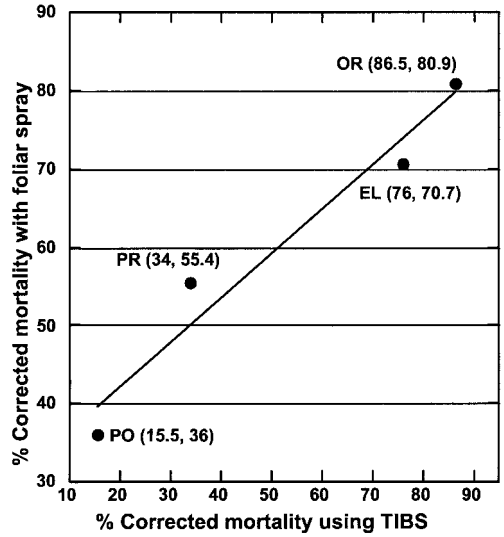

Fig. 1. Relationship between percent mortality of onion thrips using TIBS (100 ppm of λ -cyhalothrin) and percent mortality after thrips were subjected to onion plants sprayed with λ -cyhalothrin at a field rate of 100 ppm. There was a significant positive correlation between these data ($F = 71.33$; df = 1, 2; $P = 0.0137$) and the linear regression equation is $y = 30.77 + 0.5656\ x$; $r^2 = 0.95$.

small grain and forage crops. Onion thrips have been reported to colonize cabbage fields after migrating from adjacent plantings of small grains and forages (Shelton and North 1986).

Greenhouse Trials. The check mortality was 3–4% in TIBS tests and 8–11% in the foliar spray tests. There was a significant positive ($r^2 = 0.95$) correlation between percent mortality at 100 ppm using TIBS and the percent mortality achieved when onion plants were sprayed with the field rate of λ-cyhalothrin (100 ppm) (Fig. 1). These results suggest that a field of onions could be sampled using TIBS and then determination could be made as to whether acceptable control would be achieved by spraying the field (see Roush and Tabashnik 1990). By using plants sprayed in the greenhouse to make the comparison, we were able to eliminate the variability in percent control that may have been encountered in the field as a result of different environmental or plant (e.g., size or variety) factors.

TIBS proved to be an effective and rapid method for assessing differences in susceptibility in populations of onion thrips. In the majority of cases, there were nonsignificant χ^2 values (Tables 1–3), which indicates a good fit of the data to the probit model. It is not surprising that some data do not fit the probit model because of biological and technical factors. Populations taken directly from the field may have a high degree of variability in their genetic structure that will influence their response to a set of doses and analysis by the probit model. From a technical standpoint, in all tests conducted in 2001 we used the same set of doses and this may not have provided the best dose range for an individual population. However, in 2001 and 2002 we included a field concentration of 100 ppm, and differences between populations at this dose were similar to differences determined by the overlap, or lack of overlap, of the 95% CL of the LC_{50} values.

Based on these results, it is apparent that the continued heavy reliance on λ-cyhalothrin, and most likely other pyrethroids, will be problematic in New York onion fields. Other control options, such as cultural practices, should be encouraged but there are no thrips-resistant onion cultivars or effective biological control measures that can be used on a reliable basis, other than the conservation of existing biological control through the use of minimal insecticide practices. Perhaps the advent of more selective insecticides and fungicides may help conserve beneficial arthropods and fungi because λ-cyhalothrin has been shown to dramatically reduce populations of natural enemies and reduce the overall predation rate in some cropping systems (Musser and Shelton 2003).

Other classes of insecticides are currently registered for onion thrips control in onions, and we are presently evaluating the susceptibility of onion thrips in commercial onion fields to methomyl, Lannate LV (a carbamate), and methyl-parathion, Penncap-M (an organophosphate), using TIBS. It is important for growers to have several classes of insecticides with different modes of action to use against thrips so that they have a rational insecticide resistance management plan. However, pyrethroids will continue to be promoted because of their effectiveness in some areas and their relative low cost. The information we have for λ-cyhalothrin indicates that high levels of resistance have occurred in some populations and this appears to be a result of practices in individual fields within all major onion growing regions in New York. The changes in the susceptibility of onion thrips to λ-cyhalothrin within an individual field from mid sea-

son to late season, a period of <40 d, is cause for concern (Table 4). For fields in which we had reliable grower records, there was an indication that growers who did not use λ-cyhalothrin early in the season had populations of thrips that were susceptible. However, susceptibility declined later in the season after they used λ-cyhalothrin. The previous report using TIBS (Rueda and Shelton 2003) indicated similar trends, although further experiments are needed.

Our present lack of understanding on the ecology of onion thrips in onion fields (e.g., overwintering sites and movement patterns into, out of, and within onion fields) hampers our overall ability to manage resistance, although the data presented herein and the use of TIBS can provide a framework for developing a resistance management program. The rapid changes in onion thrips susceptibility to λ-cyhalothrin within a single growing season suggest the importance of regular monitoring for susceptibility to a particular insecticide or insecticide class. TIBS can be used for a timely evaluation of thrips populations so growers can select the appropriate class of insecticide to use. Further development of TIBS for other insecticide classes, and training of personnel in the private and public sector to use TIBS, should lead to a more sustainable resistance management program for onion thrips.

Acknowledgments

We thank Mary Lou Hessney, Katie Straight, and Holly Townley for technical assistance and F. Musser and S. Bates for a review of an earlier draft of the manuscript. The statistical advice of Jan Nyrop is also gratefully acknowledged. This research was supported in part by the New York State Onion Growers Research and Development Program.

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Received for publication 10 March 2003; accepted 19 July 2003.