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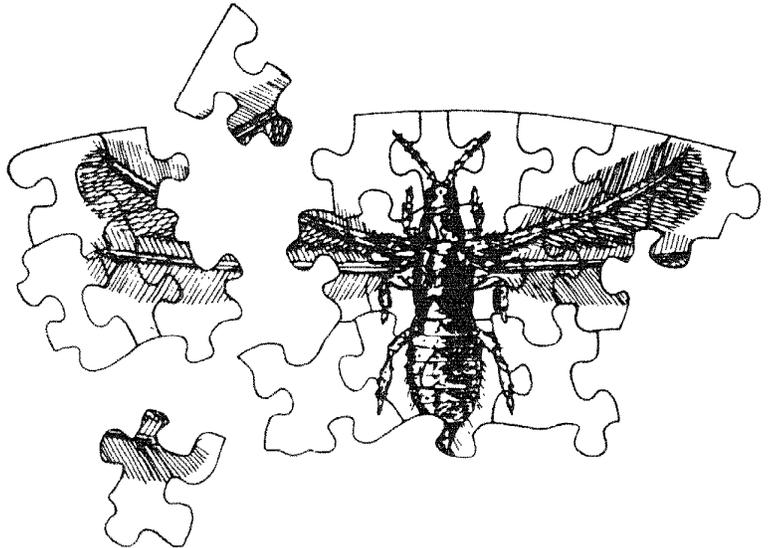
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University of Vermont

General Technical Report NE-147

# Towards Understanding Thysanoptera



**Editors:**

**Bruce L. Parker  
Margaret Skinner  
Trevor Lewis**

## **ACKNOWLEDGMENTS**

This conference would not have been possible without the dedicated efforts of many people, only a few of whom can be mentioned here. We thank Steve LaRosa for organization of special events and Eva Noronha-Doane for facilitating registration. Recording of the conference was expertly supervised by Luke Curtis; transcriptions were prepared by Peggy Verville and Nancy Burgess from the University of Vermont, Department of Plant and Soil Science; and layout of the proceedings was prepared by Frances Birdsall. Thanks also to the numerous personnel from the Vermont Department of Forests, Parks and Recreation who helped with transportation and many other technical details.

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## TOWARDS UNDERSTANDING THYSANOPTERA

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**Proceedings**  
**International Conference on Thrips**  
**February 21-23, 1989, Burlington, Vermont USA**

General Technical Report NE-147  
U.S. Department of Agriculture, Forest Service  
Northeastern Forest Experiment Station  
Radnor, PA 19087  
1991

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State of Vermont

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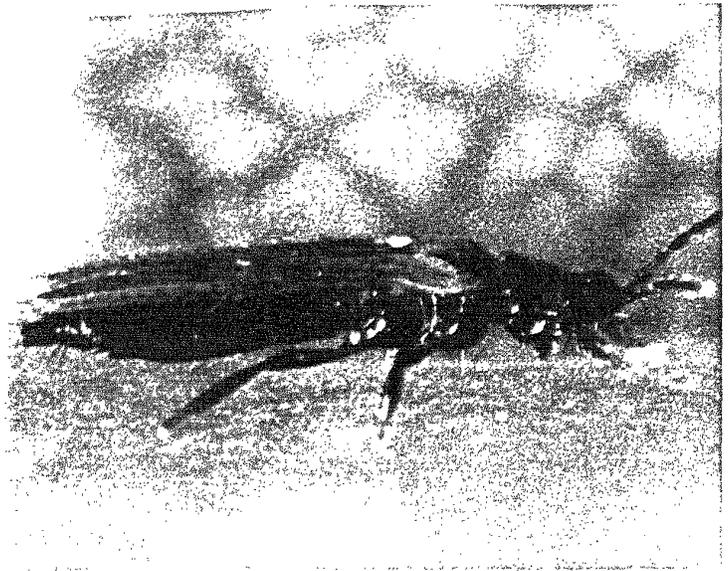
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**CLOSING REMARKS**

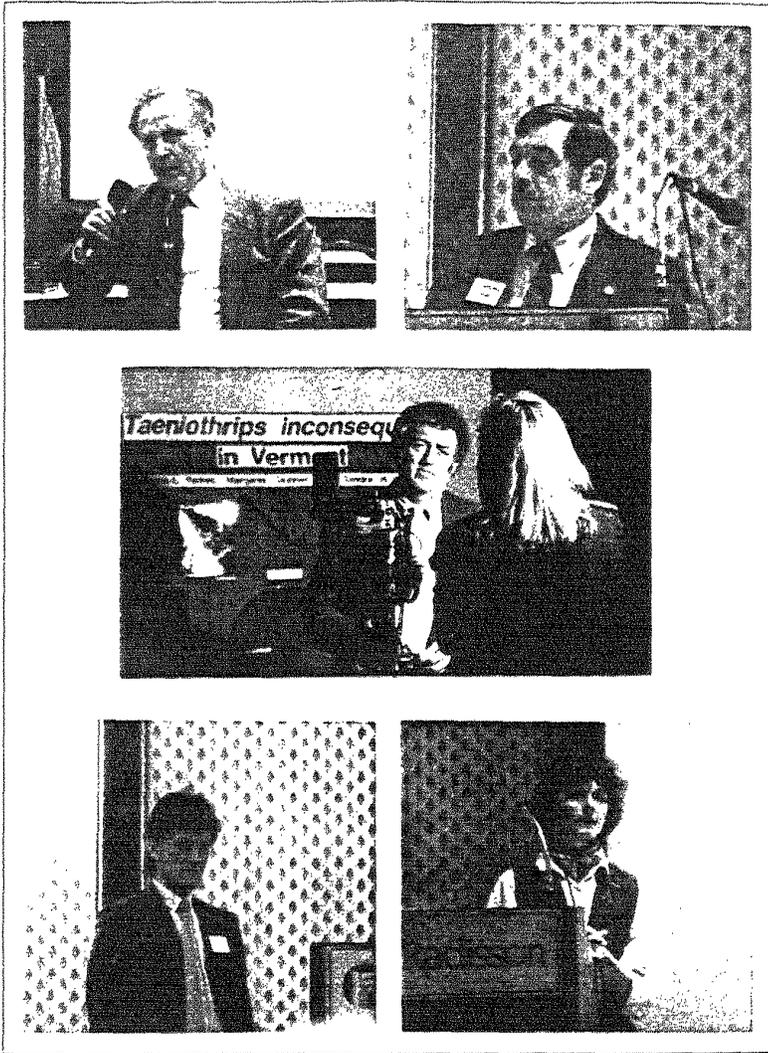
Donald L. McLean, Dean and Director  
College of Agriculture and Life Sciences  
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**APPENDIX**

List of conference participants



PEAR THRIPS, *Faeniothrips inconsequens* (Uzel)  
(photo by T. E. Downer)



A few of the conference participants (from top left to bottom right): Trevor Lewis, Institute of Arable Crops Research; Conrad Motyka, VT Department of Forests, Parks and Recreation; Bruce L. Parker, The University of Vermont; Nick J. Mills, Commonwealth Institute of Biological Control; Margaret Skinner, The University of Vermont.

## PREFACE

Pear thrips, *Taeniothrips inconsequens* (Uzel), first surfaced as a pest of sugar maple, *Acer saccharum* Marsh, in Pennsylvania in the late 1970s. Though similar damage was observed in Vermont in the early 1980s, it was probably misdiagnosed as frost damage until 1985, when finally thrips were positively confirmed as the causal agent. Pear thrips damage to sugar maple fluctuated greatly from year to year, raising only slight concern among sugarmakers and forest managers. However, the situation changed dramatically in the spring of 1988, when pear thrips caused widespread, severe foliage damage to sugar maple in southern Vermont (over 200 thousand hectares) and other New England States. Recognized as a potential threat to forest health, pear thrips received tremendous media coverage, including the front page of the New York Times and the CBS Evening News!

The response in Vermont to this crisis was swift. With support from the Vermont legislature and the Department of Agriculture, a major research effort was launched, coordinated jointly by the University of Vermont and the VT Department of Forests, Parks and Recreation. This pest presented unique research and management challenges. Pear thrips on sugar maple represented a known pest on a new host in a new habitat. As of 1988 almost no information existed on this insect in a sugar maple forest. In addition thrips in general were virtually unknown as a northern hardwood forest pest, and forest managers knew little about how to handle such an insect. Finally, because thrips are such small insects, new and specialized methods were needed for survey and study of this pest.

As Vermont's research efforts got underway, it became clear that much could be learned from scientists familiar with other thrips species. The goal of this conference was to gather these specialists together to present their ideas on thrips survey and management methodology, particularly as it related to pear thrips in a forest setting. Participants came from across the United States, Canada and the United Kingdom to share their expertise. Though many didn't know that a "sugarbush" was not a shrub, but a natural stand of mature 30-m-tall sugar maple trees (100 ft), they all knew what maple syrup was! Certainly by the end of the conference all of the participants recognized the unique value of the sugar maple to the heritage and economy of Vermont and the Northeast, and shared our concern for its future in light of the threat of pear thrips.

We thank all of the conference participants who freely and enthusiastically shared their knowledge. Without their expertise and continued technical support, our pear thrips research would not have progressed as far or as fast as it has. We thank all those attending the conference for helping to make it a productive event. Though the pear thrips problem is far from being "solved," this conference started the research process on a solid footing.

## **SURVEY AND DETECTION**

AGROECOLOGICAL NICHES  
AND THRIPS (THYSANOPTERA: THIRIPIDAE) DYNAMICS<sup>1</sup>

Michael E. Irwin

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Champaign, Illinois USA

In 1975, Illinois experienced an exceptionally mild winter, followed by a warm spring. This sequence of climatic events resulted in a massive outbreak of the soybean thrips, *Sericothrips variabilis* (Beach), along with large numbers of the flower thrips, *Frankliniella tritici* (Fitch). The outbreak covered an area of over 600 thousand hectares (1.5 million acres) of soybean and was particularly heavy in the southern third of the state. In areas where thrips densities were particularly high early in the season, entire fields of young soybean seedlings began to die, causing panic within the farming community. In their attempts to resolve the situation, growers applied large quantities of pesticides to over 20,200 hectares (50,000 acres) during the first week after the crop had begun to emerge.

Heretofore, massive invasions of thrips had not been recorded in soybean; therefore, damage potential and yield reductions resulting from thrips attacks on this crop had not been quantified. Furthermore, the possibility existed that one or both species of thrips were capable of transmitting tobacco ringspot virus (Messieha 1969, Bergeson et al. 1964) from wild hosts or soybean, where it is transmitted through seeds of infected plants, to soybean. Infection by tobacco ringspot virus dramatically reduces the quality and quantity of soybean grain.

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<sup>1</sup>I wish to thank Dr. Bruce L. Parker and Dean Donald L. McLean for involving me in this important symposium and for providing such cordial hospitality. I am also grateful to the State of Vermont for providing the funds so that I could participate. I dedicate this paper to the memory of the late Dr. Lewis J. Stannard, a thrips systematist whose life was dedicated to enhancing the knowledge base of North American thrips.

Extension specialists had only tentative responses to farmer requests for information regarding the thrips outbreak in soybeans because no knowledge base existed.

The following commentary does not address the virus transmission issue. (As a point of information, tobacco ringspot virus was subsequently found not to be a consideration because *S. variabilis* apparently does not transmit the virus and *F. tritici* does so only very inefficiently.) Instead, this paper recounts the outcome of several experiments undertaken between 1975 and 1977 to determine the ecological niches occupied by those two thrips species in relation to soybean phenology (Irwin et al. 1979). This information should prove useful to the entomological community of Vermont and other sections of northeastern North America as they mobilize to resolve the problem of the pear thrips on sugar maple.

#### Phenology of Soybean and Developmental Stages of Growth

Soybean, *Glycine max*, is a very dynamic, widespread crop in the midwestern and north central United States. It was introduced into the United States from China in 1765, but only became known throughout the eastern and central portions of the United States after the end of the 19th century (Howell 1983). Like most annual row crops, soybean plants change dramatically as the season progresses. These changes are important to the spatial and temporal distribution of both thrips species and, thus, must be defined. What follows is a brief description of soybean growth, each stage of which is followed, in parentheses, by a code identifying that stage, adapted from Fehr & Caviness (1977).

Upon germination, the soybean plant emerges as a pair of thick, green cotyledons ( $V_0$ ), followed about a week later by a pair of unifoliate leaves ( $V_1$ ). Thereafter, throughout the first half of the growing season, the plant puts out a series of alternate trifoliolate leaves that are coded  $V_2$  through  $V_n$ , the larger numbered trifoliolate leaves appearing later in the season and higher in the canopy. Depending upon soybean cultivar and local climate, flowers first appear ( $R_1$ ) at around 40 days after

planting. The field reaches full flowering ( $R_7$ ) shortly thereafter. When a plant has at least one pod that is 5 mm in length at one of the four uppermost nodes on its main stem, it has reached the "beginning pod" stage ( $R_3$ ). It reaches the "full pod" stage ( $R_4$ ) when at least one pod at one of the four uppermost nodes on the main stem reaches 20 mm in length. The "beginning seed" stage ( $R_5$ ) is reached when seeds in one of the pods at one of the four uppermost nodes on the main stem reach a length of 3 mm. When the green seeds in those pods completely fill the pod cavity, the "full seed" stage ( $R_6$ ) has been reached. The beginning of maturity ( $R_7$ ) is reached when one normal pod on the main stem has a mature, brownish or grayish pod color. "Full maturity" ( $R_8$ ) occurs when 95% of the pods have reached their mature pod color. A coding of  $V_{12}$ ,  $R_4$ , then, indicates that twelve nodes and thus twelve layers of leaves exist along the main stem and the plant is in the "full pod" stage of development.

Soybeans grow rather evenly, the heights of the different plants in a field being very similar; thus very even foliage with a smooth canopy is the rule. Soybean growth is dynamic. Plants begin as seedlings, increasing dramatically in terms of niches, both above and below ground, that are potentially occupied by fauna. Towards the end of the season, the leaves senesce and the plant becomes a naked frame containing bountiful pods at its nodes, each pod enclosing about three seeds. Thus, the niches available for thrips increases throughout most of the growing season, then decreases rapidly as the plant begins to senesce. The temporal component of niche availability is thus dictated by plant phenology.

#### Biology of Both Thrips Species

Adults of both species are probably migratory; they immigrate from the southern region of the central United States perhaps even Mexico. Early season migrant *S. variabilis* colonize alfalfa and other broad leaved plant species, then move to and reproduce on soybean throughout much of the growing season. Similarly *F. tritici* is found on many grass and broad leaved host plants, but, for the most part,

colonizes flowering parts of these plants. *F. tritici* is attracted to maize when it is silking, but before and after silking, it often colonizes soybean.

Eggs of both species are laid in leaf tissue. First instars emerge from eggs and begin feeding by sucking fluids from individual plant cells, leaving silvery, streaked feeding damage. The first instar is followed by two further larval stages, the last of which, after having finished feeding, drops to the ground, enters a prepupal stage, then pupates in the soil, and ecloses as an adult a week to ten days later. After mating, egg laying commences.

#### Alighting Distribution of Thrips within a Soybean Field

Landing activity was monitored by sticky-coated green tile traps (Irwin 1980) set horizontally at canopy height within soybean rows (Irwin & Yeagan 1980). These traps have a reflectance spectrum very similar to soybean leaves; thus, the thrips should behave as though they were landing on foliage, neither being attracted to nor repelled from the traps. These traps, therefore, measure landing activity, not population abundance or density in the canopy.

In 1976, ten green tile traps were placed at 50 m intervals along a transect across an 3.2-hectare field of soybean, cv. Williams, in Tolono, Ill. The first and tenth traps were placed in grass strips outside of the field. Three species of thrips were trapped abundantly, the two that colonize soybean and a third, *Frankliniella fusca* F., that does not. For the two species that colonize soybean, a relatively uniform landing rate occurred across the field, but outside the field in the grassy strips, landing rates were relatively low. The reverse occurred for the *F. fusca*, a grass-inhabiting species. It is clear that both species that colonize soybean are more abundantly trapped within the field, while the species that does not colonize is most abundantly trapped in the grassy strips (Fig. 1). Furthermore, both soybean-colonizing species had relatively uniform landing rates within the field, when averaged over the growing season.

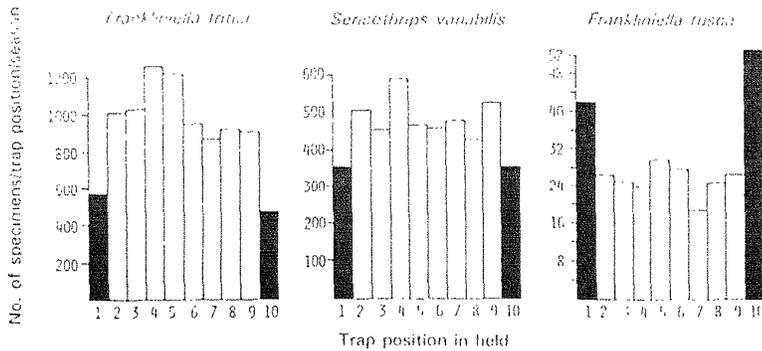


Figure 1. Distribution of three species of thrips in a south (S) to north (N) transect of a field of soybean, cv. Williams, in Tolono, Ill., 1976. Total specimens captured on horizontal green sticky traps during the growing season. Black bars represent traps located outside of the soybean field in grass borders. White bars represent traps located within the soybean field.

#### Seasonal Landing Rates of Thrips in a Soybean Field

The same soybean field in Tolono, Ill., was monitored for landing activity using horizontal sticky green tiles over two seasons, 1976 and 1977. Trends (Fig. 2) indicate a double activity peak of *F. tritici* both years even though there was a temporal displacement in peak activity one year over the other. A single peak of *S. variabilis* activity occurred each season; it too was displaced from one year to the next, earlier in 1977, later in 1976. I postulate that this may be due to a much colder winter preceding the 1976 than the 1977 season.

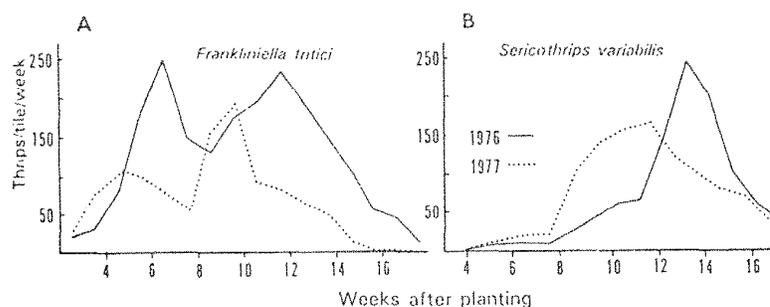


Figure 2. Flight activity curves of two thrips species in soybean for the 1976 and 1977 growing seasons Tolono, Ill. (A) *Frankliniella tritici*; (B) *Sericothrips variabilis*.

#### The Influence of Wind on Flight Direction

Thrips movement directly above the soybean canopy was monitored with a specially designed wind-directed trap. This trap (Fig. 3) was composed of a vein and shaft, which kept the axis oriented into the wind; and a set of four, small, clear plastic cups cut vertically in half--one half centered windward, the other centered leeward--and positioned perpendicular to the shaft. The cups were covered with vaseline and changed daily. The trap was very sensitive to wind changes, thus allowing us to compare the numbers of thrips adhering on the windward and leeward sides of the cups.

Over the entire soybean growing season, most *F. tritici* were found on the leeward side, with far fewer on the windward side, whereas *S. variabilis* showed the opposite trend (Fig. 4). Most *S. variabilis* were found on the windward side, with far fewer taken on the leeward side.

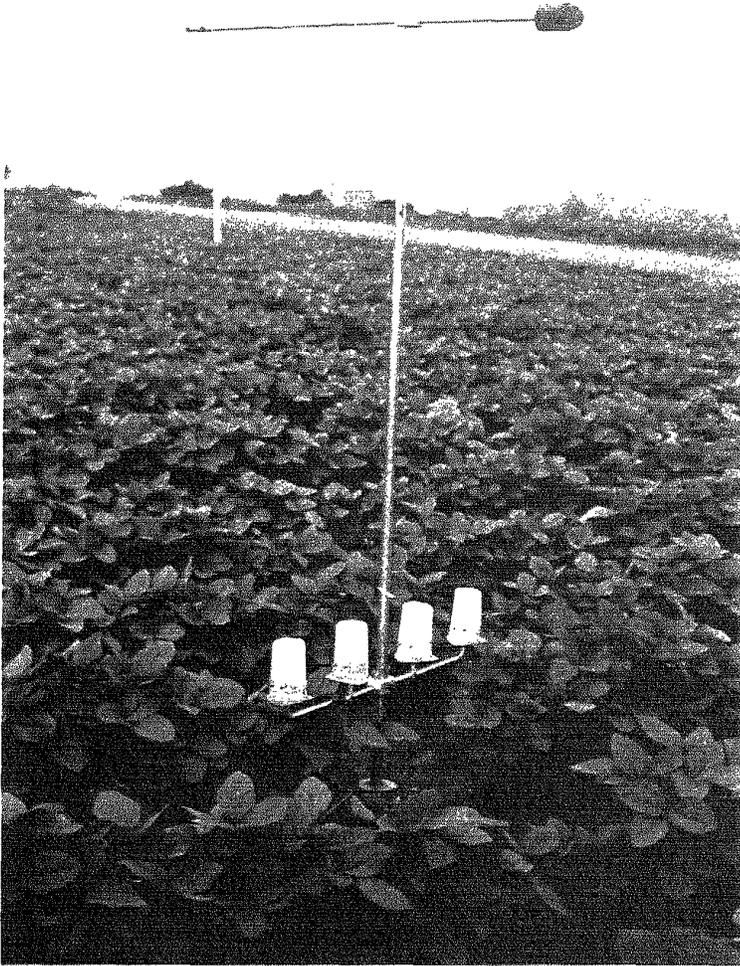


Figure 3. Modified wind-directed, vertically oriented trap for capturing small insects on windward and leeward sides of cylindrical, sticky-coated polyethylene cups.

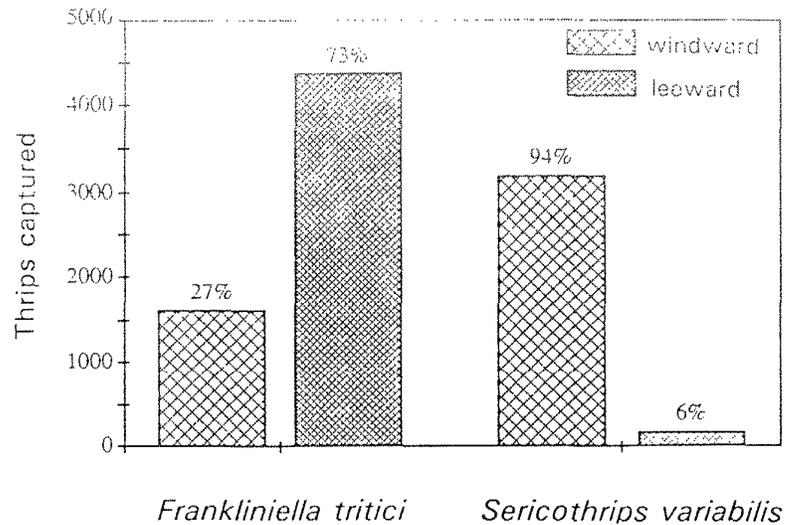


Figure 4. Proportion of two species of thrips captured on a vertically oriented cylindrical sticky trap in soybeans during the 1975 growing season, Urbana, Ill.

It seems most reasonable to postulate that those specimens collected on the windward side were being blown with the wind while those collected on the leeward side were flying against it. Because thrips are such weak flyers, those that were collected on the leeward side were probably flying at times when wind speeds were very low. This great difference in flight behavior between the two soybean-colonizing thrips species serves to point out the dangers in generalizing from one species to another.

#### Vertical Stratification in the Canopy

The within-canopy stratification of both soybean-inhabiting species of thrips was resolved so that a simplistic sampling plan could be devised that would best track the field population trends of these pests. To determine the stratification of each thrips species, the center leaflets of each main stem trifoliolate of ten plants from each plot were placed

in a bottle containing a solution of water with a drop of detergent. The bottle was shaken thoroughly, the leaves were removed and rewashed, and the effluent was placed into the bottle. The bottles, four (one per plot) for each vertical node on the soybean plant, were taken to the laboratory where the liquid was put through a fine sieve, thereby concentrating the thrips, which were identified, sexed, counted, and tabulated.

The results of this set of experiments (Fig. 5), conducted over two soybean growing seasons, were quite interesting. *S. variabilis* adults were concentrated near the top of the soybean plant, at about the second leaf down from the terminal. Because adults oviposit there, by the time the first and second instars develop, they are concentrated on about the fifth and sixth leaves down from the top, particularly early in the season when soybean plants are putting out one to two new leaves per week. Therefore, to sample for *S. variabilis* adults, the second trifoliolate from the top is most appropriate, but to sample for first or second instars, the fifth or sixth trifoliolate from the top is most appropriate. When new nodes are no longer produced, this species begins to emigrate from the plant and from the field in large numbers.

The findings were quite different with *F. tritici* (Fig. 6). Adults and larvae of this species concentrate heavily in terminals (meristem tissue) prior to the formation of buds and flowers, but once buds and flowers appear, a large-scale shift occurs into them. When flowering ceases, a shift occurs back to the terminals. Therefore, to sample *F. tritici*, terminals and flowers must be monitored. The two soybean-inhabiting thrips species, thus, occupy very different parts of the plant. Experiments conducted concurrently demonstrate that specimens of neither species move very much during a 24 hour period.

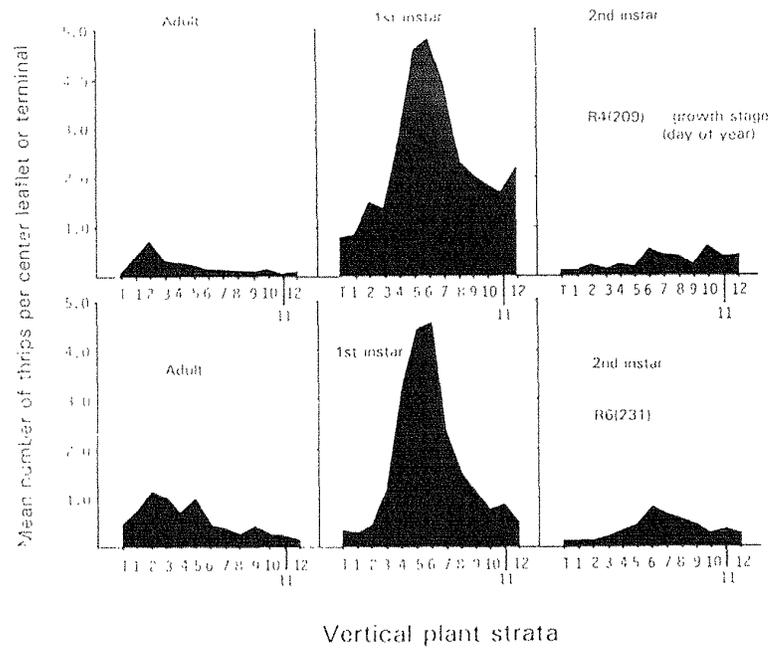


Figure 5. Within plant stratification of *Sericothrips variabilis* by life stage on soybean cv. Williams at growth stages R<sub>4</sub> (209 days post planting) and R<sub>6</sub> (321 days post planting), Urbana, Ill., 1976. T = terminal, 1-12 = center leaflets at nodes from uppermost expanded trifoliolate (1) downward on the main stem of the soybean plant.

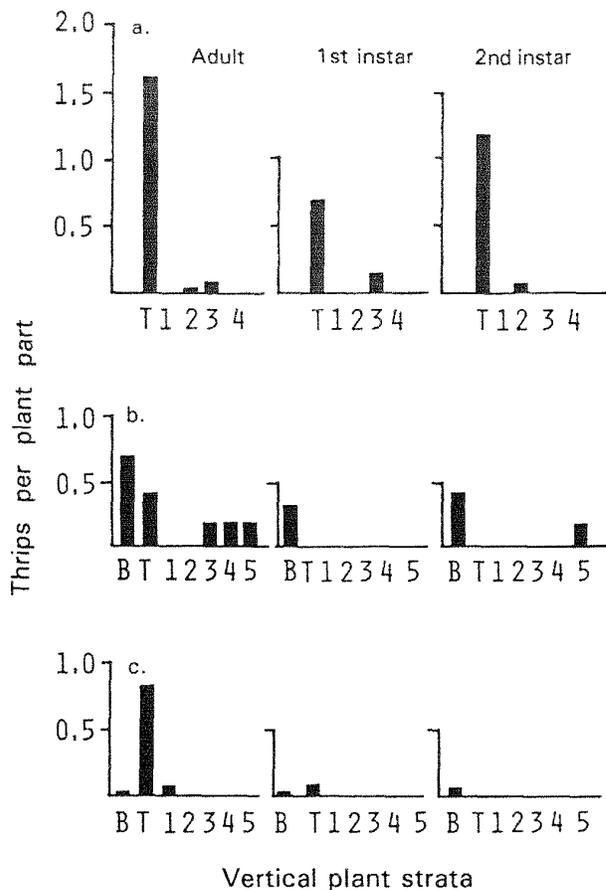


Figure 6. Within plant stratification of *Frankliniella tritici* by life stages on soybean cv. Williams at growth stages V<sub>5</sub> (a), R<sub>2</sub> (b), and R<sub>5</sub> (c), Urbana, Ill., 1976. B = blossoms, T = terminal, 1-12 = center leaflets at nodes from uppermost expanded trifoliate (1) downward on the main stem of the soybean plant.

**Seasonal Phenologies:  
Within Canopy Abundance vs. Flight Activity**

During the 1976 soybean growing season, thrips were monitored in Illinois for flight activity and for population density measurements. Flight activity was monitored with horizontal sticky green traps set just above the canopy and population density was assessed by leaf and terminal sampling (see previous section). Both sampling techniques resulted in very high catches of adult *S. variabilis* and *F. tritici* when compared with all other species. A comparison of these two methods illustrates the differences in the proportions of specimens of these two species sampled throughout the season. The leaf and terminal sample technique, used to determine the relative abundance of these two species within the canopy, showed that *S. variabilis* was four times more abundant overall. The sticky trap technique, however, indicated that *F. tritici* was twice as abundant overall (Fig. 7).

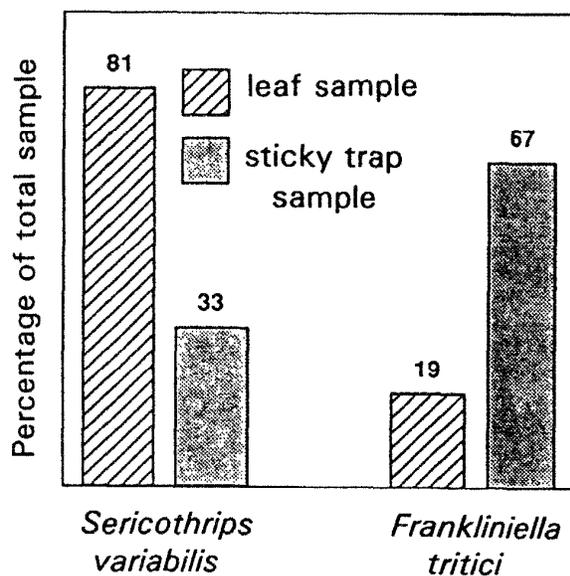


Figure 7. Proportional catches of the two most commonly collected thrips species in soybean cv. Williams, Tolono, Ill., 1976, using two methods: horizontal green sticky trap and plant part sampling.

This apparent paradox can be resolved. If the phenologies of adult thrips are plotted using the two sampling techniques, the picture becomes clearer (Fig. 8). For *F. tritici*, there are apparently two major peaks of flight activity, although from leaf samples there is but one population density peak in soybeans. The entire second peak of flight activity is most likely a product of population buildup on other host plants, thus accounting for a greater proportion of *F. tritici* in horizontal sticky traps than in terminal samples. The patterns of *S. variabilis* can also be explained. It is our contention that fewer adults immigrate, but these reproduce more successfully on soybean than *F. tritici*, and adults become active only late in the season as soybean plants begin to senesce. Thus, horizontal sticky trap samples suggest a flight peak of *S. variabilis* after the adult population within the soybean canopy begins to decline.

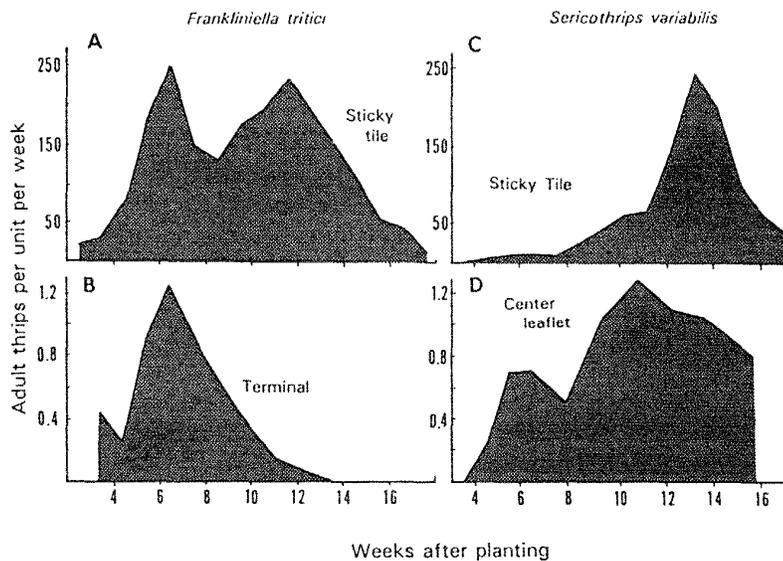


Figure 8. Seasonal phenologies of adult *Frankliniella tritici* (A, B) and *Sericothrips variabilis* (C, D), comparing abundances between flight activity patterns ("sticky tile," A, C) and population fluctuations within the soybean canopy ("terminal" and "center leaflet," B, D).

### Conclusions

Thrips colonize and build up in a habitat in a very dynamic fashion. It is important to understand the factors that drive this process and therefore experimentation involving sampling strategies must be undertaken. From the study presented on the biological dynamics of two species of thrips in soybean, it is clear that if one lacked comparative data from horizontal sticky traps and plant part samples, it would be possible to wrongly conclude that *F. tritici* was the more abundant species in soybean and that it reached peak abundances in soybean twice during the season. I believe that this points to the dangers of using a sampling technique to accomplish an objective for which it was not designed.

I caution that sampling strategies for the pear thrips in sugar maple be tailored to the aspects of the biologies you wish to determine. It is far too easy to devise a sampling strategy that will provide bogus information, setting your program back by several seasons.

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DEVELOPMENT OF SAMPLING METHODS  
FOR THE SLASH PINE FLOWER THIRPS  
*Gnaphothrips fuscus* (Morgan), (THYSANOPTERA: PHLAETHRIPIDAE)

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#### Abstract

Slash pine flower thrips typically destroy about 24% of the flowers (cones) present in slash pine seed orchards. The seasonal distribution and abundance of slash pine flower thrips are being investigated and methods for sampling field populations of the insect are being evaluated for potential use in integrated pest management strategies. The efficacies of several sampling methods, including Berlese funnel extractions of host plant materials, suction apparatus, scouting, flight traps, and soil emergence samplers are reported.

#### Introduction

There are 5.18 million hectares (12.8 million acres) of slash pine, *Pinus elliotii* Engem. var. *elliotii*, in the southern United States (Sheffield et al. 1983). Genetically improved seeds for regeneration and reforestation of this species are produced largely in more than 75 southern pine seed orchards encompassing about 1,214 hectares (3,000 acres) (Department of Agriculture 1982). Through intensive management, these orchards are expected to yield over 50 pounds of seeds per acre per year (van Buijtenen & Hanover 1986). In the absence of pest management, however, total losses of slash pine cone crops average about 55% (Fatzinger et al. 1980).

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The slash pine flower thrips (SPFT), *Gnophothrips fuscus* (Morgan), (Thysanoptera: Phlaeothripidae), is a major pest of slash pine in southern pine seed orchards. The insect has been reported to damage pine in eastern Canada (MacNay 1957), Rhode Island and New York (nursery stock of Austrian pine, *P. nigra* Arnold) (Crawford 1938), and Florida and has been collected in Massachusetts and Virginia (O'Neill 1965). Thrips-like damage has been observed on loblolly pine, *P. taeda* L., in Louisiana (Goyer & Nachod 1976) and on sand pine, *P. clausa* (Chapm. ex Engelm.) Vasey ex Sarg., in Florida.

#### Life History and Biology of SPFT

Ranasinghe (1981) estimated that in north Florida the SPFT has three overlapping generations a year with an average generation time of 46 days at 22°C. Ranasinghe & Wilkinson (1988) found all stages of the insect on young slash pine seedlings during the spring and summer; insect numbers decreased during the fall. They found macropterous adults in the crowns of mature pines during warm weather.

#### Damage Caused by SPFT

Damage caused by the SPFT is not readily observed in the field because it occurs in the upper crown during the early stages of flower development (DeBarr 1969). Infestations appear to be more prevalent on young female strobili (flowers) of open-grown trees than on those in forest stands (Ebel 1963). Differences in susceptibility to attack between clones of seed orchard trees have been observed (DeBarr et al. 1972).

SPFT feed externally on flowers for a period of about 1 month when the flowers are succulent (bud stage until pollination) (Ebel 1965). Little damage occurs after pollination because the flowers quickly become leathery enough to resist additional feeding (Merkel & Ebel 1961, DeBarr 1969, Ebel et al. 1975). Feeding sites are marked with

small beads (exudates) of oleoresin (Ebel 1961, 1965) (Fig. 1). Severe feeding activity results in the destruction of scales and bracts (Ebel 1961). When feeding is severe, the flowers are killed, dry rapidly, and fall from the trees (DeBarr 1969). Feeding activity that does not kill flowers does kill scales, causing cone distortion due to asymmetrical growth; seed yields are only about one-third those of healthy cones (DeBarr & Williams 1971).

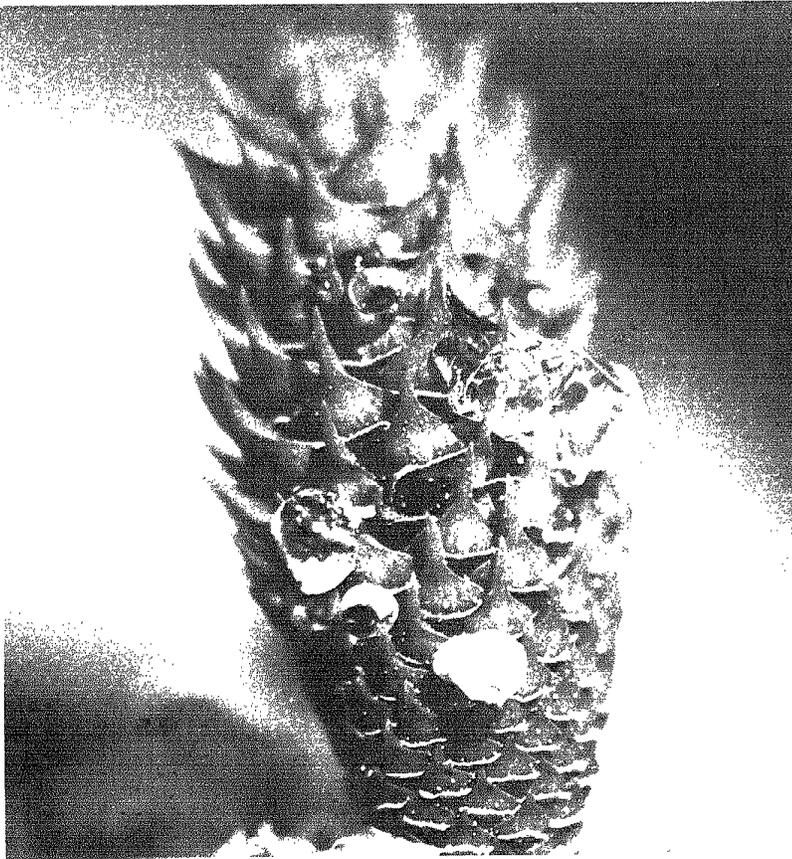


Figure 1. Adult slash pine flower thrips on female strobilus (flower) of slash pine. Small beads of oleoresin mark feeding sites.

SPFT damage an average of 24% (range 2-46%) of the flowers initially present in slash pine seed orchards (Fatzinger et al. 1980). The maximum SPFT damage we have observed was 90% of the flowers initiated during 1988 in an area of a slash pine orchard in northwest Florida that was not treated with insecticide.

#### **Control of SPFT**

Two insecticides (Cythion and acephate) are currently registered for control of SPFT. Since SPFT damage levels cannot be predicted, an insecticide is routinely applied twice during the early stages of flower development to reduce SPFT damage. Applications are timed by repeatedly observing development of female strobili: the first application is made when flowers are in the twig-bud stage and the second application is made about 2 weeks prior to maximum flower receptivity to pollen.

#### **Current Studies**

The objectives of studies we have underway are:

- 1) to evaluate the use of estimated SPFT populations to predict subsequent damage in slash pine seed orchards;
- 2) to determine the seasonal distributions and abundances of SPFT in mature and young pines;
- 3) to distinguish similar damage symptoms caused by other factors;
- 4) to simplify techniques for identifying the insect;
- 5) to develop degree-day models for timing of insecticide applications.

Methods for sampling field populations of SPFT were needed to achieve these objectives. We began evaluating several methods for collecting SPFT that are flying, on branch tips of slash pine, and in soil samples under infested trees. Techniques evaluated included Berlese funnels, a suction apparatus, scouting, beating branch tips, flight traps, and soil emergence samplers.

#### **Berlese Funnels for Extraction of SPFT from Branch Tips and Soil Samples**

Commercially available Berlese funnels were modified to hold 10 slash pine branch tips (about 25 cm long). A sheet metal cylinder (76 cm long) was used to extend the distance from the funnel to the light source (70 watt incandescent lamp). Preliminary studies, conducted during 1987 and 1988, indicated that the majority of thrips, including *Frankliniella bispinosa* (Morgan), *F. tritici* (Fitch), *Leptothrips pini* (Watson), *Oxythrips pini* (Watson), *O. pallidiventris* Hood, and SPFT were extricated from branch tips within 2 weeks (Fig. 2). During this period, we recovered up to 26 thrips per sample of 10 branch tips. Inspections of the surface soil and litter for presence of SPFT will begin this year. The seasonal distribution and abundance of SPFT are being investigated by estimating the population densities of the insect at 2-week intervals for 2 years. Population densities are estimated by counting SPFT present on 10 branch tips collected from the upper crowns of 10 mature pines, on 10 tips collected from the entire crown of 10 young pines (less than 1.8 m tall), and in 10 soil samples collected beneath the crown of infested trees.

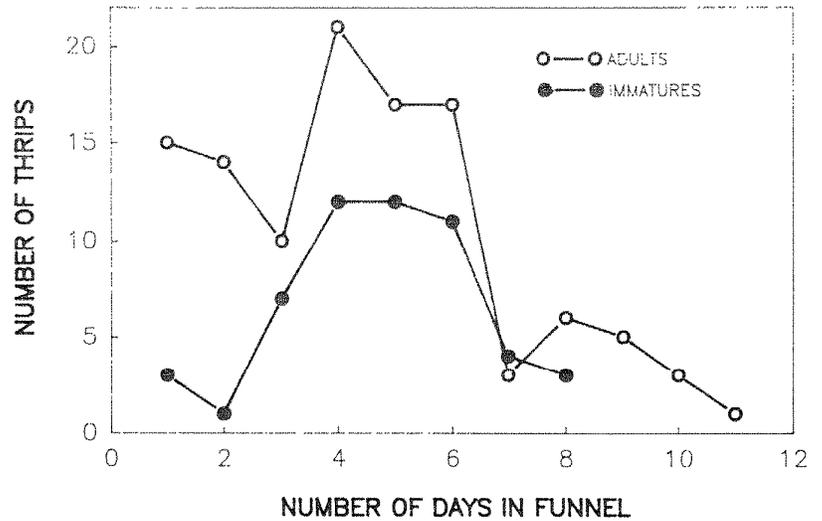


Figure 2. Time required to extract thrips, including *Frankliniella* spp., *Leptothrips* sp., and *Oxythrips* sp., from 10 branch tips of slash pine using Berlese funnels.

#### Suction Apparatus for Collections of SPFT from Foliage

Preliminary tests with a suction apparatus indicated its usefulness for collecting specimens of SPFT and *Leptothrips pini* from intact branches (Fig. 3). The suction apparatus operates with a gasoline-powered vacuum (Weed Eater<sup>®</sup>, Model No. 960 Gas Powered Blower Vac). One end of a flexible hose (10-cm-diam clothing dryer duct) is attached to the vacuum port of the vacuum engine and the other to a 10-cm-diameter hole cut into the bottom of a plastic bucket (5 gal). A porous cloth bag is placed into the plastic bucket to act as a filter for collecting thrips dislodged from branch tips held within the bag. The suction method collects thrips faster than the Berlese funnels and does not require destructive sampling of tree parts, but we consistently collected fewer specimens with the suction apparatus than we extracted in Berlese funnels. The apparatus will be calibrated by

collecting SPFT from intact branch tips with the suction apparatus and then extricating the remaining thrips from the same tips with Berlese funnels.

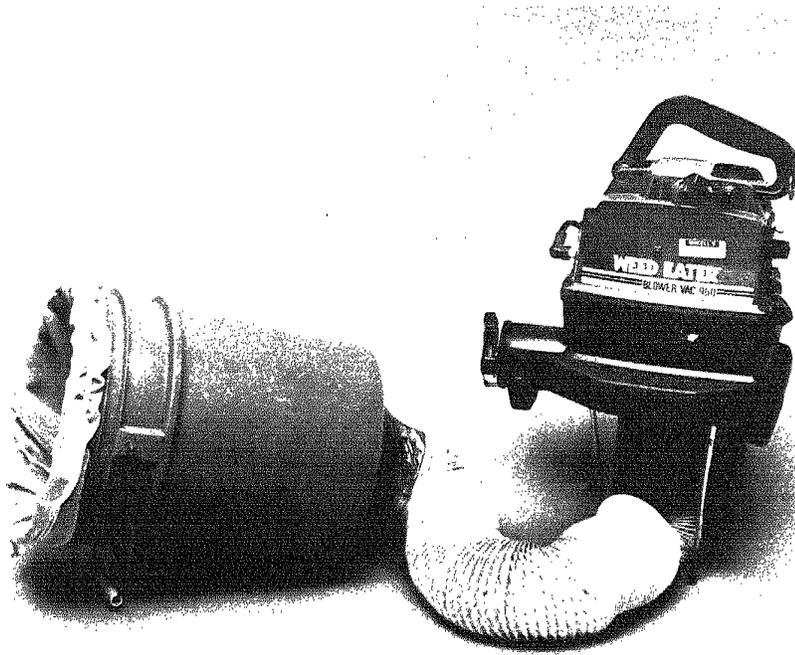


Figure 3. Suction apparatus used to collect slash pine flower thrips from intact branches of slash pine.

### Scouting for SPFT on Young and Mature Pines

SPFT were counted visually on intact branch tips of young and mature pines throughout 1988 using magnifying lenses and the unaided eye. Once SPFT were observed on a branch, it was collected and placed in a Berlese funnel for extraction. The results varied widely with weather conditions and with differences in observers' abilities to locate SPFT on host plant material. SPFT often crawl under bark scales, inside needle fascicles, and into bud scales during cold or rainy weather and are difficult to locate. The scouting method appears to be suitable for determining the presence or absence of SPFT in various habitats, but it is unsuitable for quantitative measures of the insect's population.

### Beating Branches

Thrips were dislodged from host plants by striking branches with a stick while the branches were held over the inner surface of a white dissection tray. The majority of thrips collected were *L. pini*; only a few SPFT were dislodged from the branches.

### Flight Traps

Flight traps described by Ranasinghe (1981) and Ranasinghe & Wilkinson (1988) were tested during the summer and winter of 1988 and spring of 1989 at four heights in the crowns of orchard trees (Fig. 4). Each trap consisted of four white plastic discs (15-cm-diam, coffee can lids) suspended on a piece of string at intervals of about 10 ft. Each disc was sprayed on one side with Tanglefoot (Tanglefoot Co., Grand Rapids, Mich.). Sixteen traps were deployed by tying one end of the trap string to the center of a second string attached between the tops of two adjacent trees; the other end of the trap string was fastened to a stake in the ground. Captures of macropterous adults averaged less than one per trap. Total SPFT captured by the 64 traps ranged from 2 to 39.

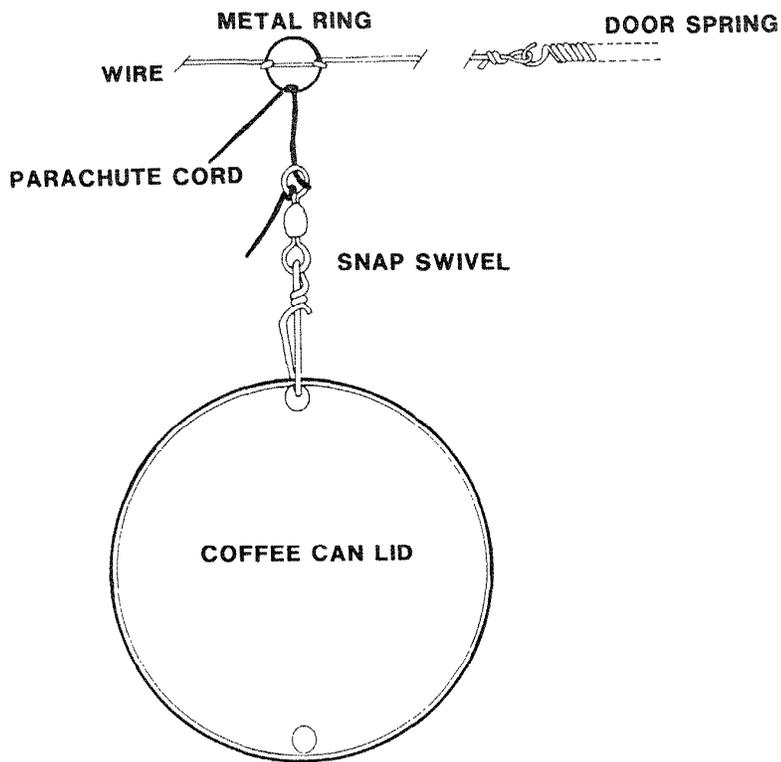


Figure 4. Components of flight trap used to collect winged adults of slash pine flower thrips.

## Soil Emergence Samplers

It is currently unknown whether SPFT spend part of their life cycle in the soil or litter. Ranasinghe (1981), however, did not recover SPFT from the top layers (5.0 to 7.5 cm) of soil beneath three mature slash pines. In addition to Berlese funnel extractions of soil samples, we began using soil emergence traps for SPFT during February, 1989 (Fig. 5). The emergence traps were constructed by gluing the large end of a plastic funnel (10 cm diam) over a 9-cm-diameter hole cut in the bottom center of a plastic bucket (20 cm in height, 28 cm diameter at top, 23 cm diameter at bottom). The small end of the funnel (1.5 cm diam) was glued through a 1.5-cm-diameter hole cut in the lid of an inverted vial (140 ml) at the top of the trap. The traps are placed with their open ends on the ground beneath infested trees to collect insects emerging from the soil. The traps have been operated for only 2 weeks thus far, and no SPFT have been observed among the insects captured.

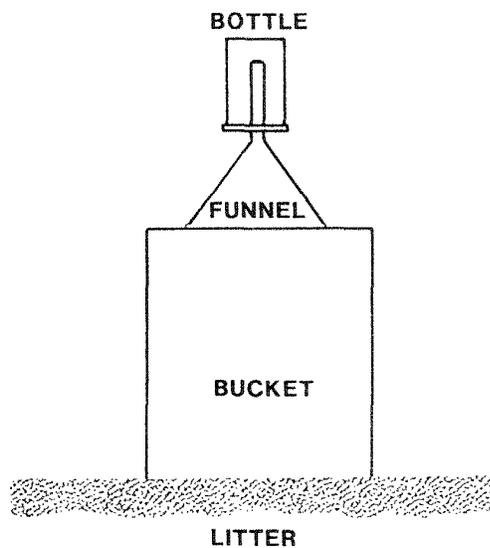


Figure 5. Soil emergence traps for collecting thrips and other insects.

### Degree-Day Model

Our other sampling effort is concerned with the development and evaluation of a degree-day model for the timing of insecticide applications for control of SPFT. Three trees of each of four clones of slash pine known to be highly susceptible to SPFT attacks are being observed from late-November through early-March to determine the onset and end of SPFT feeding activity. These data will be used in conjunction with on-site temperature records to develop and evaluate a degree-day model for predicting SPFT feeding periods on female strobili in slash pine seed orchards.

### Clarification of SPFT Damage Symptoms on Host Plant Materials

Several other insects and certain abiotic factors are capable of causing damage symptoms similar to that caused by SPFT. In an effort to further elucidate the damage symptoms caused by SPFT on female flowers and other host plant materials, SPFT are being caged on individual clusters of female flowers in a slash pine seed orchard and on potted seedlings in a greenhouse. Cages containing up to six SPFT and other cages without thrips were installed on the orchard trees in January, 1989 during the twig-bud stage of female flower development. The flowers will be photographed weekly during the period of SPFT feeding activity and monthly thereafter until the cones mature in September, 1990. The photographs will be used to trace the development of damage symptoms caused by SPFT feeding activity and to further elucidate the effects of nonlethal feeding activity on seed production.

### Acknowledgment

The authors thank Harold Denmark, Bureau of Entomology, Div. of Plant Industry, Fla. Dept. of Agriculture and Consumer Services, Gainesville, Florida, for identifications of SPFT, and Edward P. Merkel for valuable suggestions and technical assistance during the course of this study. This research is funded in part by the Integrated Forest Pest Management Cooperative, USDA Forest Service, and the Univ. of Fla.

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SOIL SAMPLING AND EXTRACTION METHODS  
WITH POSSIBLE APPLICATION TO  
PEAR THRIPS (THYSANOPTERA: THIRIPIDAE)

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**Abstract**

Techniques are described for the sampling and extraction of microarthropods from soil and the potential of these methods to extract the larval stages of the pear thrips, *Taeniothrips inconsequens* (Uzel), from soil cores taken in sugar maple stands. Also described is a design for an emergence trap that could be used to estimate adult thrips populations as they move from the forest floor into the tree canopy.

**Introduction**

The pear thrips, *T. inconsequens*, was introduced around 1904 from Europe to America where it became established on such hosts as maple, basswood, birch, beech, ash, and black cherry (Simons 1985). Since 1984 there has been a dramatic rise in the number of pear thrips infesting sugar maple trees such that the resulting damage has become a major concern among sugarmakers in the major syrup producing regions in the northeastern United States.

Very little documented work is available on pear thrips (Skinner 1988) particularly with regard to its economic importance on sugar maple. One of the problems facing workers is to develop a reliable monitoring system that will enable establishment of a threshold value for damage. Once this is determined it may be possible to monitor the number of viable larvae at emergence and warn sugarmakers of the likelihood of damage and its severity. This will allow farmers to take the recommended action against the pest before serious economic damage is done to the sugar maples.

Adult thrips attack the sugar maple at the bud stage, damaging the bud and causing the characteristic deformation of newly opening leaves. Eggs are laid in veins of the foliage and in the stem. Newly hatched larvae feed for a short time and then drop to the ground. A large proportion of their life cycle is spent below the soil surface prior to pupation and emergence of new adults the following season (Fig. 1). At this stage it is possible to use techniques currently employed in the extraction of soil arthropods, to obtain the larvae from soil cores taken in sugar maple stands. The number of larvae obtained from these soil cores can be used to assess overwintering mortality and the number of viable larvae that will become the next season's pest. In conjunction with sampling the population of adult thrips present in the tree, it may be possible, over a number of seasons, to calculate an "economic damage threshold value."

Simultaneously these techniques will enable researchers to obtain valuable qualitative and quantitative data on the soil mesofauna for use in the development of a "Total Forest Ecosystem Monitoring Program" (Teillon 1988). This would be especially important if chemical methods of thrips control, eg. carbaryl, are used because the effects of such chemicals on beneficial, as well as, non-beneficial soil arthropods may be significant.

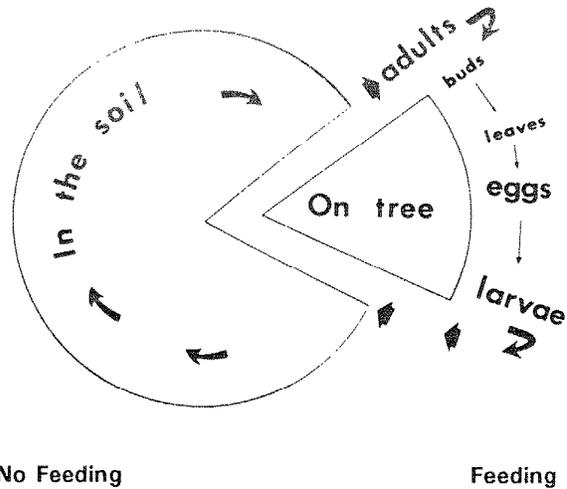


Figure 1. Probable life cycle of pear thrips in Vermont sugar maple stands (from Parker et al. 1988). For more specific life cycle information, see Skinner & Parker, poster presentation, this proceedings.

## Materials and Methods

### Soil Sampling and Extraction of Microarthropods

The large acreages of sugar maple that are infested will require many soil samples to obtain accurate data on numbers of viable larvae present. A sampling pattern must be designed that is statistically sound with a standardized sample size. This is usually a 5 cm diameter, 15 cm deep soil core, which is about 250-300 ml of soil. Commercial equipment is available to take the soil cores, eg. golf course hole cutters and bulb planters, both of which are relatively inexpensive and easy to use (material suppliers listed on page 173).

To extract a large number of soil cores efficiently and quickly requires specialized methods and equipment. A number of options are available such as heat extraction, flotation and grease film extractions (Table 1).

Table 1. List of dry funnel and flotation methods of extraction of soil arthropods (after Edwards & Fletcher 1971)

Dry Funnel	Flotation
Simple plastic funnels (Edwards & Fletcher 1970)	Simple brine flotation (Edwards & Fletcher 1970)
Rothamsted controlled gradient funnels without heat (Edwards & Fletcher 1971)	Salt and Hollick flotation (Salt & Hollick 1944)
Rothamsted controlled gradient funnels with heat (Edwards & Fletcher 1970)	Mechanized flotation (Edwards & Heath 1963)
Split funnels (Murphy 1962)	Grease film extractor (Aucamp & Ryke 1964)
High-gradient funnels (moist regime) (MacFadyen 1962)	
High-gradient cylinder extractor (MacFadyen 1962)	
Infra-red extractor (Kempson et al. 1963)	

In 1971, eleven of the most commonly used techniques were compared (Edwards & Fletcher 1971) and data were collected on the efficiency of these methods to extract soil arthropods, including Thysanoptera (Table 2). Of these eleven methods the controlled-gradient (with heat) extraction technique proved to be the most efficient for retrieving the major groups of arthropods and thrips. This method is used by many soil ecologists today.

Two controlled-gradient extractors are currently in use at the Ohio Agricultural Research and Development Center (O.A.R.D.C.), Wooster, Ohio. The first extractor built was a self-contained 80-sample

Table 2. Comparison of methods of extracting Thysanoptera from clay-loam soil under three types of management (after Edwards & Fletcher 1970, from Lewis 1973) [Mean number of thrips per soil core (10 cm diam x 5 cm deep) is expressed as log (N + 1).]

	Method <sup>a</sup>											Variance ratio		
	Dry funnel					Flotation								
	A	B	C	D	E	F	G	H	I	J	K	s.e. <sup>b</sup>	I.s.d. <sup>c</sup>	
Woodland	0.029	0.048	0.000	0.000	0.067	0.048	0.056	0.086	0.019	0.322	0.111	0.042	0.110	4.436
Pasture	0.000	0.019	0.019	0.029	0.019	0.000	0.056	0.000	0.169	0.481	0.000	0.044	0.116	11.270
Fallow	0.000	0.000	0.000	0.000	0.019	0.000	0.038	0.086	0.094	0.056	0.049	0.026	0.068	1.799

- <sup>a</sup> A. Simple plastic funnels (Edwards & Fletcher 1970)
- B. Rothamsted controlled gradient funnels without heat (Edwards & Fletcher 1970)
- C. Rothamsted controlled gradient funnels with heat (Edwards & Fletcher 1970)
- D. Split funnels (Murphy 1962)
- E. High-gradient funnel (moist regime) (MacFadyen 1962)
- F. High-gradient cylinder extractor (MacFadyen 1962)
- G. Infra-red extractor (Kempson et al. 1963)
- H. Simple brine flotation (Edwards & Fletcher 1970)
- I. Salt and Hollick flotation (Salt & Hollick 1944)
- J. Mechanized flotation (Edwards & Heath 1963)
- K. Grease film extractor (Aucamp & Ryke 1964).

<sup>b</sup> s.e. = standard error of means. I.s.d. = least significant difference.

<sup>c</sup> Significantly different at 0.01% level.

machine, which generates and maintains a heat gradient within the soil sample using a compressor, heat exchanger and pump to provide cooling to the bottom of the sample and electric light bulbs (25 watt) to supply heat to the top of the sample. A heat-gradient of about 15°C between the top and bottom of the soil sample gives the best results. A smaller 36-sample extractor was also constructed and housed in a controlled temperature room to provide cooling (21°C). Electric light bulbs (15 watt) provide heat (38°C) at the top of the sample. This heat gradient causes the soil sample to dry out from the top downwards. The arthropods respond by moving down the sample to avoid desiccation, eventually moving out of the sample, falling through the mesh bottom of the sample holder where they are collected in vials containing a mixture of 70% ethanol, 5% glycerol and 25% water.

Trials have shown that both machines operate at similar efficiencies. The major difference between the two is cost. The self-contained extractor can be constructed at a cost of \$3,500, the major expense (about \$2,500) being the compressor, heat exchanger and pump. The smaller 36-sample extractor can be built for \$160 (about \$320 for a machine capable of extracting 72 samples) but this does require a temperature-controlled room. Both machines are suitable for extracting Thysanoptera.

### **Emergence Trap**

**Trap design.** Information needed to help develop a monitoring program for pear thrips can be obtained from the numbers of adult thrips emerging from the soil in the spring and migrating to the maple trees. To obtain these data, a suitable emergence trap is required. A number of methods have been evaluated with some success (Laudermilch 1988). The following emergence trap design would enable researchers to obtain data on emerging thrips as well as other soil arthropods in one operation.

Due to the large numbers of samples required, low cost and ease of use in the field and laboratory were key elements in the design. The trap consists of two parts: a soil unit which is a mesh cylinder capable of holding a soil core, and a trapping unit which is attached to the top of the mesh cylinder. Materials and method of construction are shown in Figure 2.

Some positive aspects of this design are:

1. The soil core is kept in as natural a condition as possible during the trapping period. The mesh cylinder and perforated bottom allow gasses, moisture and arthropods normal movement in and out of the soil core.
2. The whole unit is relatively inexpensive and easy to assemble using readily available laboratory equipment.
3. The unit is durable and lightweight so large numbers of traps can be carried to the experimental site with little effort, and should last for a number of trapping seasons.
4. Both the soil core and emergence catch can be transported to the laboratory easily and the catch quickly dispensed for storage or sorting.
5. Set out and retrieval of traps can be carried out easily by one person.
6. Traps are reusable and are easily dismantled, cleaned and stored.

Apart from the cylinder mesh which can be purchased at most hardware stores, all other components are readily available from biological suppliers. The total cost of a single trap is \$7.00, but this can be reduced if funnels and bottles are bought in bulk.

Key to Figure 2

1. Perforated stopper.
2. 2 1/2" (6.25 cm) Nalgene powder funnel. Press on or glue in place to the Nalgene bottle.
3. 4 oz (125 ml) Nalgene bottle. Cut hole in bottom to make a tight fit with funnel spout.
4. 2 1/2" (6.25 cm) plastic funnel with 1/4" diam. tapering spout. Cut down spout so that when in position 1/4" protrudes through the bottom of bottle (3).
5. Cap from 4 oz (125 ml) Nalgene bottle. Cut out center using a hot scalpel blade. Heat seal mesh to outer surface, ensuring threads are facing away from mesh cylinder.
- 6 & 7. 1.5 x 1.8 mm fiberglass window screen. Form into tube and heat seal seam with soldering iron fitted with a flat tip. The diameter should be 2" and the length can be cut to suit specific experimental needs.
8. Heat seal mesh to outer surface of lid. For extra strength use pipe clips on both caps.
9. Cap from 4 oz/125 ml Nalgene bottle. Perforate with small holes for drainage.

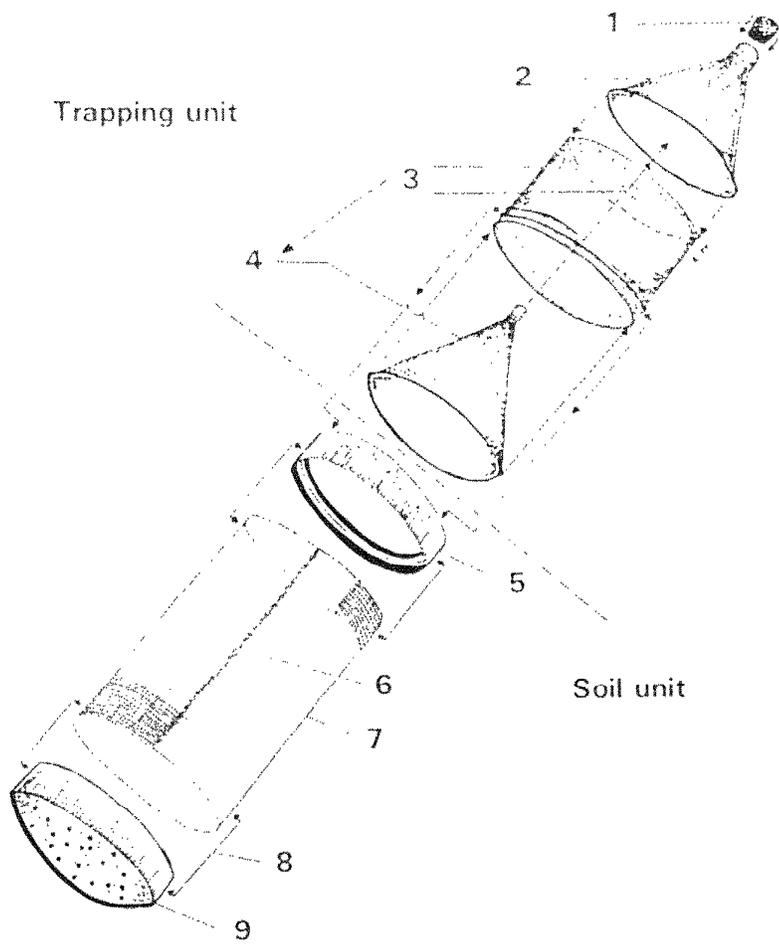


Figure 2. Diagram showing assembly of emergence trap.

**Trap operation.** A suitable size soil core is taken and placed surface side up in the mesh cylinder. This unit is then put back into the hole left by the soil core having the top flush with the soil surface. The trapping unit is then screwed into place on top of the soil unit and left for the desired trapping period. To retrieve the catch, the trapping unit is unscrewed and capped quickly with an intact bottle lid. A new unit may be attached to the mesh cylinder or it may be capped off for retrieval of the soil core. Both units can now be returned to the laboratory for processing.

The trapping unit should be inverted and placed in a cold room to immobilize the catch. To dispense catch, the stopper is removed allowing the catch to fall into storage vials or counting dish. The soil core is removed from the mesh cylinder and processed by the controlled-gradient extraction method described earlier. This will yield viable soil arthropod numbers and any remaining viable thrips. The soil core can be further processed to obtain dead arthropods, pupae, and eggs, data which the controlled-gradient extraction cannot provide. This is best accomplished using a heptane flotation method (Walter et al. 1987).

### **Results**

The emergence trap is currently being evaluated in the field so no data is available at this time. If the method proves successful, the following data will be obtained from a single soil core:

- A. Emerging adult thrips
- B. Process soil core by controlled-gradient extraction method to obtain any remaining live thrips and all other live soil arthropods.
- C. Final extraction of the soil core by the heptane flotation method will yield dead soil arthropods including thrips as well as pupae and possibly eggs.

These data will provide valuable input into a "Total Forest Ecosystem Management Program."

**Material Suppliers**

**Soil augers:** Bulb planter (short handle and wide) any garden supplier  
Bulb planters (2" diam, 6" deep, long handle)

Smith & Hawken  
55 Sunnyside  
Mill Valley, California

**Nalgene bottles:** 4 oz (125 ml) with 70 mm cap diam  
(cat. # 11-823-30)

Fisher Scientific  
461 Riverside Ave.  
P.O. Box 376  
Medford, Massachusetts

**Plastic funnels:** Nalgene PF 65 (cat. # 10-348A)  
PF 45 (cat. # 10-347D)  
Fisher Scientific

**Cylinder mesh:** 1.5 x 1.8 mm fiberglass window screen available at  
most hardware stores

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