# Winter Occurance and Spring Migration of *Frankliniella fusca* (Hinds) (Thysanoptera: Tripidae) in North Carolina Peanut (*Arachis hypogaea* L.) Fields

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**ABSTRACT**

Overwintering of *Frankliniella fusca* (Hinds), tobacco thrips, in North Carolina and their subsequent spring movement into peanut fields were evaluated using two winter sampling techniques and three spring sampling techniques at the Peanut Belt Res. Sta., Lewiston, NC. In the spring of 1992 and 1993, for 14 d following peanut planting, the aerial movement of tobacco thrips was monitored using cylindrical sticky traps, trap plants, and exclusion cages. *Frankliniella fusca* were trapped significantly more often at 0.2 m and 0.9 m than at 1.8 m and during the afternoons. Thrips catch was significantly influenced by prevailing wind direction. No thrips were caught on sticky traps on days when maximum temperatures did not exceed 18.7 C. *Frankliniella fusca* began to colonize emerging peanut plants as they cracked the soil surface on days when there were temperatures above 18.7 C and times when there was no precipitation. Aerial *F. fusca* movement was monitored with sticky traps for three consecutive winters during 1993-96. Tobacco thrips were collected on sticky traps throughout the winter; however, counts were lower in months and years with lower temperatures. Tobacco thrips, caged throughout the winter with peanut plants infected with tomato spotted wilt virus (TSWV), were analyzed for the presence of a nonstructural protein (NSs) encoded for by the small RNA of TSWV and infectivity by ELISA. A total of eight tobacco thrips were collected, of which one tested positive.

Key Words: Overwintering, tobacco thrips, tomato spotted wilt virus.

Tomato spotted wilt (caused by TSWV) is a virus disease of worldwide importance affecting numerous field, vegetable, and ornamental crops (Peters *et al.*,1996). Periodic economic losses attributable to TSWV have occurred in Texas and Georgia peanuts, *Arachis hypogaea* L. (Mitchell and Smith, 1991). At least eight species of thrips transmit TSWV (Ullman *et al.*, 1997). The principal TSWV vector in North Carolina peanut fields is considered to be *F. fusca* (Barbour and Brandenburg, 1994). However, the complex relationship that exists in the field between tobacco thrips, TSWV, and peanuts is poorly defined, thus hindering development of management practices to reduce economic losses resulting from TSWV. The objective of this study was to better understand the environmental factors influencing the spring movement of thrips into and through peanut fields and to determine if overwintering of TSWV-infected thrips could be a potential source of TSWV spread into crops in North Carolina. Overwintering of TSWV-infected tobacco thrips on peanuts has been reported in Georgia (Chamberlin *et al.*, 1993). The ability of tobacco thrips to overwinter on TSWV-infected peanut plants in North Carolina was investigated during the winter of 1995-96. Sampling was conducted in peanut fields and in corn fields, which are often rotated to peanut.

## Materials and Methods

### Winter Trapping

Winter trapping was undertaken to determine if tobacco thrips populations were present and active in peanut and corn fields throughout the winter. Trapping was conducted and tobacco thrips populations were sampled during the winter months at the Peanut Belt Res. Sta. (PBRS), Lewiston, NC. The aerial movement of tobacco thrips was monitored from Dec. through April in peanut fields during three consecutive winters during 1993 to 1996, and in corn fields during two consecutive winters during 1994 to 1996. Traps consisted of a 10.2 cm x 2.9 cm piece of clear acetate film coated on one side with Tanglefoot 7 (Great Lakes IPM, Vestaburg, MI). The film was wrapped around an 11.4 cm section of 1.9 cm diam. polyvinyl chloride (PVC) pipe painted blue (Sinclair Paint, Co., Tucson, AZ) (Matteson and Terry, 1992). Traps were slid onto a 61 cm section of 1.3 cm diam. conduit pipe and held at 0.2 m above ground level. Four traps were placed in a 1 to 2 ha peanut field and in an approximately 1 ha corn field each year. Traps were replaced monthly during Dec., Jan., and Feb., and every 2 wk during March and April of each year. After each sampling period, the sticky sheets were removed from the PVC tube and placed sticky side down on polyethylene film until the thrips could be removed after soaking for 15 min in Histoclear' (Great Lakes IPM, Vestaburg, MI). Thrips were then mounted on a microscope slide with CMC-10 Mounting Media (Masters Chem. Co., Inc., Elk Grove, IL), identified, and counted using a dissecting microscope.

### Winter Survival of TSWV Infected Tobacco Thrips

The winter survival of viruliferous tobacco thrips was investigated to determine whether overwintering thrips could be a winter reservoir of TSWV in North Carolina. Forty-five field-grown peanut plants (cv. NC 7) showing visible symptoms of TSWV, including ring spots and twisted petioles, were dug from a field within 10 k of the PBRS on 23 June. The plants were transplanted to a field at the PBRS on the same day into groups consisting of three plants (15 groups of three plants each). Individual plants in a group were 25 cm apart and groups were 1 m apart in a row. Dead plants were replaced on 20 and 27 July with diseased plants from the original field.

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Each group of three plants was enclosed in a circular cage on 10 Aug. with a perimeter of 1.8 m and a height of 61 cm. The cages consisted of a wire frame and a tubular sleeve made of thrips-proof nylon screen (Bugbed 123™, Greenthumb Group, Downers Grove, IL). The frame and screen extended 15.2 cm into the soil. The screening was gathered and twisted above the plants then secured with nylon string. Three additional cages without peanut plants were erected on methyl bromide fumigated soil. On 10 Aug., from 100 to 200 laboratory-reared adult *F. fusca* were added to each group of caged peanut plants. No thrips were added to the three cages without peanut plants. All cages were then secured with duct tape in addition to the nylon string. Water was applied to the soil at the perimeter of the cages as required by the plants.

The peanut plants in the cages died during the low temperatures of Nov. and Dec. Weeds within cages were killed by an application of Gramoxone Extra® (Zeneca Ag Products, Inc., Cordova, TN) with a hand-held sprayer at 1/3 oz per gal. on 1 Feb. 1996 to eliminate alternative thrips host plants.

Beginning on 1 March, and at 7 d intervals thereafter, a 1 wk old greenhouse grown peanut seedling was added to each cage. Each seedling was held in a watered floral tube that was inserted in the soil so that the cotyledons were at ground level. Previously placed plants were collected every week for 8 consecutive wk as new seedlings were added to cages. Collected plants were placed individually into sealable plastic bags and examined in the laboratory for the presence of tobacco thrips.

All tobacco thrips recovered from the peanut seedlings were assayed for TSWV by enzyme-linked immunoabsorbant assay (ELISA) using a monoclonal antibody (Bandla *et al.*, 1994). This monoclonal antibody bonds to a nonstructural protein encoded for by the small RNA (NSs) of TSWV. The protein is only present during replication of the virus. Replication of the virus in thrips is necessary for virus transmission (Ullman *et al.*, 1993).

**Movement into Peanut**

In an effort to understand the origins and time of primary tobacco thrips colonizers in newly planted peanut fields and gain insight into the overwintering locations of TSWV, samples of *F. fusca* were taken during the period when peanut fields were being colonized. The movement of tobacco thrips into a peanut field was monitored for 14 d post-planting in 1992 (13-26 May) and 1993 (12-25 May) in two fields at the PBRS. Cylindrical sticky traps were used to monitor aerial dispersal of thrips. Trap plants were used to monitor colonization of peanut plants. The number of days after peanut emergence or cracking until thrips colonization was monitored using removable thrips exclusion boxes.

***Sticky Traps***. Aerial movement of thrips was sampled with sticky traps at different heights to indicate short or long distance movement. Each year, thrips counts were taken from 13 locations within a field arranged on two perpendicular transects with six locations each, plus a common midpoint. Locations along each transect were 13.72 m apart. At each location, three sticky traps, of the type used during the winter surveys, were slid onto a 2.4 m x 1.3 cm section of conduit pipe driven into the ground. Traps were spaced on the conduit pipe at 0.2 m, 0.9 m, and 1.8 m above the soil surface. The ends of each PVC trap were notched with two grooves 180° apart that allowed the tube to rest in a stable position on a 0.64 cm diam. wooden dowel inserted through the conduit pipe. The dowels were aligned along a north/south axis and the compass cardinal direction of each captured thrips was recorded. Traps were changed three times per day at 0600, 1200, and 1800 hr. Sticky traps were collected and mounted on slides for identification as described previously in Winter Trapping. Collection of thrips on sticky traps was characterized as either being in the direction of the prevailing wind, or not being in the direction of the prevailing wind during the trapping interval. Tobacco thrips counts were recorded by day, location, elevation, sample period, and compass cardinal direction (N, S, E, or W).

***Trap Plants***. The second method of sampling aerial movement of tobacco thrips used 14 to 21d old potted (10.2 cm diam. pots) peanut plants placed in the field rows 3 m north of each of the sticky trap locations. Each plant was trimmed to a uniform size with three unopened tetrafoliate leaves prior to being placed in the field. All of the plants were replaced three times per day at 0600, 1200, and 1800 hr. At each of the sampling periods, the plants were cut just below the cotyledons with scissors and placed in a vial with 70% ethanol. Thrips collected from the plants were mounted as described above and the day, location, and sample time were recorded for each tobacco thrips.

***Exclusion Boxes***. To determine the peanut stage when primary thrips colonization occurs, exclusion boxes were used in the same field where the trap plants were used. Fifty-six clear plastic boxes (50.8 cm x 30.5 cm x 20.3 cm) were placed over the sown peanuts rows immediately after seeds were planted. The boxes were spaced throughout the field, 13.5 m apart within rows and 9 m apart across rows, and each box was assigned a location number. Each day three randomly selected boxes were removed to expose the row sections beneath the boxes to migrating thrips. Boxes were replaced after 24 hr. A fourth box was also randomly selected each day and the peanut seeds/plants were removed to estimate plant development. At the end of the 14 d period, all above ground foliage from each box was removed with scissors and placed in 70% ethanol. Adult tobacco thrips counts per box were recorded.

***Weather Monitoring***. Daily minimum and maximum temperatures and precipitation measurements were collected at a weather station located on the PBRS. Wind direction information was collected hourly at two airport weather stations. The stations were located at the Rocky Mount/Wilson Airport (55 k SW) and the Elizabeth City Airport (85 k NE). Readings from these two stations were compared and the prevailing wind direction was recorded when both stations reported the same wind direction. Weather data collected at the nearby airports were provided by the State Climate Office of North Carolina.

***Statistical Analysis***. Winter sticky trap thrips counts were considered too low for statistical analysis. Tobacco thrips counts from spring sticky traps and trap plants were analyzed by factorial analysis of variance using the General Linear Models Procedure and Least Squares Means of SAS (SAS Inst., 1998) with each of the 13 locations as a replicate to test for the effect of height and direction on the independent variables year, day, and time. The least significant differences in the reported means of counts at different heights and from different sample periods were calculated by t-test with heights as replicates. Segmented regression with Proc NLIN of SAS was utilized to estimate the maximum temperature where daily thrips counts on sticky traps becomes nonzero.

# Results

## Winter Trapping

Tobacco thrips were caught on sticky traps during the winter months in each of the sampling seasons (Table 1). More thrips were trapped in the winter of 1994-95. This winter experienced the warmest temperatures of the three winters sampled with only three recorded days when temperatures fell to -10 C, which resulted in a greater abundance of winter weedy plant habitat for thrips. The winter of 1993-94 experienced 4 d with temperatures < -10 C, and 1 d with a temperature of -15 C, all occurring in January. An equal number of thrips were trapped in peanut fields during the winters of 1993-94 and 1995-96. The coldest recorded temperatures during the winter of 1995-96 occurred in February when temperatures reached -10 and -16.7 C. A low of -7.8 C was recorded on 10 March 1996.

**Table 1. Trapping period mean temperatures and total number of tobacco thrips collected from cylindrical sticky traps set 20.3 cm above ground level at a rate of four traps per field.[a]**

| | Season/crop | | | | | |
|---|---|---|---|---|---|---|
| | 1993-94 | | 1994-95 | | 1995-96 | |
| Trap period | Mean temp. | Peanut[b] | Mean temp. | Peanut/ corn | Mean temp. | Peanut/ corn |
| | C | # thrips | C | # thrips | C | # thrips |
| December | 5.4 | 0 | 9.5 | 12/19 | 9.7 | 0/0 |
| January | 3.5 | 0 | 6.5 | 2/1 | 8.6 | 1/0 |
| February | 6.7 | 0 | 5.5 | 0/1 | 10.9 | 0/2 |
| 1-14 March | 10.1 | 0 | 10.0 | 18/13 | 6.7 | 0/1 |
| 15-31 March | 12.7 | 0 | 12.5 | 21/18 | 10.0 | 0/0 |
| 1-14 April | 16.4 | 1 | 14.2 | 20/22 | 13.2 | 4/0 |
| 15-30 April | 19.6 | 4 | 17.4 | 22/58 | 18.2 | 0/5 |

[a]One peanut field was trapped in 1993-94, and one peanut and one corn field were trapped in the two subsequent winters (Bertie Co., NC, 1993-1996).

[b]A peanut field at PBRS was monitored during the winter of 1993-94, and a peanut field and a corn field were monitored in the two subsequent winters.

## Winter Survival of TSWV Infected Tobacco Thrips

A total of eight adult tobacco thrips were collected from the overwintering cages: seven on 6 March 1996, and one on 14 March. All thrips were analyzed by ELISA. A single thrips, collected on 6 March, tested positive for TSWV by ELISA. The optical density reading for this thrips, 0.6780 nm, was greater than three times the healthy, or non-TSWV, control's standard deviation plus the healthy control's mean, 0.0220 nm.

## Sticky Traps and Trap Plants

Location of sticky traps and trap plants was not a significant ($F = 1.56$; $df = 12$; $P = 0.09$; and $F = 2.10$; $df = 12$; $P = 0.02$, respectively) factor in the number of tobacco thrips trapped in either year. However, the number of thrips trapped per day per trap varied significantly in each year for both sticky traps ($F = 15.99$; $df = 26$; $P < 0.001$) and trap plants ($F = 6.99$; $df = 26$; $P < 0.001$). Significantly more thrips were trapped at the two lower trap heights in both years on the sticky traps ($F = 8.19$; $df = 2$; $P < 0.001$) (Table 2). Number of thrips varied significantly with sampling time in both years for sticky traps ($F = 225.4$; $df = 2$; $P < 0.001$) and trap plants ($F = 35.4$; $df = 2$; $P < 0.001$). More tobacco thrips were caught in the afternoons than in the mornings or the evenings with both sticky traps and trap plants (Table 3). Spring migration of thrips occurs primarily in the afternoon when temperatures are the highest.

## Exclusion Boxes

In 1992, a total of 23 tobacco thrips were collected from the plants exposed to colonization by thrips for a 24-hr period beginning on day 9 post planting when four thrips were collected. Peanut plants were cracking the soil surface on day 5 post planting; however, precipitation (≥ 0.5 cm) was recorded on days 6, 7, and 8. Days 7 and 8 also were cool (maximum temperature ≤ 19.6 C). In 1993, a total of 34 tobacco thrips were collected from peanut plants exposed to colonization for 24 hr beginning on day 4 post planting when a single thrips was collected. Peanut plants were cracking the soil surface on day 4 post planting in 1993.

## Weather Effects

In both years, numbers of thrips caught on sticky traps varied significantly ($F = 26.48$; $df = 3$; $P < 0.0001$) with compass direction. The number of tobacco thrips caught on

**Table 2. Total tobacco thrips per trap per day at three trap heights above the ground (Bertie Co., NC, 1992-93).**

| | | Trap height (m)[a] | | |
|---|---|---|---|---|
| Year | Total[b] | 0.2 | 0.9 | 1.8 |
| | n | ----------no. thrips---------- | | |
| 1992 | 546 | 0.094±0.02 a | 0.056±0.01 b | 0.044±0.01 b |
| 1993 | 546 | 0.058±0.01 ab | 0.061±0.01 a | 0.044±0.01 b |

[a]Means within rows followed by the same letter do not differ significantly at $P \leq 0.05$ (LSD test).

[b]Sample size made up of traps at 13 locations and three heights monitored for 14 d.

**Table 3. Mean number of tobacco thrips and SEM per sticky trap and trap plant at each sampling period with years combined (n = 364) (Bertie Co., NC, 1992-93).[a]**

| Sampling period[b] | Sticky traps | Trap plants |
|---|---|---|
| hr | no. | no. |
| 0600-1200 | 0.43±0.04 b | 0.12±0.02 b |
| 1200-1800 | 1.51±0.09 a | 0.34±0.04 a |
| 1800-0600 | 0.19±0.03 c | 0.07±0.01 b |
| LSD | 0.16 | 0.08 |

[a]Means in columns followed by the same letter do not differ significantly at $P \leq 0.05$ (LSD test).

[b]Sampling periods are presented in 24-hr format.

the sticky traps was significantly greater on the portion of the trap facing the prevailing wind direction in 1993 ($F = 6.70$; df = 3; $P < 0.011$) (Table 4). Weather station wind direction data were not available for 1992.

Precipitation and/or low temperature were associated with low numbers of tobacco thrips being trapped (Fig. 1). No thrips were trapped on days when mean maximum temperature failed to reach at least 18.7 C (Fig. 2) regardless of rainfall. Precipitation also negatively influenced the number of tobacco thrips trapped on the sticky traps. However, this was difficult to demonstrate with the data in Figure 1 because high numbers of thrips were trapped in periods that fluctuated between rainy and clear skies, as on day 6 in 1992 and day 7 in 1993. Low numbers of thrips were trapped during periods of low temperature even when there was no rainfall; however, it is apparent that rainfall also has a negative impact on aerial movement of thrips.

**Table 4. Mean number of tobacco thrips captured and on cardinal compass orientations of cylindrical sticky traps under different prevailing wind conditions (n = 365) at the Peanut Belt Res. Sta., Lewiston, NC (Bertie Co., NC, 1993).[a]**

| Trap orientation | Wind direction: South or west[b] | Wind direction: Not south or west |
|---|---|---|
| | ----------no.---------- | |
| South or west | 0.12 ± 0.03 a | 0.02 ± 0.01 b |
| Not south or west | 0.03 ± 0.02 b | 0.04 ± 0.02 b |

[a]Means across columns and rows followed by the same letter do not differ significantly at $P \leq 0.05$ (LSD test).

[b]The prevailing wind direction at the PBRS during the May 1993 sampling period was from the south to southwest.

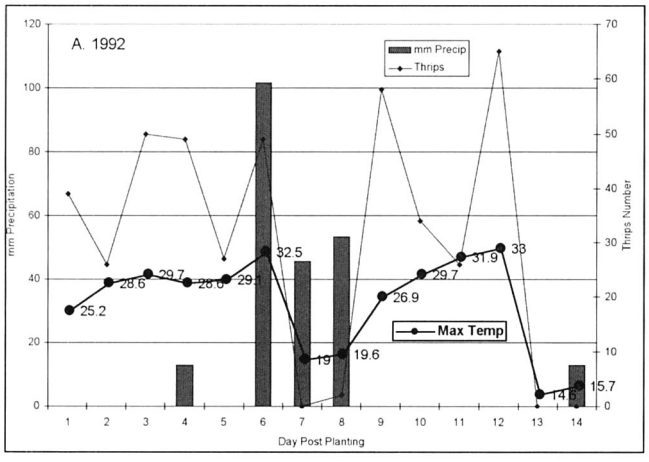


**Fig. 1. Daily tobacco thrips catch and precipitation 14 d post planting with maximum daily temperature superimposed on figure (13-26 May 1992 and 12-25 May 1993) at the PBRS, Bertie Co., NC.**

## Discussion

At the time of these experiments, North Carolina had not experienced significant economic losses to peanut due to

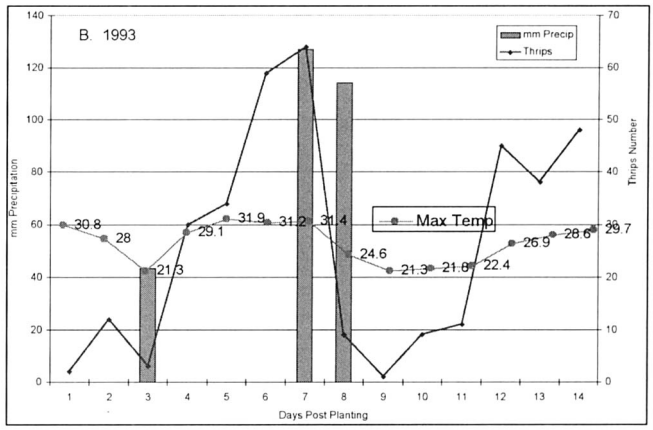


**Fig. 2. Total of daily tobacco thrips catches on sticky traps plotted by daily maximum temperatures for the 14-d trapping periods during May 1992 and 1993 at the PBRS, Bertie Co., NC.**

TSWV as had Georgia and Texas even though the virus has been present in the state since 1990. Differences between the states in the varieties that are grown may account partially for the comparatively low incidence of TSWV in North Carolina, but it is likely that environmental differences between the regions also play a role. Winter survival of tobacco thrips in North Carolina may be related to temperature. The low number of captures of 1993-94 and 1995-96 may reflect a direct impact of cold temperatures on thrips survival. In these winters, temperatures fell quickly to ≤ 15 C and potentially reduced the thrips' ability to acclimate (McDonald *et al.*, 1997). Winter thrips survival also may be an indirect result of cold damage to thrips host plants resulting in fewer sites for thrips to develop and for thrips to use as a refuge from the cold temperatures. However, more information is required before a strong correlation can be made between winter temperatures and tobacco thrips overwintering survival.

In Georgia, a high proportion of the winter tobacco thrips population is brachypterous (Chamberlin *et al.*, 1992). The brachypterous form would not have been trapped on the aerial traps used in this study. Because of the colder winter temperatures in North Carolina, a large proportion of tobacco thrips also may survive that can allow spring populations to build rapidly and spread TSWV.

Previous experiments have established that tobacco thrips can overwinter in North Carolina (Cho *et al.*, 1995). In the current experiment, it was shown that TSWV viruliferous tobacco thrips also can overwinter in North Carolina. At the time the single viruliferous thrips was collected (6 March), there were numerous weed species were present at the PBRS which are suitable hosts for both TSWV and tobacco thrips. Overwintering viruliferous thrips may move into peanut fields at planting. However, it seems more likely they transmit TSWV to alternate host plants where it can be acquired by subsequent generations of tobacco thrips in the spring, which then transmit the virus to other plants including peanuts. Groves *et al.* (2001) demonstrated that both tobacco thrips and western flower thrips (*F. occidentalis*) overwintering on infected winter annual weeds spread TSWV to other weeds in late winter and early spring.

At the time of peanut planting in North Carolina, tobacco thrips are already abundant and dispersing. This has been documented in North Carolina (Barbour and Brandenburg, 1994) and also in Virginia (Birdswhistell, 1992). Most of the

dispersing thrips move close to the ground over peanut fields and movement appears to involve short distances. This has been documented indirectly in Georgia (Camann *et al.*, 1995) and in Australia (Latham and Jones, 1997) with *F. occidentalis*, where the distribution of TSWV in a field was followed. Additionally, tobacco thrips movement in spring can be restricted by low temperatures and by precipitation.

The evidence collected in this experiment indicates that in addition to long distance thrips movement on prevailing winds (Lewis, 1973) there is an association between wind direction and direction of tobacco thrips movement. This suggests that most thrips are of local origin. Since it has been shown that most tobacco thrips are migrating to peanut fields from relatively short distances, immigrating populations likely originate in nearby weedy vegetation (Cho *et al.*, 1986; Groves *et al.*, 2002) located upwind from peanut fields. By surveying the upwind weed populations and resident thrips for TSWV, it may be possible to determine the relative threat an individual peanut field is subject to each spring. The ability to predict the relative abundance of tobacco thrips adjacent to peanut fields, their level of TSWV infection, and the probability of these populations moving into adjacent peanut fields would be important for management. A number of factors listed in Georgia's TSWV Risk Assessment Index (Yancey, 1997) are proposed to affect field incidence of TSWV in peanuts. These include historical occurrence of TSWV in peanut fields, peanut cultivar, planting date, plant spacing, and the use of chemical controls. The research reported herein indicates that additional environmental factors, such as low winter temperatures and the localized spring wind patterns, are important in the early incidence of thrips and TSWV in peanut fields.

The winter occurrence of viruliferous tobacco thirps in North Carolina indicates that localized thrips populations are present and may migrate to native host plants and transmit TSWV throughout the winter and spring. A spring generation of TSWV-infected tobacco thrips is then present and can migrate quickly to peanuts soon after they crack the soil surface and the environmental conditions are favorable for migration. The presence of viruliferous tobacco thrips in North Carolina throughout the year indicates that the occurrence of TSWV is not dependent on long distance movement of infected thrips from southern locations and that the prevalence of the disease probably increase as the virus load in the environment increases with time as infected tobacco thrips migrate.

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