Management of Onion Thrips (Thysanoptera: Thripidae) on Cabbage by Using Plant Resistance and Insecticides

A. M. SHELTON, W. T. WILSEY, AND M. A. SCHMAEDICK

Department of Entomology, Cornell University, New York State Agricultural Experiment Station, Geneva, NY 14456

J. Econ. Entomol. 91(1): 329–333 (1998)

ABSTRACT Control of *Thrips tabaci* Lindeman was evaluated using insecticides and host plant resistance. In 7 insecticide trials conducted from 1987 to 1996, using a total of 17 different insecticides, insecticide applications reduced thrips damage in only 2 of the trials. In 8 plant resistance trials conducted from 1985 to 1993 using >300 varieties or inbreds, some plant lines significantly reduced thrips injury in each trial. A 1996 trial testing variety and insecticide together found that both factors significantly affected thrips damage, although their interaction was not significant. Insecticide treatments in the 1996 experiment were unnecessary for the more tolerant varieties but helped reduce damage to acceptable levels in many of the moderately susceptible cultivars. In the highly susceptible varieties, we concluded that even the frequent application of insecticides was not sufficient to keep thrips damage at acceptable levels. Planting tolerant varieties, however, is a reliable way to keep thrips damage at low levels, even without insecticides.

KEY WORDS *Thrips tabaci*, cabbage, host plant resistance, insecticide

IN THE LAST 2 decades the onion thrips, *Thrips tabaci* Lindeman, has become a key pest of cabbages in New York and other regions of the United States. Thrips feed on the leaves and cause a bronze color and rough texture on white cabbage and white bumps known as edema on red cabbage. When injury is severe on either cabbage type, damage can be observed on the leaves of the outer third of the head (Shelton et al. 1983). Several approaches have been taken to manage *T. tabaci* on cabbage. The ecology and movement of *T. tabaci* from early-season hosts into cabbage has been studied to help identify the time of infestation and agronomic and environmental factors that may increase the risk of colonization by *T. tabaci* in certain areas (North and Shelton 1986a, b; Shelton and North 1986). Prevention of damage has focused on host plant resistance, use of insecticides, and the use of natural enemies. Varietal resistance for processing, fresh market and storage cabbage has been evaluated (Shelton et al. 1983, Shelton et al. 1988, Hoy and Kretchman 1991), the mechanism and inheritance of plant resistance has been studied (Stoner and Shelton 1988 a–c; Stoner et al. 1989), and the use of tolerant varieties has been promoted through the Cornell cabbage integrated pest management program. Seed companies have increased their efforts to breed for *T. tabaci* resistance in their commercial releases and there is a definite trend for more tolerant varieties to be released. However, when selecting a variety, a grower considers other characteristics besides thrips susceptibility (e.g., head size, color, dry matter content, date of maturity, storagability). Growers may select more thrips-susceptible varieties if these other characteristics are judged more important and hope that supplemental insecticide treatments can reduce thrips injury to acceptable levels.

In this study we report on a series of trials conducted from 1985 to 1996 to evaluate the effectiveness of insecticides and host plant resistance, individually and in combination, for management of *T. tabaci* on cabbage.

Materials and Methods

All experiments except 1 were conducted at the vegetable farm of the New York State Agricultural Experiment Station, Geneva, NY. To increase thrips populations in field plots, oats were planted upwind from the cabbage (North and Shelton 1986b). One of the 1988 experiments was conducted in a grower's field near Geneva.

Cabbage Varietal Evaluations. The number of varieties and inbreds tested and their commerical source are listed in Table 1. In each year, trials were conducted by transplanting the cabbage into blocks consisting of at least 10 plants of a single type per row, replicated 3–4 times in a randomized complete block design. Each row was on 0.9-m centers with 41-cm plant spacing. Plants were treated as needed with a formulation of *Bacillus thuringiensis* Berliner to suppress lepidopterous populations. As each variety or inbred became mature, 2–5 plants per plot, free from disease and other damage, were evaluated for thrips injury by splitting the head along the core axis and peeling back each of the outer 10 leaves of

Table 1. Number of varieties and inbreds, by company and year, tested for resistance to *T. tabaci*

Company	Varieties by year								
	1985	1987	1988	1989	1990	1991	1992	1993	Total
Asgrow					3				3
Bejo				10	8	5	5	3	31
Ferry Morse			4						4
Harris Moran				17			12		29
Nickerson Zwann		20	18	12					50
Northrup King				4		1			5
Peto			10	20	6	5	7		48
Reed's	20	36		13	8	7	3		87
Royal Sluis			20	17	10	20	14	9	90
Takii							5		5
Other		1	1	1	1	1	2	5	12
Total	20	57	53	94	36	39	48	17	364

one side. The untransformed mean number of damaged leaves per plant per plot was used for analysis of variance (ANOVA).

Insecticide Evaluations. The insecticides tested and frequency of application are noted in Table 2. Foliar sprays were applied with a CO_2-assisted drop nozzle sprayer that was calibrated to deliver ≈360 liters/ha at 3.15 kg/cm^2 with 3 hollow cone nozzles per row (1 in the center and 1 on each side). A sticker-spreader (Bond; Loveland Industries, Loveland, CO) was added to all treatments at 0.2% (vol: vol) to enhance spray deposition. Soil-incorporated insecticides were applied by using a drench at the base of the plant. Plant damage was assessed as in the varietal evaluations listed above. All trials were analyzed using ANOVA for randomized complete block designs on untransformed data with mean separation by the Fisher (protected) least significant difference (LSD) test (Steel and Torrie 1980).

Variety × Insecticide Evaluations. An experiment was conducted in 1996 to determine the thrips injury sustained by 12 commercial cultivars of cab-

Table 2. Insecticides tested for control of *T. tabaci* on cabbage

Insecticide	Formulation	Rate kg(AI)/ha	Years tested
Acephate	75 S	1.12	1987, 1988, 1992*
Acephate	75 S	0.56	1994, 1995
Cypermethrin	2.5 EC	0.09	1995
Dimethoate	4 EC	0.56	1987, 1988, 1992*, 1994, 1995
Esfenvalerate	1.9 EC	0.03	1987, 1988
Esfenvalerate	0.66 EC	0.06	1992*, 1995
Formetanate hydrochloride	SP	1.55	1996
Imidacloprid	2 F	0.28	1994, 1995, 1996*
Imidacloprid	2 F	0.56	1994
Imidacloprid	1.6 F	0.56	1995, 1996
Insecticidal soap	49%	3.26	1992*
Lambda-cyhalothrin	1 EC	0.02	1992,* 1994
Lambda-cyhalothrin	1 EC	0.015	1994, 1996*
Lambda-cyhalothrin	1 EC	0.01	1992*
Methamidophos	4 EC	1.12	1987, 1988, 1992[a]*
Methomyl	1.8 EC	0.50	1987, 1988
Methyl parathion	2 EC	0.56	1987, 1988
Mevinphos	4 EC	0.56	1987, 1988
Naled	8 EC	0.56	1992[b]*
Oxydemeton methyl	2 EC	0.56	1987, 1988
Oxydemeton methyl	2 EC	0.42	1996
Oxydemeton methyl	2 EC	0.84	1995, 1996
Parathion	8 EC	0.56	1987, 1988
Permethrin	2 EC	1.12	1987, 1988, 1992[c], 1994, 1995, 1996
Zeta-cypermethrin	1.5 EW	0.02	1996*
Zeta-cypermethrin	1.5 EW	0.04	1995, 1996*

Insecticides applied on a 7- to 10-d schedule from head initiation to harvest, except for oxydemeton methyl, which was restricted to 3 applications in 1995 and 1996, imidacloprid 1.6 F, which was applied 5 times in 1996, and imidacloprid 2 F, which had a single soil application. Cabbage varieties used: 'Supergreen', 1987; 'Superdane', 1988, 1992; 'Atria', 1994, 1995*, Years in which the insecticide significantly reduced thrips damage compared to untreated check (Fisher protected LSD, $P = 0.05$). S, SP, soluble powder; EC, emulsifiable concentrate; F, flowable; EW, water emulsifiable.

[a] Applied in a split season program with three sprays of methamidophos followed by five sprays of naled.

[b] Applied in 3 different treatments: (1) alone, (2) in tank mix with permethrin, and (3) applied in a split season program with 3 sprays of methamidophos followed by 5 sprays of naled. Only treatments 1 and 3 significantly reduced damage compared to untreated.

[c] Applied in 2 different treatments: alone and in tank mix with naled.

Table 3. Mean number of layers of cabbage head damaged by *T. tabaci* for 12 cabbage cultivars untreated and treated with lambda-cyhalothrin

Variety	Market	Recommended days to maturity	Layers damaged	
			Untreated	Treated
Masada	Storage/Processing	103	0.02a	0a
Galaxy	Storage	123	0.02ab	0a
Brutus	Storage	103	0.03ab	0a
Amtrack	Storage	112	0.62abc	0.74a
Fresco	Fresh/Processing	75	0.65bc	0.27a
SuperElite	Fresh	85	0.74c	0.04a
Satellite	Processing	83	1.16c	0.59ab
Protector	Storage	90	1.18c	0.21a
Bartolo	Fresh/Processing	113	1.76cd	0.54ab
Supergreen	Fresh	95	2.00cd	0.24a
Hinova	Processing	100	3.15de	2.30b
Rinda	Processing	75	4.84e	2.48b

Means based on 3 replicates of 6 plants. Means within a column followed by the same letter are not significantly different based on Tukey test ($P = 0.05$).

bage when the plants were treated or not treated with an insecticide, thereby evaluating any potential benefit of the insecticide when used on each cultivar. Additionally, because planting date of cabbage may influence the amount of injury (Stoner and Shelton 1988b), 2 planting dates (31 May and 17 June) were incorporated in the design to examine whether the effects of cultivar and insecticide may differ according to date of planting. Varieties are listed in Table 3. Plots were planted in a split-split plot design with 3 replications. Each replication consisted of 2 main plots, 1 treated with lambda-cyhalothrin (Warrior 1 EC [emulsifiable concentrate], Zeneca, Wilmington, DE) at 0.02 kg(AI)/ha and the other untreated. This insecticide was chosen because our experience has shown it to be one of the most effective materials against thrips. The main plots were each divided into 2 split plots, 1 for each planting date. Within each split plot the 12 varieties were planted as split-split plots. Each cultivar was planted in a single 6-m row on 0.9-m centers with 41-cm plant spacing. The split plot for each planting date consisted of 3 sets of double rows with 2 cultivars in each row for the total of 12 cultivars. Double rows of cabbage were separated by plantings of oats to enhance the thrips population. A 1.8-m wide strip of oats along the length of the rows was planted on 31 May with a 2nd strip planted adjacent on 10 July. Foliar sprays were applied with a 2-row tractor mounted boom, having 3 nozzles per row with CO_2 pressurized 80015 flat fan tips delivering 254.3 liters/ha at 2.36 kg/cm^2. Silwet L-77 spreader-sticker (Loveland Industries) was applied at 0.1% (vol·vol) with all applications. Applications of lambda-cyhalothrin were made on 26 June; 16, 25 July; 7, 14, 23, 29 August; 6, 20, 27 September; and 9 and 17 October. All plants were treated as needed with *B. thuringiensis* subsp. *kurstaki* (Javelin WG [wettable granules], 6.4% [AI] Sandoz, Des Plaines, IL) at 1.1 kg formulated material per hectare to control Lepidoptera and ensure readable plants at harvest. Harvest evaluations were made as each cultivar matured. Evaluations for thrips damage were made by randomly selecting 6 mature heads per plot and evaluating the injury as described above. For each plot, the mean layers damaged was determined from the 6 plants sampled per plot. Square roots of the plot means were calculated to reduce heterogeneity of variance, and the transformed data were analyzed in a split-split plot ANOVA model with insecticide as the whole plot treatment, planting date as the split plot, and cabbage variety as the split-split plot.

Results

Varietal and Insecticide Evaluations. From 1985 to 1995 we conducted 8 trials evaluating plant resistance and 7 trials evaluating insecticides (Table 4). Variety had a significant effect on thrips damage in all 8 variety trials, but insecticide treatments provided significant differences, compared with the untreated, in only 2 of the 7 insecticide experiments. In the 7 insecticide experiments, there was no consistency of the significance of the insecticide treatment being related to the level of damage in the control nor to any particular insecticide used (Tables 2 and 4).

Variety × Insecticide Evaluations. As shown in Table 3, thrips damage levels in 1996 differed dramatically on the different cabbage cultivars ($F = 26.03$; df = 11, 88; $P = 0.0001$). The effect of insecticide application, though less dramatic, was also significant ($F = 22.99$; df = 1, 2; $P = 0.0408$). Although the insecticide treatments reduced thrips damage, the damage levels were still high in the highly susceptible cultivars 'Hinova' and 'Rinda', despite the frequent sprays. In general, insecticide treatments were unnecessary for the slightly susceptible cultivars (i.e., 'Masada', 'Galaxy', and 'Brutus') but helped reduce damage to acceptable levels in many of the moderately susceptible cultivars (i.e., 'SuperElite', 'Protector', 'Satellite', 'Supergreen', and 'Bartolo'). In the highly susceptible varieties, even frequent sprays were not sufficient to keep thrips damage at low levels. The main effect of

Table 4. Summary of ANOVA results from 15 field experiments on effects of cabbage varieties or insecticides on thrips damage

Year	Trial	Treatments	Replications	Subsamples[a]	Means untreated	*F* test
1985	Variety	13	3	2	1.8–9.8	S
1987	Variety	50	3	2	0.2–7.2	S
1987	Insecticide	10	4	2	3.4	NS
1988	Variety	63	3	2	1.3–9.5	S
1988	Insecticide	4	2	5	2.3	NS
1988	Insecticide	10	4	2	2.1	NS
1989	Variety	86	3	2	0.2–8.5	S
1990	Variety	13	3	2	2.4–8.4	S
1991	Variety	38	4	2	1.1–6.4	S
1992	Variety	45	4	2	0.4–4.3	S
1992	Insecticide	10	3	2	6.8	S
1993	Variety	17	4	2	1.6–6.8	S
1994	Insecticide	8	4	2	2.4	NS
1995	Insecticide	11	4	2	3.0	NS
1996	Insecticide	10	4	2	3.1	S

All trials used randomized complete blocks designs. Levels of natural thrips infestation during a given trial are indicated in column 6 by mean layers damaged in plots untreated by insecticides. S, significant; NS, not significant for ANOVA F test at $P = 0.05$.

[a] Number of plants sampled per plot.

planting date ($F = 7.47$; df = 1, 4; $P = 0.0522$) and its interactions with cultivar ($F = 1.14$; df = 11, 4; $P = 0.341$) and insecticide ($F = 3.00$; df = 1, 4; $P = 0.158$) were not significant in the ANOVA model, and the variety by insecticide interaction was also not significant ($F = 1.33$; df = 11, 4; $P = 0.220$).

Discussion

Results reported herein demonstrate the variable and usually poor control of onion thrips on cabbage obtained through the use of insecticides. Use of thrips tolerant varieties, however, consistently kept damage at low levels. Other control tactics such as inundative releases of predatory mites for control of thrips on cabbages in the field have not provided adequate control (Hoy and Glenister 1991). In our 1996 trial, the use of insecticides, although reducing the amount of injury on susceptible varieties, did not reduce the injury below that which was sustained by using a more tolerant variety in the first place. From these studies we conclude that the primary control for thrips infesting cabbage should be selection of tolerant varieties.

Plant resistance in cabbage for thrips control is one of the few instances where host plant resistance to insects has been widely adopted for vegetables (Eigenbrode and Trumble 1994). Our early success at identifying tolerant lines has enabled seed companies to incorporate such resistance into their newer varieties, which also have other desirable characteristics. Several of the major seed companies now provide information on thrips resistance in their catalogs to assist growers in their selection of varieties. Cornell Cooperative Extension's annual pest management recommendations for cabbage also summarizes the results of variety trials conducted in New York in a table listing the relative susceptibility of commercially available cultivars (Bellinder et al. 1996).

Acknowledgments.

The advice of Laura Pedersen was greatly appreciated. We are grateful for the financial support received from the New York State Cabbage Research Association.

References Cited

Bellinder, R. R., H. R. Dillard, C. J. Eckenrode, L. A. Ellerbrock, D. E. Halseth, J. R. Hicks, M. P. Hoffmann, R. Loria, M. T. McGrath, C. H. Petzoldt, and others. 1996. 1997 pest management recommendations for commercial vegetable and potato production. Cornell University, Ithaca, NY.

Eigenbrode, S. D., and J. T. Trumble. 1994. Plant resistance to insects in integrated pest management in vegetables. J. Agric. Entomol. 11: 201–224.

Hoy, C. W., and C. S. Glenister. 1991. Releasing *Amblyseius* spp. (Acarina: Phytoseidae) to control *Thrips tabaci* (Thysanoptera: Thripidae) on cabbage. Entomophaga 36: 561–573.

Hoy, C. W., and D. W. Kretchman. 1991. Thrips (Thysanoptera: Thripidae) injury to cabbage cultivars in Ohio. J. Econ. Entomol. 84: 971–977.

North, R. C., and A. M. Shelton. 1986a. Colonization and intraplant distribution of *Thrips tabaci* on cabbage. J. Econ. Entomol. 79: 219–223.

1986b. Ecology of Thysanoptera within cabbage fields. Environ. Entomol. 15: 520–526.

Shelton, A. M., and R. C. North. 1986. Species composition and phenology of Thysanoptera within field crops adjacent to cabbage fields. Environ. Entomol. 15: 513–519.

Shelton, A. M., R. F. Becker, and J. T. Andaloro. 1983. Varietal resistance to onion thrips in processing cabbage. J. Econ. Entomol. 76: 85–86.

Shelton, A. M., C. W. Hoy, R. C. North, M. H. Dickson, and J. Barnard. 1988. Analysis of resistance in cabbage varieties to damage by Lepidoptera and Thysanoptera. J. Econ. Entomol. 81: 634–640.

Steel, R.G.D., and J. H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach, 2nd ed. McGraw-Hill, New York.

Stoner, K. A., and A. M. Shelton. 1988a. Role of nonpreference in the resistance of cabbage varieties to the onion thrips (Thysanoptera: Thripidae). J. Econ. Entomol. 81: 1062–1067.

1988b. Effect of planting date and timing of growth stages on damage to cabbage by onion thrips (Thysanoptera: Thripidae). J. Econ. Entomol. 81: 1186–1189.

1988c. Influence of variety on abundance and within-plant distribution of onion thrips (Thysanoptera: Thripidae) on cabbage. J. Econ. Entomol. 81: 1190–1195.

Stoner, K. A., M. H. Dickson, and A. M. Shelton. 1989. Inheritance of resistance to damage by *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) in cabbage. Euphytica 40: 233–239.

Received for publication 12 May 1997; accepted 26 September 1997.