Post-harvest Management of Tobacco Thrips (Thysanoptera: Thripidae) Overwintering in Peanut Fields[1]

J. R. Chamberlin[2], J. W. Todd, A. K. Culbreath[3], W. C. Johnson III[4] and J. W. Demski[5]

University of Georgia, Department of Entomology, Coastal Plain Experiment Station Tifton, GA 31793

J. Entomol. Sci. 28(4):433-446 (October 1993)

ABSTRACT A combination of fallow tillage and a March application of carbofuran were assessed as tactics for decreasing survival and reproduction of tobacco thrips overwintering in six harvested peanut fields. Large numbers of tobacco thrips, *Frankliniella fusca* (Hinds) (Thysanoptera: Thripidae), developed in three fields on volunteer peanut, *Arachis hypogaea* L., and winter annual weeds. Adult tobacco thrips collected during the late winter were predominantly brachypterous, with percent brachyptery averaging 71-95% for females. Brachypterous adults tended to be more abundant in fields harvested in September than in those harvested in October. Disking during November and February greatly reduced the density of volunteer peanut and winter annual weeds but did not measurably decrease abundance of brachypterous tobacco thrips. Carbofuran application reduced abundance of brachypterous adults and thrips larvae on volunteer peanut by 85-100% during the early spring. Post-harvest tillage and carbofuran application did not measurably reduce incidence of tomato spotted wilt virus in the subsequent peanut crop. Implications for winter ecology and management of spotted wilt are discussed.

KEY WORDS Thrips, tomato spotted wilt virus, peanut, weed, pest management, winter.

Spotted wilt disease, which is caused by tomato spotted wilt virus (TSWV), poses a continuing threat to the production of peanut, *Arachis hypogaea* L. (Hagan et al. 1990, Culbreath et al. 1992) and solanaceous crops (Greenough et al. 1985, Culbreath et al. 1991, McPherson et al. 1992) in the southeastern United States. TSWV is vectored exclusively by thrips, and two demonstrated vectors, the tobacco thrips, *Frankliniella fusca* (Hinds), and the western flower thrips, *F. occidentalis* (Pergande), (Sakimura 1962, 1963) infest several crop hosts of TSWV in this area (Morgan et al. 1970, Greenough et al. 1990, Weeks et al. 1990, McPherson et al. 1992).

The source(s) of viruliferous thrips that are responsible for primary TSWV infection in initial plantings of spring crops is (are) unknown. The virus can be acquired by thrips only during their larval stages (Bald and Samuel 1931), but aside from tobacco transplant beds, crops known to host the virus and support thrips reproduction are not generally grown in Georgia from approximately

[1] Accepted for publication 15 September 1993.
[2] Current Address: Yoder Brothers, Inc. P. O. Box 68, Alva, FL 33920.
[3] Department of Plant Pathology, Coastal Plain Experiment Station, Tifton, GA 31793.
[4] USDA-ARS, Coastal Plain Experiment Station, Tifton, GA 31793.
[5] Dept. of Plant Pathology, Georgia Station, Griffin, GA 30223.

November 15 - March 1. Therefore, unless viruliferous thrips annually immigrate from more southerly regions, thrips probably acquire TSWV locally during this period from noncultivated plant species or survive in diapause from the previous cropping season (Mitchell et al. 1991).

Harvested peanut fields have been postulated as important winter reservoirs for spotted wilt and sources of viruliferous thrips during the spring (Mitchell et al. 1991, Chamberlin et al. 1992). Peanut hectarage is extensive in Georgia, with ~350,000 ha under production in 1991, and many peanut fields are left relatively fallow between harvest and the following spring (J. Beasley, personal communication). As a result, large numbers of volunteer peanut and annual weeds, such as cutleaf eveningprimrose, *Oenothera laciniata* Hill, which can support the virus (Cho et al. 1987) and support thrips reproduction (Eddy and Livingstone 1931, Beckham et al. 1971, Chamberlin et al. 1992) often develop during this period. Tobacco thrips, western flower thrips, and *Frankliniella* spp. larvae have been collected from volunteer peanut in harvested peanut fields throughout the fall and spring in Georgia (Chamberlin et al. 1992). Adult tobacco thrips were predominantly brachypterous during the late fall and early spring which suggested that some populations overwintered within these fields. Finally, we have serologically detected TSWV with enzyme-linked immunosorbent assay (ELISA) in brachypterous tobacco thrips collected from harvested peanut fields during the winter and spring (Chamberlin et al. 1993).

Brachypterous tobacco thrips, given their limited dispersal capability, represent a potential "weak link" in the TSWV cycle and should be vulnerable to post-harvest management. In this study, we investigated the effects of repeated fallow tillage and a March application of carbofuran on survival and reproduction of brachypterous tobacco thrips overwintering in six harvested peanut fields. Each field was replanted with peanut during the spring to assess whether these management practices reduced spotted wilt incidence in the subsequent crop.

Materials and Methods

Harvested peanut fields. The study was conducted from November 1990 - April 1991 in six harvested peanut fields, 0.6-1.4 ha in size. Three fields were located at the University of Georgia Attapulgus Research Station, Attapulgus, GA (Attapulgus 1, 2 and 3), and three others were located at the Ponder Research Farm, Tifton, GA (Ponder 1, 2 and 3). Each field had been planted with peanut during the spring of 1990 and subsequently experienced a TSWV epidemic. Attapulgus 1 and 2 were harvested on 2-3 September, Ponder 3 on 17 September, Ponder 1 and 2 on 3 October, and Attapulgus 3 on 31 October.

All fields at Attapulgus were disked on 5 and 28 November and 15 February. Attapulgus 2 and 3 were disked again on 5 April, and Attapulgus 3 was disked once more on 12 May. All fields at the Ponder Farm were disked on 15 November and 20 February. Ponder 1 and 2 were disked again on 13 April, and Ponder 2 was disked once more on 13 May. A 6-12 m wide strip running the length of each field at its center was not disked during the study and served as a non-treated check. This design was employed to minimize the potential for thrips to move from non-treated into treated plots. Disking was timed to destroy volunteer peanut and winter annual weeds that could potentially serve as hosts for

overwintering thrips and TSWV. Carbofuran (Furadan 4F [flowable]; FMC Corp., Philadelphia, PA), a systemic insecticide, was sprayed on all disked areas of each field in early March at the rate of 2.24 kg (AI)/ha. Application was timed to destroy brachypterous tobacco thrips before they could begin reproducing on volunteer peanut, which typically begins emerging during mid-March in southern Georgia. To minimize potential immigration of viruliferous thrips from outside test fields, carbofuran was applied to all other fields at Attapulgus that were planted to peanut during 1990; fields planted with small grains during the fall were treated at planting, while fallow fields were treated in early March. Carbofuran was not applied at the Ponder Farm, except in the three test fields.

The center strip was divided into four, and each adjacent treated area was divided into two equal-sized plots for sampling. Volunteer peanut in nontreated plots was sampled for thrips on 3 to 4 dates between 7 November and 18 December 1990, and on 2 to 4 dates between 26 March and 19 April 1991, depending upon the field. Volunteer peanut in disked plots briefly emerged between diskings and were sampled for thrips on 1 to 2 dates in the fall and spring. On each date, we collected 20 volunteers from each plot.

In early and late January 1991, peanuts were planted in the greenhouse in peat pots containing sterilized field soil. After 4 - 6 leaves had expanded, we transplanted 20 plants into each disked and nondisked plot of each field. Transplant dates were 31 January and 20-22 February for the two plantings, respectively, and thrips were sampled from 10 plants/plot ~5 and 10 d after transplanting. Plants sampled from disked plots were located at least 10 m from adjacent nontreated plots or field margins in order to minimize potential immigration of brachypterous adult tobacco thrips from these areas. At Attapulgus, we also sampled thrips from cutleaf eveningprimrose, *Oenothera laciniata* Hill, and purple cudweed, *Gnaphalium purpureum* L., on 13 March. Finally, thrips were sampled from cutleaf eveningprimrose at the Ponder Farm on 19 March. On each sample date, we collected 20 plants per weed species per plot. Plant samples were placed in plastic bags and transported to the laboratory on ice. Thrips were washed from foliage with phosphate buffered saline-tween (Agdia, Elkhart, IN), which is used in ELISA procedures, and the solution was poured through 105-μm mesh polyester screening to collect thrips. We then counted thrips under a dissecting microscope and classified them according to lifestage, species, sex, and wing-form.

Density of volunteer peanut was estimated in four quadrants, 2 m^2 in size, of each plot on most dates when thrips were sampled. Density of winter annual weeds was similarly estimated during late February. Given that our experimental design precluded randomization of treatments, Student's t test with equal N and unequal variances was used to assess the effects of post-harvest management practices and date of peanut harvest on the abundance of thrips, volunteer peanut, and weed pests.

Cultivated peanut - 1991. All six test fields were replanted with peanut during spring 1991. Attapulgus 1 and Ponder 3 were planted in early April, Attapulgus 2 and Ponder 2 in mid-May, and Attapulgus 3 and Ponder 1 in early June. Immediately before planting, the nontreated (fallow) center strip of each field was disked twice and then bedded; at Attapulgus, nontreated strips also were chisel plowed before the final disking. Adjacent treated (disk + carbofuran)

areas were disked, deep turned, and then bedded. Nontreated strips were not deep turned in order to minimize burying any overwintering viruliferous thrips that might have been present. After land preparation, we divided the nontreated strip into four equal plots and each adjacent treated area into two equal plots. Two plots in each treatment were planted with 'Florunner' or 'Southern Runner' peanut at the rate of 112 kg seed/ha, with winter treatment × peanut cultivar combinations arranged in a completely randomized design. Standard agronomic practices were employed during this study, except that no insecticides were applied.

Four sample area, 7.7 m × 2 rows in size, were randomly demarcated in each plot shortly after plant emergence and plants were then counted in each sample area. Ten plants immediately adjacent to each sample area were sampled for thrips ~1 and 2 wk after plants began emerging. We collected and identified thrips as described previously for volunteer peanut. Plants that exhibited symptoms of TSWV infection within each sample area were flagged ~8, 12 and 16 wk after planting. Finally, we tested a subsample of flagged plants with ELISA to confirm infection.

Analysis of variance was used to test the effects of winter management practices and peanut cultivar on thrips abundance (two sample dates pooled) and cumulative virus incidence in each field. Least significant differences (LSD) were calculated to compare means. A pooled standard error was derived from the LSD, and Student's *t* test with equal N and unequal variances was used to compare mean abundance (averaged across winter treatment and peanut cultivar) of tobacco thrips in different plantings. Standard errors for each planting were generated by dividing the pooled standard error by SQRT (2).

Results and Discussion

Harvested peanut fields. We recovered adult tobacco thrips and *Frankliniella* spp. larvae on each date that volunteer peanut was sampled during the fall and spring. Adult western flower thrips also were collected on most sample dates (data not shown), but typically made up <10% of the adult thrips collected. Thrips larvae could not be identified to species because taxonomic keys have not been developed. The majority were probably tobacco thrips because western flower thrips reproduce poorly on peanut (Chamberlin et al. 1992).

Adult tobacco thrips, *Frankliniella* spp. larvae, and a small number of western flower thrips (data not shown) were recovered from peanut transplants, cutleaf eveningprimrose, and purple cudweed during February and March (Tables 1 and 2). Adult tobacco thrips and *Frankliniella* spp. larvae also have been observed on winter annual weeds in harvested cotton fields in Georgia (Beckham et al. 1971).

In nontreated plots of Attapulgus 1 and 2 and Ponder 3, the percentage of female tobacco thrips that were brachypterous increased steadily during the fall (Fig. 1). Female tobacco thrips collected from transplanted peanut and weeds during winter months were predominantly brachypterous, with percent brachyptery reaching 100% in some samples (Fig. 1). Percent brachyptery declined rapidly during the spring, reaching 29% by mid-April (Fig. 1). Small numbers of brachypterous male tobacco thrips were collected, but no distinct temporal pattern in

Table 1. Influence of post-harvest tillage and carbofuran on adult tobacco thrips and *Frankliniella* spp. larvae in old peanut fields, Attapulgus Research Station, Attapulgus, Ga., November 1990 - April 1991.†

Lifestage / Field	Treatment§	Plant host: Volunteer peanut 16 Nov	Volunteer peanut 28 Nov	Transplanted peanut‡ 14 Feb (P1)	Transplanted peanut‡ 07 Mar (P2)	Cutleaf evening primrose 13 March	Purple cudweed 13 March	Volunteer peanut 26 Mar	Volunteer peanut 02 Apr
Brachypterous adult									
1	NT	4.0 ± 1.6*	3.2 ± 1.4*	2.0 ± 0.0	11.5 ± 4.6	8.0 ± 2.1	0.5 ± 0.3	17.0 ± 2.0*	8.5 ± 1.8*
	D+C	30.2 ± 5.4	14.0 ± 3.5	5.7 ± 3.5	1.2 ± 0.5	.....£	.....	0.2 ± 0.2	0.0 ± 0.0
2	NT	2.0 ± 1.0	3.2 ± 0.7	1.5 ± 0.5	1.5 ± 0.7	3.0 ± 1.3	0.5 ± 0.3	14.7 ± 4.5*	7.0 ± 6.0
	D+C	2.2 ± 1.6	5.2 ± 1.5	2.7 ± 1.8	2.0 ± 1.4	.....	.....	0.0 ± 0.0	1.2 ± 0.9
3	NT	1.0 ± 0.4	1.0 ± 0.4	0.5 ± 0.3	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	1.0 ± 0.6
	D+C	.....	.....	0.0 ± 0.0	0.0 ± 0.0	.....	.....	0.0 ± 0.0	0.0 ± 0.0
Macropterous adult									
1	NT	4.2 ± 1.4	0.7 ± 0.5	0.5 ± 0.3	1.5 ± 0.9	0.5 ± 0.3	0.5 ± 0.5	5.5 ± 1.2*	7.7 ± 2.6
	D+C	3.7 ± 1.4	2.7 ± 2.4	0.0 ± 0.3	2.5 ± 0.5	.....	.....	14.2 ± 1.7	9.5 ± 0.9
2	NT	5.0 ± 1.7	3.0 ± 0.7	0.0 ± 0.0	0.5 ± 0.5*	0.2 ± 0.2	0.5 ± 0.3	4.2 ± 1.1*	4.3 ± 0.7*
	D+C	4.7 ± 1.5	3.0 ± 0.9	0.0 ± 0.0	2.7 ± 0.5	.....	.....	12.5 ± 1.9	15.7 ± 3.1
3	NT	4.2 ± 2.3	2.2 ± 0.2	0.0 ± 0.0	0.2 ± 0.2	0.2 ± 0.2	0.7 ± 0.5	12.2 ± 1.8	3.7 ± 1.2*
	D+C	.....	.....	0.0 ± 0.0	1.2 ± 0.6	.....	.....	9.7 ± 1.0	21.7 ± 4.5
Larvae									
1	NT	4.7 ± 2.0	3.7 ± 2.2	1.2 ± 0.9	39.2 ± 13.9*	86.5 ± 10.2	6.5 ± 2.1	12.5 ± 2.9*	18.0 ± 2.8*
	D+C	4.7 ± 1.1	6.0 ± 2.2	0.5 ± 0.3	3.0 ± 0.0	.....	.....	0.0 ± 0.0	1.7 ± 1.7
2	NT	4.0 ± 1.2	11.0 ± 7.7	6.5 ± 4.0	4.5 ± 1.5	45.0 ± 14.1	15.5 ± 3.5	27.0 ± 10.9*	35.3 ± 6.0*
	D+C	7.5 ± 4.3	6.0 ± 4.1	2.2 ± 0.6	9.2 ± 5.0	.....	.....	0.2 ± 0.2	2.0 ± 0.8
3	NT	2.7 ± 1.1	8.7 ± 4.3	1.2 ± 0.7	2.0 ± 1.1	4.0 ± 2.7	3.0 ± 1.2	5.7 ± 2.4	42.7 ± 7.0*
	D+C	.....	.....	0.0 ± 0.0	0.2 ± 0.2	.....	.....	2.7 ± 1.7	8.7 ± 4.3

† Mean thrips /20 volunteers, 20 primrose, 20 purple cudweed or 10 transplants ± SEM (N = 4). For each field, asterisk indicates that treatment means within a column are significantly different ($P \leq 0.05$) by Student's t test.
‡ Transplants set out in field on 31 January (P1) and 20 February (P2).
§ NT = nontreated; D + C = disking + carbofuran; disk-harrowed on 5 and 29 November, and 19 February. Carbofuran applied @ 2.24 kg (AI)/ha on 11 March.
£ ..... = plant host not present in sufficient numbers to sample.

Table 2. Influence of post-harvest tillage and carbofuran on adult tobacco thrips and *Frankliniella* spp. larvae in peanut fields, Ponder Research Farm, Tifton, GA, November 1990 - April 1991.†

Lifestage		Plant host						
		Volunteer peanut		Transplanted peanut‡		Cutleaf eveningprimrose	Volunteer peanut	
Field	Treatment§	19 Nov	30 Nov	13 Feb (P1)	07 Mar (P2)	19 March	25 Mar	03 Apr
Brachypterous adult								
1	NT	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	1.7 ± 0.5	0.7 ± 0.2	.....	.....
	D+C	.....£	.....	0.0 ± 0.0	0.0 ± 0.0	.....	.....	0.0 ± 0.0
2	NT	0.0 ± 0.0	0.7 ± 0.5	0.0 ± 0.0	1.5 ± 0.9	2.2 ± 0.9	.....	.....
	D+C	.....	.....	0.0 ± 0.0	1.0 ± 0.7	.....	.....	0.2 ± 0.2
3	NT	1.0 ± 0.4	1.2 ± 0.5	0.2 ± 0.2	2.5 ± 0.5	1.5 ± 0.5	9.2 ± 0.9*	9.2 ± 1.2*
	D+C	.....	4.5 ± 2.2	0.2 ± 0.2	1.5 ± 0.5	.....	0.7 ± 0.5	0.0 ± 0.0
Macropterous adult								
1	NT	0.7 ± 0.5	1.5 ± 0.6	0.0 ± 0.0	0.5 ± 0.3	1.7 ± 0.6	.....	.....
	D+C	.....	.....	0.0 ± 0.0	0.2 ± 0.2	.....	.....	19.0 ± 3.1
2	NT	0.7 ± 0.5	0.7 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	1.5 ± 0.5	.....	.....
	D+C	.....	.....	0.0 ± 0.0	1.5 ± 0.5	.....	.....	25.5 ± 1.9
3	NT	0.7 ± 0.5	1.0 ± 0.4	0.0 ± 0.0	1.5 ± 0.5	0.2 ± 0.2	5.7 ± 1.4*	10.0 ± 2.3*
	D+C	.....	1.7 ± 0.5	0.0 ± 0.0	1.0 ± 1.0	.....	12.0 ± 1.9	37.2 ± 5.0
Larvae								
1	NT	1.2 ± 0.2	2.7 ± 0.9	0.2 ± 0.2	2.2 ± 1.6	14.0 ± 5.2	.....	.....
	D+C	.....	.....	0.0 ± 0.0	0.0 ± 0.0	.....	.....	3.5 ± 0.9
2	NT	7.0 ± 2.5	3.5 ± 1.2	0.5 ± 0.3	1.7 ± 0.6	24.0 ± 4.0	.....	.....
	D+C	.....	.....	0.2 ± 0.2	0.5 ± 0.3	.....	.....	0.0 ± 0.0
3	NT	40.2 ± 7.0	4.5 ± 1.8	0.5 ± 0.5	5.5 ± 2.5	13.8 ± 6.9	35.7 ± 13.7*	68.7 ± 19.0*
	D+C	.....	9.0 ± 1.3	0.0 ± 0.0	0.0 ± 0.0	.....	1.7 ± 1.2	13.0 ± 4.1

† Mean number/ 20 volunteers, 20 primrose, or 10 transplants ± SEM (N = 4). For each field, asterisk indicates that treatment means within a column are significantly different ($P \leq 0.05$) by Student's t test.

‡ Transplants set out in field on 31 January (P1) and 22 February (P2).

§ NT = nontreated; D + C = disking + carbofuran; disk-harrowed on 15 November, and 20 February. Carbofuran applied @ 2.24 kg (AI)/ha on 15 March.

£ ..... = plant host not present in sufficient numbers to sample.

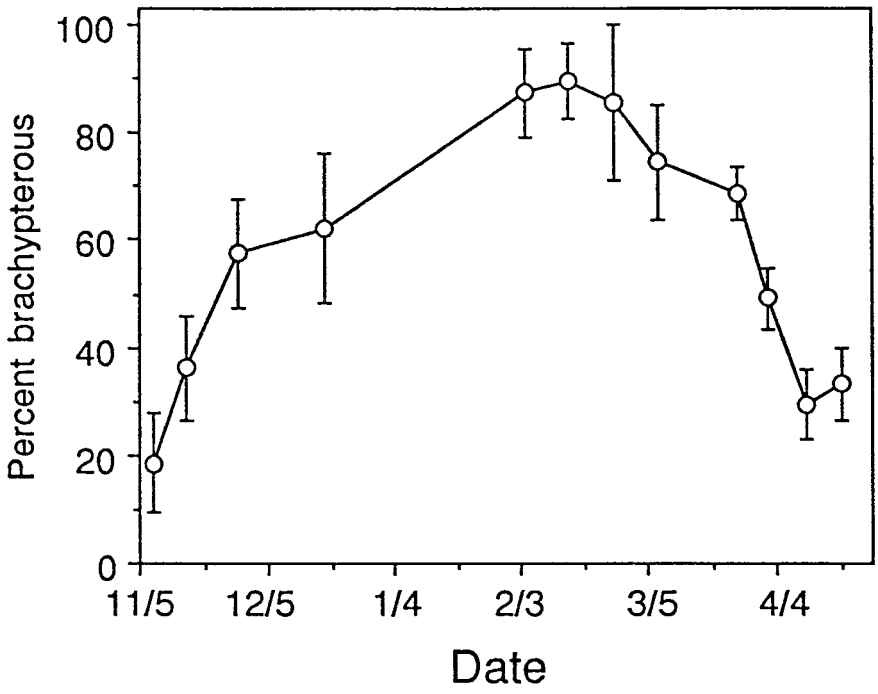

Fig. 1. Mean percentage of brachypterous tobacco thrips in Attapulgus 1, Attapulgus 2 and Ponder 3. Error bars represent one SEM.

brachyptery was evident among them. Similar seasonal trends in brachyptery have been observed for tobacco thrips on white clover, *Trifolium repens* L., in Louisiana (Burns 1951, Newsom et al. 1953).

We suspect that most brachypterous adults collected from volunteers during the fall had developed on those plants because thrips larvae were present on volunteers and weeds known to support reproduction by tobacco thrips were uncommon in fields until late fall. Supporting this hypothesis, the majority of brachypterous adults collected during the fall were from Attapulgus 1 and 2 and Ponder 3 (Tables 1 and 2). These fields were harvested from 2-17 September and large numbers of volunteer peanut began emerging soon thereafter; by late November, density of volunteers in these three fields averaged 17.6-37.7 plants/2 m^2 or 88,000-188,000 plants/ha (Table 3), which is ~0.6-1.3X typical plant populations for cultivated peanut. Conversely, brachypterous adults were less common and distinct temporal trends in brachyptery were not observed during the fall in Ponder 1 and 2 and Attapulgus 3 (Tables 1 and 2). However, these fields were not harvested until October and relatively few volunteers emerged in the fall following harvest (Table 3). Consequently, relative to fields harvested in September, there were fewer volunteers available for brachypterous adults to develop on and less time was available

Table 3. Effects of post-harvest tillage on density of volunteer peanut and cutleaf eveningprimrose in harvested peanut fields, November 1990-April 1991.†

Location‡ Field§	Treatment£	Volunteer peanut 16-19 Nov	Volunteer peanut 27-30 Nov	Cutleaf eveningprimrose 27-28 Feb	Rabbit tobacco 27-28 Feb	Volunteer peanut 27-30 Mar	Volunteer peanut 01-02 Apr
Attapulgus							
1	NT	30.7 ± 3.4*	37.7 ± 3.8*	8.8 ± 1.5*	22.7 ± 1.6	10.2 ± 1.6	11.0 ± 1.9
	D+C	3.7 ± 0.5	12.0 ± 1.5	0.0 ± 0.0	0.0 ± 0.0	8.8 ± 0.9	9.9 ± 1.2
2	NT	18.4 ± 2.0*	18.2 ± 1.7*	7.4 ± 1.1*	10.4 ± 1.5	4.0 ± 1.0*	5.9 ± 2.1
	D+C	1.2 ± 0.2	6.1 ± 1.2	0.0 ± 0.0	0.0 ± 0.0	7.6 ± 1.0	11.4 ± 2.1
3	NT	2.7 ± 0.8	1.3 ± 0.4	2.1 ± 0.4*	13.7 ± 2.2	3.1 ± 1.4	4.6 ± 2.1
	D+C	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	3.2 ± 0.5	1.9 ± 0.6
Ponder							
1	NT	0.0 ± 0.0	1.2 ± 0.5*	3.5 ± 1.0*	5.9 ± 0.9	0.0 ± 0.0	0.1 ± 0.1
	D+C	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.6 ± 0.2
2	NT	9.0 ± 2.3*	5.0 ± 1.4*	Not sampled	Not sampled	0.0 ± 0.0	0.1 ± 0.1
	D+C	0.0 ± 0.0	0.6 ± 0.6	Not sampled	Not sampled	0.0 ± 0.0	0.2 ± 0.1
3	NT	18.4 ± 2.3*	17.6 ± 2.6*	13.6 ± 2.5*	1.7 ± 0.6	0.7 ± 0.2*	1.1 ± 0.4*
	D+C	0.0 ± 0.0	3.7 ± 0.9	0.0 ± 0.0	0.0 ± 0.0	3.9 ± 0.9	6.7 ± 1.3

† Mean number plants / $2m^2$ ± SEM (N = 16). For each field, asterisk indicates that treatment means within a column are significantly different ($P \leq 0.05$) by Student's t test.
‡ Attapulgus = Attapulgus Research Station, Attapulgus, GA; Ponder = Ponder Research Farm, Tifton, GA.
§ Harvest dates: Attapulgus 1 = 2-3 September, Attapulgus 3 = 31 October, Ponder 1 and 2 = 3 October, Ponder 3 = 17 September, 1990.
£ NT = nontreated; D+C = disk-harrowed + carbofuran.

for development to take place before freezing temperatures killed plants in December. In addition, the fall decline in abundance of macropterous adults may have further limited colonization of later harvested fields.

Brachypterous adults may have survived the winter on winter annual weeds such as cutleaf eveningprimrose and purple cudweed, which are winter/spring hosts of tobacco thrips and western flower thrips (Beckham et al. 1991, Chamberlin et al. 1992). During late February, counts of these two weeds averaged 2.1-13.6 plants/2 m^2 (~10,000-70,000 plants/ha) and 1.7-22.7 plants/2 m^2 (~8,000-113,000 plants/ha), respectively in nontreated plots (Table 3). Common chickweed, *Stellaria media* Cyrillo (L.), also was fairly abundant at Attapulgus, where counts reached 2.6-5.2 plants/2m^2 (~13,000-26,000 plants/ha). We did not sample chickweed for thrips but have previously observed tobacco thrips on this weed during the spring (Chamberlin et al. 1992).

Disking during November destroyed most volunteer peanut and relatively few additional peanuts germinated in the fall after fields were disked (Table 3). Effects of fall disking on winter annual weeds were not quantified in December and January, but we observed very few weeds in disked plots during this time. Disking during late February destroyed weeds that were present and emergence of winter annual weeds was limited thereafter in disked plots.

Disking did not measurably reduce the number of adult tobacco thrips and thrips larvae collected during the fall and winter, except in the 7 March sample of larvae at Attapulgus 1 (Tables 1 and 2). Collection of brachypterous adults from disked plots suggests that some individuals survived disking because lack of flight capability would have restricted immigration from nontreated plots or field margins. However, brachypterous individuals that survived disking may have concentrated on the limited number of volunteers and weeds that emerged between diskings. Conversely, the large number of volunteers and weeds in nontreated plots probably diluted populations of brachypterous adults (Table 3). This could explain why at Attapulgus 1 more brachypterous adults were collected during November in disked than in nondisked plots (Table 1). In addition, although volunteer peanut began emerging in Attapulgus 1 and 2 and Ponder 3 soon after harvest in early September, we did not begin disking fields until early November. Consequently, large numbers of brachypterous adults probably developed on volunteers in "disked" plots during the 2-mo period and some may have survived disking.

Carbofuran application in early March destroyed nearly all brachypterous tobacco thrips in treated plots of Attapulgus 1 and 2 and Ponder 3, based on collections from volunteer peanut (Table 1). Thrips larvae were much more abundant on volunteers in nontreated plots than in carbofuran treated plots (Tables 1 and 2). By mid-March, however, large larval populations had developed on cutleaf eveningprimrose, purple cudweed (Tables 1 and 2), and possibly on other weeds in nontreated plots. Therefore, we suspect that many larvae on volunteers in nontreated plots had originated on adjacent weeds. Macropterous tobacco thrips often were more numerous during the spring on volunteers in carbofuran treated plots than on those in nontreated plots (Tables 1 and 2). However, populations may have been greater than indicated in nontreated plots because of potential dilution by winter annual weeds. Treatment effects could not be assessed during the spring in Ponder 1 and 2 because extremely few volunteers emerged in these fields (Table 3).

Cultivated Peanut - 1991. Large numbers of adult tobacco thrips (~95% female) colonized recently-emerged peanut in the April planting at both study sites (Tables 4 and 5) but were much less abundant in the May and June plantings (t = 21.5 and 24.2, df = 62). A small percentage of these adults (0.3-1.2%) were brachypterous, except in the June planting at Attapulgus where all adults were macropterous. Brachypterous adults were more commonly collected in the April planting than in subsequent plantings (t = 1.2 and 6.9, df = 62). Brachypterous individuals had probably survived land preparation because not enough time had elapsed for them to have developed on cultivated peanut seedlings.

No significant ($P \leq 0.05$) interaction between winter management practices and peanut cultivar were detected for adult tobacco thrips on young peanut plants or for cumulative TSWV incidence. Winter treatments did not measurably reduce abundance of adult tobacco thrips (brachypterous + macropterous), except in the April planting at the Ponder Farm (Table 4). Brachypterous adults were more abundant in nontreated than in disk + carbofuran plots of the April planting at both study sites (Table 4), but not in other plantings. Peanut cultivar did not significantly affect tobacco thrips abundance, except in the June planting at the Ponder Farm where thrips were more abundant on Southern Runner (Table 5).

Winter treatments did not significantly decrease the cumulative incidence of plants exhibiting virus symptoms relative to nontreated checks (Table 4). However, the low incidence of symptomatic plants made assessment of winter treatments difficult. Nontreated plots also were disked before planting which may have destroyed any viruliferous thrips present. Finally, viruliferous thrips from outside areas may have immigrated into test fields and colonized newly-emerged peanut, thus masking potential benefits of post-harvest disking and carbofuran application.

TSWV incidence in Southern Runner was significantly less than in Florunner in the April and May plantings at Attapulgus, but not in other plantings (Table 5). This was somewhat surprising because in several previous tests apparent TSWV incidence in Southern Runner has been consistently less than in Florunner (Culbreath et al. 1992).

Conclusions

The potential exists in southern Georgia for large numbers of tobacco thrips to develop in harvested peanut fields. Based on the density of volunteer peanut at Attapulgus 1 (Tables 1 and 3) and counts of thrips larvae on these plants, larval density on volunteers was ~36,000 and 49,000 larvae/ha in late November and early April, respectively. Similarly, larval density on cutleaf eveningprimrose and purple cudweed in Attapulgus 1 during mid-March was ~190,000 and 37,000 larvae/ha, respectively (Tables 1 and 3). Considering the short generation time of tobacco thrips and the fact that many peanut fields are left relatively fallow between harvest and the following spring, several hundred thousand tobacco thrips/ha or more may develop in some fields during this period. On average, larger populations of tobacco thrips will tend to develop in fields harvested earlier than in those harvested later because concomitant warmer temperatures will stimulate germination of volunteers and development of thrips on these plants.

Table 4. Effects of fallow tillage + carbofuran application on adult tobacco thrips abundance and TSWV incidence in subsequently planted peanut.*

Planting	Tillage + carbofuran	Attapulgus Research Station			Ponder Research Farm		
		Total adults†	Brachypterous adults	TSWV incidence‡	Total adults†	Brachypterous adults	TSWV incidence‡
1	No	78.3 ± 5.8	1.2 ± 0.2	6.2 ± 0.9	153.0 ± 8.3	1.1 ± 0.3	4.1 ± 0.6
	Yes	80.2 ± 5.8	0.2 ± 0.2	5.0 ± 0.9	101.9 ± 9.7	0	4.0 ± 0.6
	LSD§	16.8	0.5	2.5	24.2	0.8	1.7
2	No	11.4 ± 1.3	0.1 ± 0.1	2.0 ± 0.5	24.1 ± 2.6	0.3 ± 0.1	3.9 ± 0.9
	Yes	15.6 ± 1.3	0.1 ± 0.1	3.1 ± 0.5	19.1 ± 2.6	0.1 ± 0.1	2.9 ± 0.9
	LSD	3.9	0.2	1.5	7.4	0.3	2.5
3	No	12.9 ± 1.2	0	2.2 ± 0.4	32.6 ± 3.6	0.4 ± 0.2	5.5 ± 0.7
	Yes	10.9 ± 1.2	0	2.7 ± 0.4	26.8 ± 3.6	0.3 ± 0.2	3.7 ± 0.7
	LSD	3.5	–	1.1	10.4	0.5	2.0

* Mean ± SEM. SEM = (LSD/2.048 (i.e. critical t value at $P = 0.05$ and 28 df) / SQRT(2).
† Total = macropterous + brachypterous. Plants sampled ≈ 5 and 12 d after plant emergence; counts from two dates pooled before analysis.
‡ Cumulative percentage of peanut plants that exhibited symptoms of TSWV infection.
§ $P = 0.05$.

Table 5. Peanut cultivar effects on abundance of adult tobacco thrips and TSWV incidence.*

Planting	Cultivar	Attapulgus Research Station			Ponder Research Farm		
		Total adults†	Brachypterous adults	TSWV incidence‡	Total adults†	Brachypterous adults	TSWV incidence‡
1	Florunner	79.1 ± 5.8	1.1 ± 0.2	7.8 ± 0.9	136.6 ± 12.7	0.6 ± 0.3	4.3 ± 0.6
	So. Runner	79.4 ± 5.8	0.4 ± 0.2	3.5 ± 0.9	118.3 ± 7.6	0.6 ± 0.3	3.8 ± 0.6
	LSD§	16.8	0.5	2.5	24.2	0.8	1.7
2	Florunner	13.5 ± 1.3	0.1 ± 0.1	3.3 ± 0.5	22.0 ± 2.6	0.1 ± 0.1	2.5 ± 0.9
	So. Runner	13.7 ± 1.3	0.1 ± 0.1	1.7 ± 0.5	21.2 ± 2.6	0.3 ± 0.1	4.4 ± 0.9
	LSD	3.9	0.2	1.5	7.4	0.3	2.5
3	Florunner	11.4 ± 1.2	0	2.6 ± 0.4	16.1 ± 3.6	0.1 ± 0.2	4.2 ± 0.7
	So. Runner	12.4 ± 1.2	0	2.3 ± 0.4	43.3 ± 3.6	0.6 ± 0.2	5.0 ± 0.7
	LSD	3.5	–	1.1	10.4	0.5	2.0

* Mean ± SEM. SEM = (LSD/2.048 (i.e. critical t value at $P = 0.05$ and 28 df) / SQRT(2).
† Total = macropterous + brachypterous. Plants sampled ≈ 5 and 12 d after plant emergence; counts from two dates pooled before analysis.
‡ Cumulative percentage of peanut plants that exhibited symptoms of TSWV infection.
§ $P = 0.05$.

Periodic disking effectively prevented large populations of volunteer peanut and winter annual weeds from developing, and as a result, reproduction by tobacco thrips was probably limited in disked plots. The impact of disking on brachypterous tobacco thrips could not be determined because not all potential weed hosts were sampled, but it seems likely that disking killed some individuals.

A single application of carbofuran in early March destroyed nearly all brachypterous adult tobacco thrips based on counts from volunteer peanut. This finding may have important implications for spotted wilt management because TSWV was repeatedly detected in brachypterous adults during our study (Chamberlin et al. 1993). In addition, Mitchell et al. (1991) postulated that tobacco thrips diapause during winter months in the soil of harvested peanut fields and that these individuals are the primary winter reservoir for spotted wilt in Texas. If this scenario is accurate, then the potential activity of carbofuran or other soil-active compounds against diapausing thrips merits investigation.

A combination of fallow disking and carbofuran application did not lower spotted wilt incidence in subsequently planted peanut, despite causing substantial reductions in the abundance of brachypterous tobacco thrips, volunteer peanut, and winter annual weeds. However, we believe that the impact of these practices cannot be determined in individual fields because viruliferous adult thrips probably immigrate from surrounding areas. As a result, coordinated area-wide usage of fallow disking and insecticide application probably will be required to assess their usefulness in managing spotted wilt disease.

Acknowledgments

We gratefully acknowledge the technical assistance of Bert Crowe, Peggy Goodman, Simmy McKeown, and Sheran Thompson. We also thank Ben Mullinix for assistance with statistical analysis. Finally, we thank Robert McPherson and Richard Chalfant for reviewing an early version of the manuscript. This study was supported in part by a grant from the Georgia Agricultural Commodity Commission for Peanut.

References Cited

Bald, J. G. and G. Samuel. 1931. Investigations on "spotted wilt" of tomatoes, II. Aust. Commonwealth Coun. Sci. Ind. Res. Bull 106.

Beckham, C. M., R. J. Beshear and H. H. Tippins. 1971. Some winter host plants of thrips. University of Georgia Agricultural Experiment Station Bulletin 86.

Burns, E. C. 1951. A study of some factors influencing wing form in the tobacco thrips *Frankliniella fusca* (Hinds). M. S. Thesis, Louisiana State University, Baton Rouge.

Chamberlin, J. R., J. W. Todd, R. J. Beshear, A. K. Culbreath and J. W. Demski. 1992. Overwintering hosts and wing-form of thrips, Frankliniella spp., in Georgia (Thysanoptera: Thripidae): implications for management of spotted wilt disease. Environ. Entomol. 21: 121-128.

Chamberlin, J. R., A. K. Culbreath, J. W. Todd and J. W. Demski. 1993. Detection of tomato spotted wilt virus in tobacco thrips (Thysanoptera: Thripidae) in harvested peanut fields. J. Environ. Entomol. 22: 40-45.

Cho, J. J., R. F. L. Mau, W. C. Mitchell, D. Gonsalves and L. S. Yudin. 1987. Host list of plants susceptible to tomato spotted wilt virus (TSWV). Univ. Hawaii Coll. Trop. Agric. Hum. Resour. Res. Ext. Ser. 078.

Culbreath, A. K., A. S. Csinos, P. F. Bertrand and J. W. Demski. 1991. Tomato spotted wilt virus in flue-cured tobacco in Georgia. Plant Dis. 75: 483-485.

Culbreath, A. K., J. W. Todd, J. W. Demski and J. R. Chamberlin. 1992. Disease progress of spotted wilt in peanut cultivars Florunner and Southern Runner. Phytopathyology 82: 766-771.

Eddy, C. O. and E. M. Livingstone. 1931. *Frankliniella fusca* Hinds (thrips) on seedling cotton. South Carolina Agr. Exp. Sta. Bull. 271.

Greenough, D. R., L. L. Black, R. N. Story, L. D. Newsom and W. P. Bond. 1985. Occurrence of *Frankliniella occidentalis* in Louisiana: a possible cause for the increased incidence of tomato spotted wilt virus. Phytopathology 75: 1362.

Greenough, D. R., L. L. Black and W. P. Bond. 1990. Aluminum-surfaced mulch: an approach to the control of tomato spotted wilt virus in solanaceous crops. Plant Dis. 74: 805-808.

Hagan, A. K., J. R. Weeks, J. C. French, R. T. Gudauskas, J. M. Mullen, W. W. Gazaway and R. Shelby. 1990. Tomato spotted wilt virus in peanut in Alabama. Plant Dis. 74: 615.

Mitchell, F. L. and J. W. Smith, Jr. 1991. Epidemiology of tomato spotted wilt virus relative to thrips populations, Pp. 46-52. *In* H. Hsu and R. H. Lawson [eds.], Virus-thrips-plant interaction of tomato spotted wilt virus. Proceedings of a USDA Workshop, United States Department of Agriculture, Agricultural Research Service, ARS-87.

McPherson, R. M. and R. J. Beshear. 1990. Thrips fauna in Georgia flue-cured tobacco plant beds and fields. J. Entomol. Sci. 25: 559-561.

McPherson, R. M., R. J. Beshear and A. K. Culbreath. 1992. Seasonal abundance of thrips (Thysandoptera: Suborders Terrebrantia and Tubeluifera) in Georgia flue-cured tobacco and impact of management practices on incidence of tomato spotted wilt virus. J. Entomol. Sci. 27: 257-268.

Morgan, L. W., J. W. Snow and M. J. Peach. 1970. Chemical thrips control: effects on growth and yields of peanuts in Georgia. J. Econ. Entomol. 63: 1253-1255.

Newsom, L. D., J. S. Roussel and C. E. Smith. 1953. The tobacco thrips, its seasonal history and status as a cotton pest. Louisiana Agr. Exp. Sta. Tech. Bull. 474.

Sakimura, K. 1962. *Frankliniella occidentalis* (Thysanoptera: thripidae), a vector of the tomato spotted wilt virus, with special reference to the color forms. Ann. Entomol. Soc. Am. 55: 387-389.

1963. *Frankliniella fusca,* an additional vector for the tomato spotted wilt virus, with notes on *Thrips tabaci,* another vector. Phytopathology 53: 412-415.

Weeks, J. R. J. C. French and A. K. Hagan. 1990. Virus vectoring thrips common in Alabama peanut fields. Alabama Agric. Exp. Stn. High. Agric. Res. 37:9.