SPIDERS ASSOCIATED WITH APPLE TREES IN VIRGINIA WITH NOTES ON THEIR IMPORTANCE IN CONTROLLING ORCHARD INSECT PESTS

by

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Blacksburg, Virginia

To My Parents

Joe and Esther McCaffrey

Thank You

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I. INTRODUCTION

There has been increasing interest during the past decade in the utilization of indigenous natural enemies for the regulation of orchard insect and mite pests. This is exemplified by several successful integrated pest management (IPM) programs recently developed for the nonchemical or selective chemical control of phytophagous orchard mites (Croft 1975). Since there is a substantial complex of pests and natural enemies associated with the orchard ecosystem, further IPM control strategies would obviously benefit from a broader consideration of the natural enemies of the entire pest fauna, including such important insect pests as the tortricid moths, aphids, and leafhoppers. Before such an extensive program could be undertaken in Virginia, a survey and evaluation of the predators present was needed.

Preliminary studies of the predatory arthropod complex were undertaken by the author in an abandoned orchard in Augusta Co., Virginia during the spring of 1976. Spiders were observed to be the predominant predators present. As a result of these observations and the fact that all spiders are obligate carnivors with insects constituting their principal prey (Turnbull 1973), a series of studies were undertaken with the following objectives in mind:

1) Determine the species composition of the complex of spiders found in abandoned and commercial orchards throughout the growing season.

2) Record seasonal population fluctuations of the major groups and species.

3) Provide information on the biologies of some of the important species including habitat preference, predatory behavior, and activity periods.

4) Determine the suitability of the major orchard pests and beneficial insects as prey for the more common spider species.

5) Determine the importance of spiders relative to other predators in suppressing orchard insect pests.

6) Evaluate the efficiency of the limb-beating sampling technique currently used to estimate spider populations in orchards.

II. SURVEY AND POPULATION ASSESSMENTS OF SPIDERS IN ABANDONED AND COMMERCIAL ORCHARDS IN VIRGINIA WITH NOTES ON THEIR BIOLOGIES AND RELATIVE IMPORTANCE IN THE SUPPRESSION OF ORCHARD PESTS

1. Introduction

Spiders are a diverse group of animals that encompass a wide range of life styles, behavior, and morphological and physiological adaptations (Turnbull 1973). This study was undertaken to determine the species complex, seasonal populations, habitats, and behavior of spiders associated with apple trees in Virginia. The importance of spiders in the suppression and regulation or orchard insect pests was also studied.

2. Literature Review

A. Surveys and Population Assessments

The studies of Chant (1956) in England and Dondale (1956, 1958) in Nova Scotia on the spiders associated with apple orchards were among the first of such studies in any agroecosystem. Chant reported that 20 and 41 species of spiders were found in sprayed and unsprayed orchards respectively. The Theridiidae and Linyphiidae were the predominant groups in most orchards, but their numbers were higher in the unsprayed environments. Generally, late season population increases were noted. He attributed this to reduced pesticide applications late in the season in the sprayed orchards and the hatching of late season eggs in all orchards.

Dondale (1956) reported on the species of spiders in orchards under "modified" spray programs. A total of 77 species were collected during the three year study. Web builders were represented by 48 species and non-web builders by 29 species. Dondale (1958) later reported that *Paraphidippus* (=*Eris*) *marginatus* (Walckenaer), *Metaphidippus protervus* (Walckenaer), *Philodromus cespiticolis* Walckenaer, *P. rufus* Walckenaer, and *Araniella displicata* (Hentz) were the principal species represented. Two peaks of abundance were observed; a small one in the spring and a larger one in the late summer or fall.

Specht and Dondale (1960) found approximately the same overall seasonal populations of spiders in commercial orchards under "modified" spray programs in New Jersey. Unsprayed orchards, however, showed no distinct trends in population fluctuations, possibly because of the low number of samples taken. Only 34 species were found in this one year study. Web builders were represented by 16 species and non-web builders by 18 species. There appeared to be fewer visually dependent hunters in the sprayed than unsprayed orchards. Some of the more important species included Theridion murarium Emerton, T. albidum Banks, Anyphaena celer (Hentz), Metaphidippus galathea (Walckenaer), Hentzia palmarum (Hentz), Philodromus vulgaris (Hentz), P. rufus, Misumenops asperatus (Hentz) and Araniella displicata.

In comparing the spider fauna of insecticidal (DDT), fungicidal (captan), and "natural" unsprayed environments in Wisconsin orchards, Legner and Oatman (1964) reported that the highest spider numbers were found in the fungicide environment. They attributed this to more abundant foliage, which in turn provided a more favorable environment for the predators. The insecticide environment was least favorable, especially to the non-web building, hunting spiders. In all, they found 24 species, with 15 non-web and 9 web builders represented. Paraphidippus (=Eris) marginatus, Philodromus cespiticolis, Philodromus sp., Araniella displicata, and an undescribed salticid were the most abundant species collected during the study.

Other surveys of spiders associated with apple orchards include those of Hukusima (1961) in Japan, Dondale (1966) in Australia, and Hagley (1974) in Ontario. Because of their distinct regional differences, the studies of Hukusima and Dondale will be discussed no further. Hagley's study was part of a survey of the codling moth predators in unsprayed orchards in Ontario. He listed 50 species, but considered them of little importance because they were never present in large numbers.

Related orchard studies include those of Putman (1967) on the spiders associated with peach orchards in Ontario and Muma (1975) on citrus in Florida.

B. The Importance of Spiders in the Orchard Ecosystem

The importance of spiders in any agroecosystem may well depend on the presence or absence of specific predators of a particular pest species (Riechert 1974). The studies of Dondale (1958) and Specht and Dondale (1960) have alluded to this point. They observed spiders to represent a large percentage of the predator complex early and late in the season, but the percentage was reduced mid-season by the presence of more specific density-dependent predators that were responding to high pest densities.

Hauschild and Parker (1976) found spiders and coccinelids to be important predators of the tarnished plant bug in Vermont orchards. Spider populations were high early and late in the season, but low in mid-season. The converse was true for the coccinelids.

MacLellan (1973) evaluated the natural enemies of the light brown apple moth (Epiphyas postvittana Walker) in Australian orchards using numerical, serological, and forced feeding techniques. Spiders were considered valuable predators which were aided for short periods of time by other predators, primarily chrysopids and mirids.

The role of spiders in the control of phytophagous mites has been studied in some detail. Chant (1956) observed that in England certain spiders, particularily the small and immature forms, fed readily on phytophagous orchard mites. The larger species usually confined their feeding to the other orchard insects including winter moth larvae, apple suckers, aphids, and predacious insects.

After studying the spiders of Ontario peach orchards, Putman (1967) concluded that spiders form an important part of the complex of minor predators that aid major predators in regulating the density of phytophagous mites at endemic levels.

Hoyt (1967) reported an undetermined species of spider to be quite numerous in a study orchard in Washington and suggested that it could have had a local effect on the mite population.

A few other notes appear in the literature pertaining to the influence of spiders on particular pest-prey. Often no attempt was made to identify the spider. More specific reference will be made to these notes in another section.

3. Methods and Materials

A. Description of the Study Areas

Four orchards were sampled throughout the study. They differed in geographic location, age, and cultural and pest management practices. The following descriptions will prove helpful in evaluating the importance of spiders in each respective environment.

1) Moomau abandoned orchard

This 3.2 ha study orchard is located in Greenville (Augusta Co.), Virginia. According to the owner, the orchard had been neglected and unsprayed for about five years prior to this study. Trees of the Red Delicious, Golden Delicious, Grimes Golden, Jonathan, and Stayman cultivars were in rows of ca. 9 x 9m spacing, running in an east to west direction. Numerous, but irregularly placed interplants were present. The trees were ca. 10-15 years old and 3-6 m in height. Their canopies were generally dense as a result of inadequate pruning. The orchard was non-bearing during the 1976 season, possibly as a result of spring frost, but there was a good fruit set on most cultivars in 1977.

The orchard floor was characteristic of an old field community. Poison ivy (*Rhus radicans*), Honeysuckle (*Lonicera japonica*), and other vines were often associated with the trees. A small farm bordered the orchard to the north and west. A paved road divided the orchard from a pasture and wooded lot to the south and east respectively.

2) Alexander commercial orchard

The Alexander orchard is located in Fairfield (Rockbridge Co.), Virginia. Early in 1977 a one hectare block containing Red Delicious, Golden Delicious, and York cultivars was selected for study. Trees 15-20 years in age and 4-5 m in height were in rows of 9 x 9 m spacing that ran in a north to south direction. The tree canopies were dense and a considerable number of water sprouts were present. Fruit set was heavy in 1977, but no chemical thinners were used.

The chemical program for the 1977 season was similar to that used during the previous three years and is summarized in Appendix 1. Phosmet and phosphamidon were the major insecticides and Diker® the primary fungicide used. Materials were applied by the grower to alternate rows as 3X concentrate air-blast sprays with a truckmounted John Bean Speed-sprayer.

The orchard floor consisted primarily of grasses and was cut at least twice during the season. The study block was bordered to the north, east, and west by orchard of similar variatel composition and to the south by a paved road and more orchard.

3) Gerling commercial orchard

Located in Monroe (Amherst Co.), Virginia, this orchard represented the southern-most sample area. In 1977 a one hectare block containing Red Delicious and Golden Delicious cultivars was selected for study. Tree rows were in 6 x 7 m spacings and ran in a north to south direction. The trees were 8 years old and 3-4 m in height with open canopies. Water sprout growth was minimal. Fruit set was light for both cultivars, consequently, no chemical thinners were applied.

Because of the light fruit set, the chemical program (Appendix 2) for 1977 was somewhat reduced, but basically it was in keeping with that used during the previous three years. Phosalone and polyram were the primary insecticide and fungicide respectively. Materials were applied by the grower to every row as 2X concentrate sprays with a Myer's Mist Sprayer.

The orchard floor consisted mostly of grasses and was cut at least twice during the growing season. The western aspect of the study block was bordered by a paved road and a wooded area. The northern and southern aspects were also bordered by wooded area. The eastern side continued on to more orchard.

4) Flippin commercial orchard (Blocks A, B, and C)

The Flippin orchard is located in Tyro (Nelson Co.), Virginia. Previous to this study, a large relatively homogeneous group of trees approximately 7 years old and 4-5 m in height had been divided into three separate but adjacent 1.6 ha blocks, noted as blocks A, B, and C. Each block was subjected to a different pest management program (Appendix 3A, 3B, and 3C), but all programs were generally consistent with those used the previous three years. Experimental integrated pest management programs were supervised for blocks A and B by Dr. R. L. Horsburgh of the Shenandoah Valley Research Station. Sprays were applied as 6X concentrates to alternate rows with a truckmounted Swanson airblast sprayer. Block C was under a grower applied standard pest management program. Materials were applied as 6X concentrates to alternate rows with a John Bean airblast sprayer.

The chemical programs consisted primarily of low rates of phosalone, Bacillus thurigiensis Berliner (Thuricide®), and Dikar® for block A; reduced rates of azinphosmethyl, Bacillus thuringiensis Berliner (Dipel®), and benomyl and oil for block B; and standard rates of azinphosmethyl, captan and thylate in block C. Late season frost resulted in substantial fruit loss for the Red Delicious cultivar; consequently, the grower applied spray program (block C) for this cultivar was discontinued in May.

Block A contained Red Delicious, Golden Delicious, Rome, and Jonathan cultivars and blocks B and C contained Red Delicious, Golden Delicious, and Paula Red cultivars. There was a good fruit set for all cultivars except Red Delicious.

The orchard floor was primarily grasses and was cut regularly during the season. A paved road bordered the orchard to the west. A pasture bordered the orchard to the north. More orchard and a road bordered the orchard to the south.

B. Sampling and Field Observations

1) Moomau abandoned orchard

To assess the seasonal population trends, weekly samples were taken without regard to cultivar during the months of June to November, 1976 and March to June, 1977. The sampling procedure was similar to that reported by Specht and Dondale (1960).

Each sample consisted of tapping the lower limbs of one-fourth of a tree for each of four trees forming a square. This provided for a one-tree equivalent sample. Dislodged spiders were caught on a one-meter square muslin covered tray (Fig. 1), aspirated from the tray, and transferred to 70% ethyl alcohol for preservation.

During the 1976 and 1977 seasons, considerable time was spent examining the foliage, branches, and tree trunks for spiders. Most observations were made during the day, but limited night observations were made with the aid of a headlamp. Habitat associations were noted for all spiders encountered. Furthermore, spiders not represented by previous collections were hand-picked and placed in 70% ethyl alcohol for further study.

2) Commercial orchards.

Twice-monthly limb-tap samples were taken from April to September, 1977 in a manner similar to that previously described (one-tree equivalent). Only Red Delicious cultivars were sampled. Spiders and other predators were collected. Adjacent Red Delicious trees were also sampled for pest-prey in the following manner:

a) A 25 leaf sample was taken; 5 leaves per tree from 5 trees. Leaves were taken at chest height (1.5 m) and at arms length into the canopy while slowly walking around the tree. The leaf samples were immediately placed into small plastic bags and put into an ice chest. Samples were later processed with a Henderson-McBurnie mite brushing machine and mites were counted with the aid

Figure 1. Limb-tap technique used to collect spiders from apple trees.

of a stereomicroscope.

b) 40 leaf clusters were visually examined; 5 randomly selected clusters from each of 2 limbs of 4 trees. The pests and predators present were recorded as observed.

c) A 3 minute timed count of leafroller larvae was made and recorded for each of 4 trees.

Regular examinations of the foliage, limbs, and tree trunks were made throughout this study. Notes on habitat and predator-prey associations were made. Spiders not represented in previous collections were captured and placed in 70% ethyl alcohol for preservation and further study.

C. Spider Identification

Spiders were identified to the species level if possible by the author. Verifications of representative identifications and further identification of difficult specimens were made by qualified specialists. The general works of Kaston (1948, 1972, 1976) and the specific papers of Dondale (1961a), Dondale and Redner (1968, 1976), Edwards (1958), Gertsch (1939), Levi (1957, 1973), Levi and Randolph (1975), Platnick (1974), and Turnbull et al. (1965) were the primary taxonomic sources consulted. The specimens collected in this study are preserved in 70% ethyl alcohol and the entire collection is permanently housed at the Shenandoah Valley Research Station, Steeles Tavern, Virginia.

4. Results and Discussion

A. Moomau Abandoned Orchard

1) Species: Spiders collected by all methods are listed in Table 1. A total of 13 families, 47 genera, and 68 species were recorded during the two year study. There were 35 species of non-web builders and 33 species of web builders. Many species were only collected once or twice. Others were only collected as immatures and therefore could not be identified beyond the genus or family level.

2) Abundance: The weekly limb-tap samples yielded 1117 spiders (Table 2). Most spiders belonged to the Salticidae, Philodromidae, Theridiidae, Thomisidae, Anyphaenidae, and Dictynidae and together these groups composed 90% of all the spiders collected. There were generally two peaks of abundance observed; one in the spring and the other in late summer to fall. Seasonal population assessments for some of the more common species including *Hentzia* sp., *Metaphidippus galathea*, *Philodromus* sp., *Misumenops oblongus* (Keyserling), *Theridion* sp., *Wulfila saltabunda* (Hentz), and *Dictyna* sp. are summarized in Figures 2-8 respectively.

The last weekly sample of September, 1976 was not collected due to inclement weather. To adjust for this discrepency, an estimate was made by adding the mean of the third September plus first October samples to the previous September samples. It was felt that this would provide a reasonable estimate which would reflect the general trends of the populations at this time.

The immature stages of Hentzia mitrata (Hentz) and H. palmarum could not be distinguished from one another, consequently, they are treated as a species complex. This was also true for Philodromus sp. represented by 5 species, Theridion sp. represented by 3 species, and Dictyna sp. represented by 2 closely related species.

Dondale (1961) has discussed the principal seasonal relationships among spiders from trees and shrubs of the North Temperate Zone. Generally there are two groups to be considered. There are spring-maturing species that overwinter as late instar immatures and become adults in the spring and early summer and there are autumn-maturing species that overwinter as early stage immatures and mature during the following late summer and fall. The adults of the autumn-maturing species die with the onset of winter. In both cases there is only a single generation per year.

Dondale further stated that some species in Nova Scotia exhibited a two year development cycle, for at least a proportion of their populations. He indicated that Philodromus rufus and possibly P. placidus Banks, Theridion differens Emerton, and T. murarium exhibited this phenomenon. All these spider species were represented in this study.

The predominant species in this study orchard appear to be spring maturing (Figs. 2-8). Subadults and adults were primarily associated with the spring and early summer. Late season sampling periods yielded mid to late stage immatures. Other spiders not as common as those already mentioned, but nevertheless prevalent, may

Table 1. Spiders collected from the Moomau abandoned orchard, June, 1976 - September, 1977.

Family, genus, species[a]
Theridiidae
Anelosimus studiosus (Hentz)
Enoplagnatha marmorata (Hentz)
Euryopsis funebris (Hentz)
Spintharus flavidus Hentz
Theridion albidum Banks
Theridion differens Emerton
Theridion murarium Emerton
Theridula opulenta (Walckenaer)
Genus sp.
Linyphiidae
Frontinella pyramitela (Walckenaer)
Meioneta sp.
Micryphantidae
Ceraticelus alticeps (Fox)
Ceraticelus bryantae Kaston
Ceratinopsis nigriceps Emerton
Eridantes erigonoides (Emerton)

Table 1 (continued).

Family, genus, species[a]
Araneidae
Acacesia hamata (Hentz)
Araneus cingulatus (Walckenaer)
Araneus partitus (Walckenaer)
Araneus pegnia (Walckenaer)
Araniella displicata (Hentz)
Cyclosa turbinata (Walckenaer)
Eustala anastera (Walckenaer)
Mastophora hutchinsoni Gertsch
Micrathena gracilis (Walckenaer)
Micrathena sagittata (Walckenaer)
Neoscona arabesca (Walckenaer)
Neoscona hentzi (Keyserling)
Neoscona sp.
Tetragnathidae
Pachygnatna autumnalis Keyserling
Tetragnatha sp.
Agelenidae
Agelenopsis uthana (Chamberlain and Ivie)
Oxyopidae
Oxyopes salticus Hentz

Table 1 (continued).

Family, genus, species[a]
Clubionidae
Chieracanthium inclusum (Hentz)
Clubiona mixta Emerton
Clubiona sp.
Trachelas tranquillus (Hentz)
Anyphaenidae
Anyphaena pectorosa L. Koch
Aysha gracilis (Hentz)
Wulfila saltabunda (Hentz)
Thomisidae
Coriarachne utahensis (Gertsch)
Coriarachne versicolor (Keyserling)
Misumenoides formosipes (Walckenaer)
Misumenops asperatus (Hentz)
Misumenops oblongus (Keyserling)
Synema parvulum (Hentz)
Tmarus angulatus (Walckenaer)
Xysticus funestus Keyserling
Xysticus triguttatus Keyserling

Table 1 (continued).

Family, genus, species[a]
Philodromidae
Philodromus keyserlingi Marx
Philodromus marxi Keyserling
Philodromus minutus Banks
Philodromus placidus Banks
Philodromus rufus vibrans Dondale
Salticidae
Eris aurantia (Lucas)
Eris marginata (Walckenaer)
Evarcha hoyi (Peckham)
Hentzia mitrata (Hentz)
Hentzi palmarum (Hentz)
Maevia inclemens (Walckenaer)
Metaphidippus galathea (Walckenaer)
Phidippus audax (Hentz)
Phidippus clarus Keyserling
Phidippus princeps Peckham
Sitticus floridanus Gertsch and Malick
Talavera minuta Banks
Tutelina elegans (Hentz)

Table 1 (continued).

Family, genus, species[a]
Dictynidae
Dictyna foliacea (Hentz)
Dictyna sublata (Hentz)

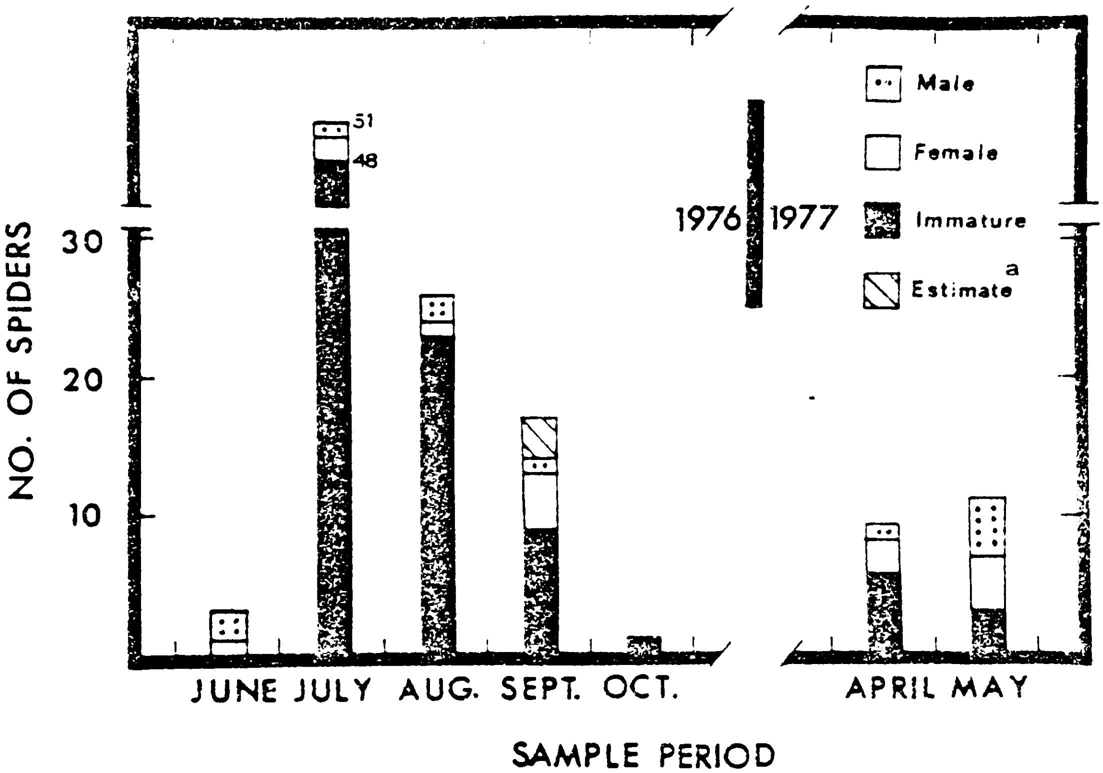
[a] Family names are arranged according to Kaston's (1976) Supplement to the Spiders of Connecticut; genera and species are listed alphabetically.

Table 2. Summary of spider populations, Moomau abandoned orchard, June 1976 - June 1977.

Family	Sample Period									Total	%	Cumulative %
	June (4)[a]	July (4)	Aug. (4)	Sept. (3)	Oct. (4)	Nov.-Mar. (2)	April (4)	May (4)	June (1)			
Salticidae	19	73	70	17	17	0	44	44	2	306	27.4	27.4
Philodromidae	6	27	122	51	17	1	17	19	9	262	23.5	50.9
Thomisidae	19	27	15	20	5	0	16	8	3	119	10.7	61.6
Theridiidae	17	22	33	22	36	5	13	12	3	163	14.6	76.2
Anyphaenidae	5	8	32	17	2	0	7	10	0	81	7.3	83.5
Dictynidae	3	21	30	15	0	0	1	7	0	77	6.9	90.4
Clubionidae	4	17	6	2	0	0	0	6	0	35	3.1	93.5
Araneidae	2	10	9	3	3	3	0	2	2	31	2.8	96.2
Oxyopidae	4	2	6	7	1	0	0	5	0	25	2.2	98.4
Others[b]	2	8	1	2	1	0	2	1	1	18	1.6	100
Total	81	215	324	175	82	6	100	114	20	1117		
$\bar{X}$	20.3	53.8	81.0	58.3	20.5	3.0	25.0	28.5	20			

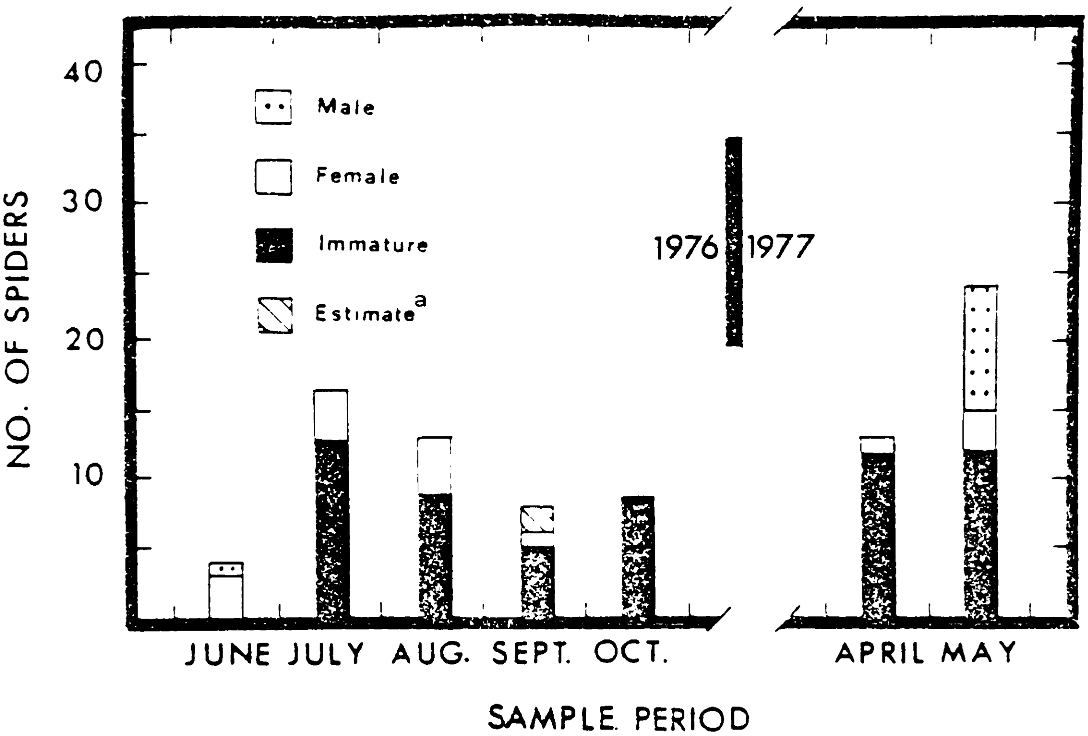
a numbers in parenthesis represent the number of weekly samples.

b Linyphiidae, Micryphantidae, Tetragnathidae, and unidentified.



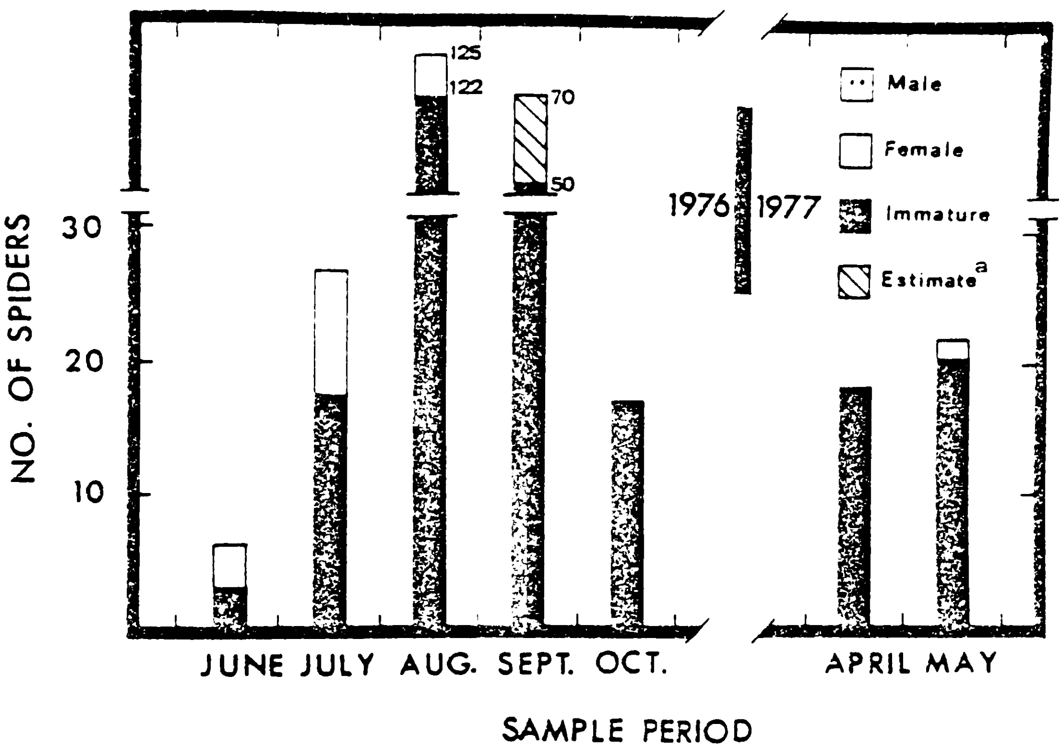
[a] Last weekly Sept. sample not collected due to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 2. Seasonal abundance of Hentzia sp., Moomau abandoned orchard, June, 1976 - May, 1977.



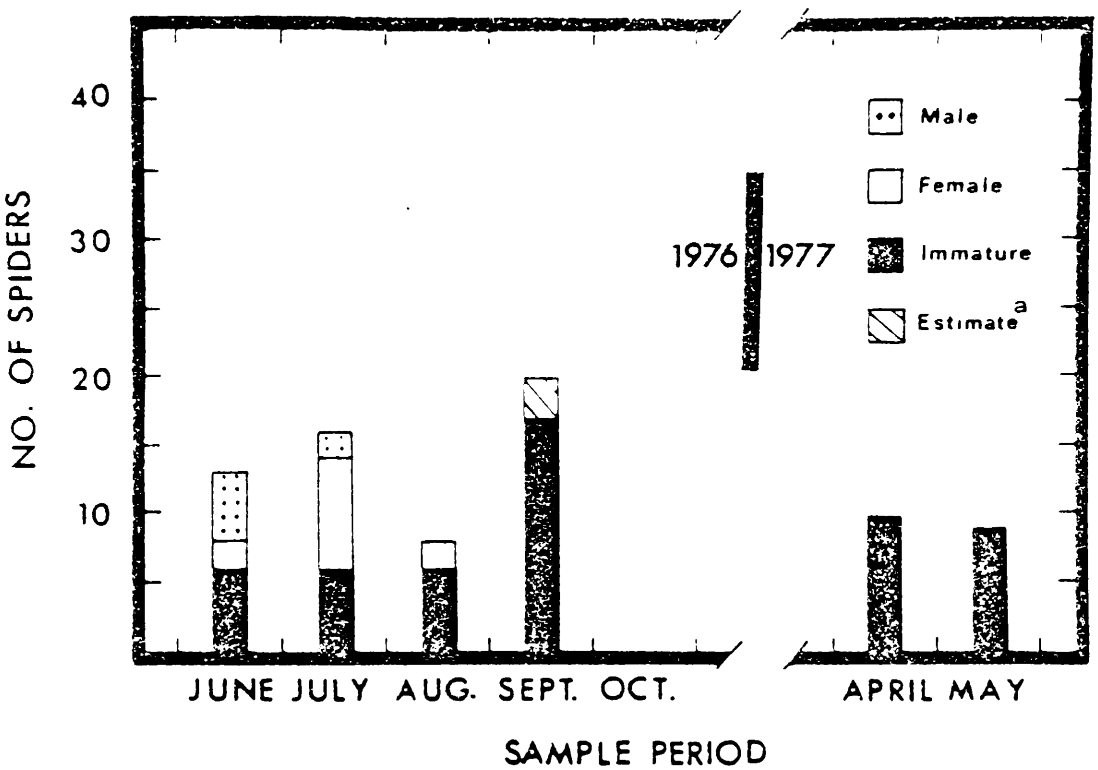
a Last weekly Sept. sample not collected due to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 3. Seasonal abundance of *Metaphidippus galathea* (Walckenaer), Moomau abandoned orchard, June, 1976 - May, 1977.



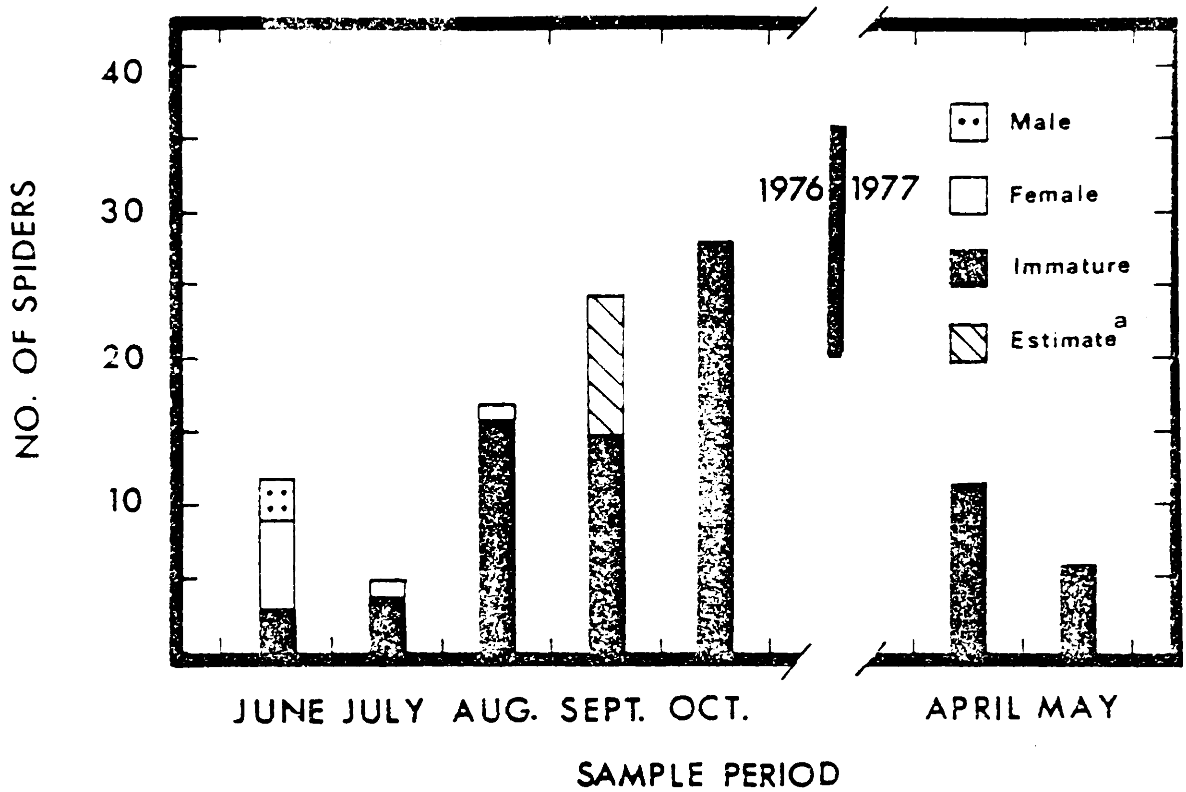
[a] Last weekly Sept. sample not collected due to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 4. Seasonal abundance of *Philodromus* sp., Moomau abandoned orchard, June, 1976 - May, 1977.



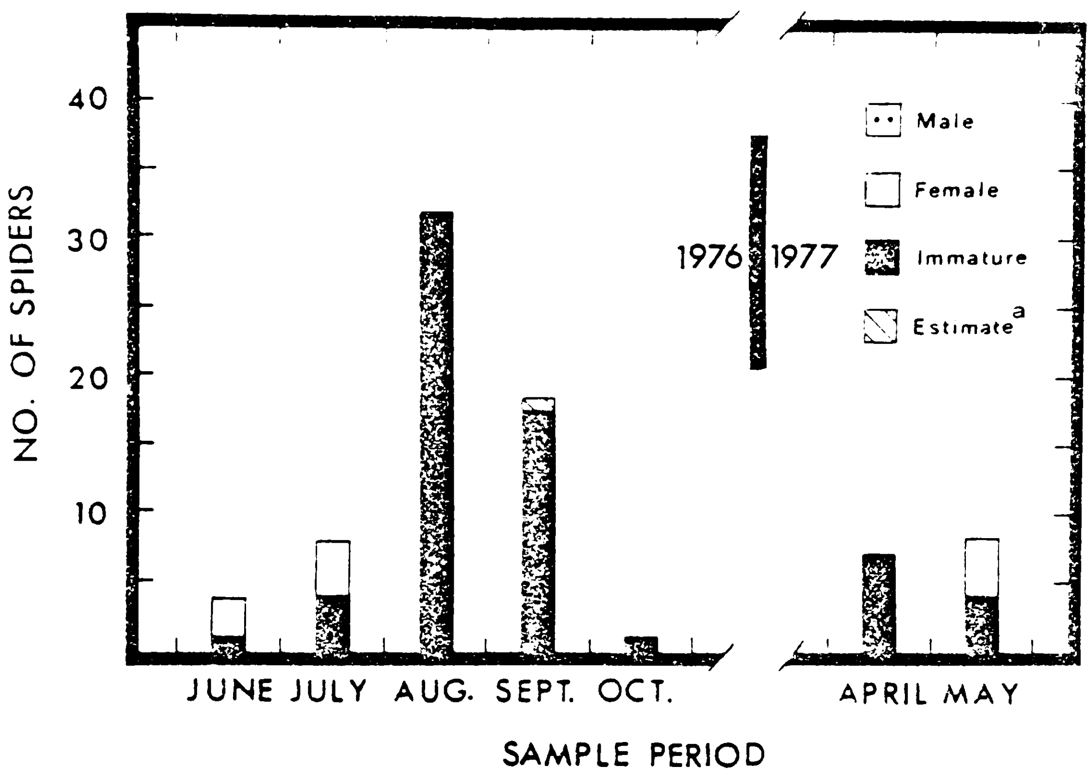
[a] Last weekly Sept. sample not collected due to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 5. Seasonal abundance of Misumenops oblongus (Keyserling), Moomau abandoned orchard, June, 1976 - May, 1977.



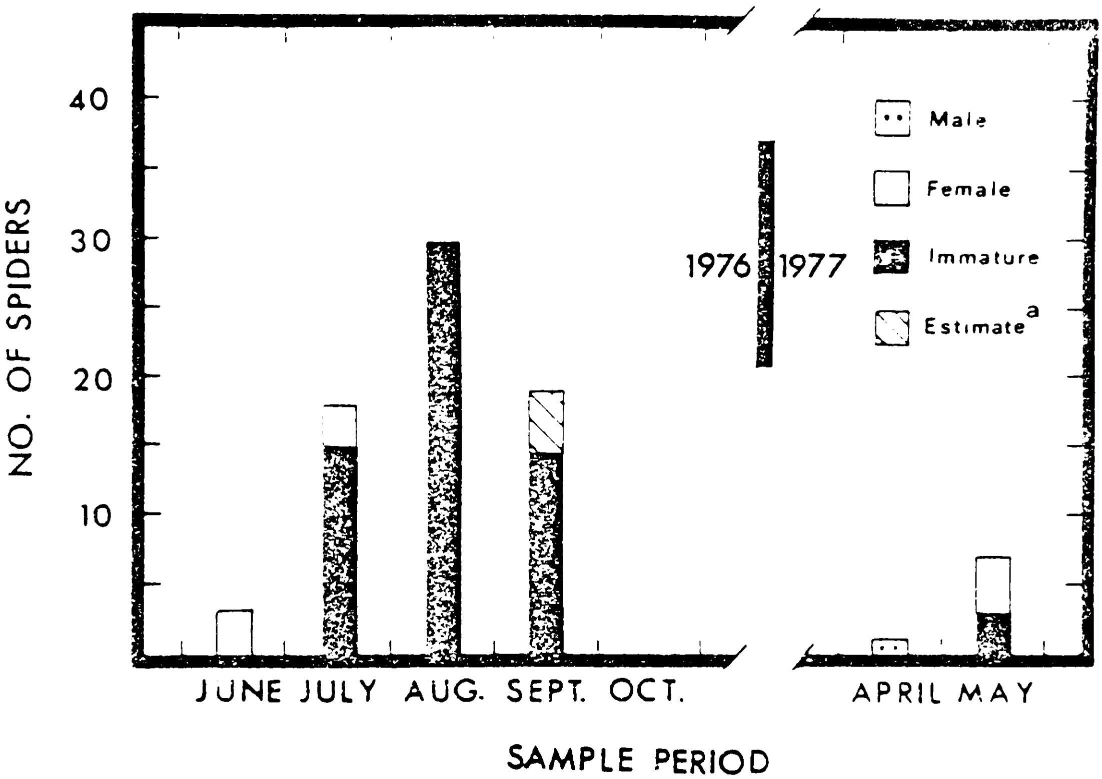
[a] Last weekly Sept. sample not collected due_to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 6. Seasonal abundance of <u>Theridion</u> sp., Moomau abandoned orchard, June, 1976 - May, 1977.



[a] Last weekly Sept. sample not collected due_to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 7. Seasonal abundance of Wulfila saltabunda (Hentz) Moomau abandoned orchard, June, 1976 - May, 1977.



[a] Last weekly Sept. sample not collected due to inclement weather; estimated population = $\bar{X}$ of 3rd Sept. plus 1st Oct. samples.

Figure 3. Seasonal abundance of <u>Dictyna</u> sp. Moomau abandoned orchard, June, 1976 - May, 1977.

be autumn-maturing. These include Misumenoides formosipes (Walckenaer), Misumenops asperatus (Hentz), and Eris aurantia (Lucas).

There is no evidence that indicates a two year developmental period for Virginia spiders. As Dondale (1961) indicates, even in Canada, species that normally require two years to develop are believed to have shorter development times when the growing season is an unusually warm one. The comparatively warmer seasonal temperatures of Virginia may have had this effect.

3) Field and laboratory observations on the habitats and behavior of the common spider species: The field observations were made primarily in the Moomau abandoned orchard; however, unless otherwise noted, they are typical of observations made in the commercial orchards. Notes relating to feeding are only briefly discussed here as more detailed descriptions and prey records will be presented in a later section of this thesis.

a) Salticidae - The salticids or "jumping spiders" are visually oriented, diurnal hunting spiders that search the foliage, branches, and tree trunks for prey. Hentzia mitrata (Fig. 9), H. palmarum (Figs. 10-11), and Metaphidippus galathea (Fig. 12) were the most frequently encountered species. Eris aurantia (Fig. 13), E. marginata, and Phidippus audax (Hentz) were also common. As can be seen in Figures 10-11, there is often considerable sexual dimorphism in this group. This is further complicated by a great deal of color and size variation within a species.

All the aforementioned species have been collected from tall grasses, trees, and shrubs (Kaston 1948; Dondale 1958; Jennings 1976),

Figure 9. Adult female Hentzia mitrata (Hentz), (magnified 8X).

Figure 10. Adult male *Hentzia palmarum* (Hentz), (Magnified 8X).

Figure 11. Adult female Hentzia palmarum (Hentz), (magnified 8X).

Figure 12. Adult female Metaphidippus galathea (Walckenaer), (magnified 8X).

Figure 13. Adult female Eris aurantia (Lucas), (magnified 5X).

and most have been reported from other agroecosystems and apple orchards in other regions.

M. galathea is probably the most completely studied of the salticid species encountered during the study. Horner and Starks (1972) reported on its bionomics and Horner (1972) discussed its potential role as a biocontrol agent of the greenbug (*Schizaphis graminum* (Rondani)) on sorghum in Oklahoma. A similar study conducted by Muniappan and Chada (1970a) indicated *P. audax* as a potential biocontrol agent of the greenbug on barley in Oklahoma.

In the orchard, *M. galathea* as well as other salticids were observed as they searched the apple foliage cluster by cluster in an apparent systematic fashion; moving out from the limb crotch to the periphery. Since this appeared to be a general manner of hunting in the salticids, temporal or prey size differences for each species may have kept competition to a minimum (Enders 1976). On several occasions, interspecific and intraspecific confrontations between spiders of similar size were observed. In all cases, there was a mutual display by leg movements with subsequent fleeing by one or both of the spiders.

M. galathea and *E. aurantia* females were often found on the trees guarding their egg masses which were placed within silken retreats in rolled leaves. The rolled leaves closely resembled the shelters of tortricid leafroller larvae. Horner and Starks (1972) reported that laboratory reared *M. galathea* produced as many as 8 egg masses with an average of 19 eggs per mass. Egg masses of

2 E. aurantia found in the orchard yielded 18 and 20 eggs each.

To determine the overwintering areas of these spiders, leaf litter samples (enough to fill a 2 litre plastic bag) were taken from beneath each of 8 trees in the abandoned orchard in March, 1977. Loose bark was also removed from several limbs. The leaf litter samples were taken to the laboratory and sorted by hand. Subadult M. galathea were found in the leaf litter, but no salticids were found beneath the tree bark. Jennings (1972) reported finding an aggregation of 21 spiders, including P. audax under the bark of a cottonwood tree limb in New Mexico and Kaston (1948) reported finding an aggregation of 30 individuals of P. audax in one small log in Connecticut.

Generally, the salticids were a difficult group to observe. Any efforts to move within a reasonable distance (1-2 m) for observation were noted by the spiders and they would either flee, move to the other side of a leaf or branch, or simply stare back at the observer. Consequently, only limited time was spent observing their behavior.

b) Philodromidae and Thomisidae - The family Philodromidae represented in this study by the genus Philodromus was recently considered a subfamily of the Thomisidae. Their sleek bodies, slender legs of nearly equal size, and other characteristics set them apart from the typical "crab" spiders (Dondale 1976). Spiders of the genus Philodromus lead active predatory lives on the limbs and foliage of woody plants (Kaston 1948; Dondale 1976; Jennings 1976). Many species are endemic to the decidious forest of the eastern United States (Dondale 1976).

Haynes and Sisojevic (1966) and Putman (1967) have described the prey capture technique of three species of Philodromus. Since the thomisids exhibit similar prey capture behavior, the following discussion will also include them. Briefly, there are two positions relating to attack readiness that may be assumed by the spiders when on the limbs or foliage. The first is the attack position in which the front pair of legs are held perpendicular to the longitudinal axis of the body (Fig. 14). The other position is simply the non-attack position where the front pair of legs are held directly in front of the body (Fig. 15). When the spider is unprepared for attack, stimulation received from contact (or possibly vibrations from the prey) usually cause the spider to throw its legs out into the attack position, and it is not until after the second stimulus that the attack is completed. Hungry thomisids usually rest in the attack position. As mentioned earlier, Philodromus tends to be more active and will move along the substrate, tapping their first pair of legs in front of them. Prey contact results in stopping and assumption of the attack position.

The Philodromidae and Thomisidae are generally cryptic in their respective habitats. Misumenops oblongus (Fig. 14), M. asperatus, and Misumenoides formosipes were the most frequently encountered thomisids and they are all known for their ability to vary their color to better conform to the substrate (Gertsch, 1939).

_M_. _oblongus_ collected in this study varied in color from white to greenish yellow. Obviously, this is important with regard to camouflage because in the orchard they are usually associated with the leaves and leaf clusters where they wait to ambush prey. _Philodromus_ sp., (Fig. 15), _Xysticus_ sp., and _Coriarachne_ sp. are mottled with black, brown, and white. They are very difficult to see on a limb or trunk of the tree, but they are very obvious on the foliage. Observations made in the field indicated that _Philodromus_ sp. hunted on both substrates. _Xysticus_ sp. and _Coriarachne_ sp. on the other hand were usually found on the bark.

The biologies of _Philodromus_ sp. and the Thomisids have received little attention. Life history studies have been reported for _P_. _rufus_, _P_. _cespiticolis_, and _P_. _praelustris_ Keyserling by Dondale (1961b) and Putman (1967). The only major study of the thomisids found was that of Muniappan and Chada (1970) on _Misumenops_ _celer_ (Hentz).

Immature _Philodromus_ sp. were found beneath loose bark in March indicating this as a possible overwintering site. No thomisids were found under bark or in leaf litter. More intensive sampling might have yielded more information relating to this matter.

Females of both _Philodromus_ and the thomisids often placed their silken enclosed egg masses on leaves. Sometimes another leaf would be placed over the first to form a cover. Kaston (1948) reported a range of 14-180 eggs per mass for _Misumenoides_ _formosipes_ in Connecticut. He also reported 77 eggs from an egg mass of _Misumenops_ _oblongus_. In general, female philodromids and thomisids rested atop

Figure 14. Adult female Misumenops oblongus (Keyserling) in attack position, (magnified 6X).

Figure 15. Adult female Philodromus sp. in non-attack position, (magnified 7X).

and guarded their egg masses. It was not discerned if they fed at that time.

c) Theridiidae - The "combfooted" spiders are represented primarily by the genus *Theridion* in Virginia orchards. These are relatively small spiders that usually have a somewhat globose abdomen decorated with a folium, as exemplified by *Theridion differens* (Fig. 16).

Chant (1956) discussed the habitat of *T. pallens* Blackwall in England. His description generally fits that of *T. albidum*, a common theridiid observed in this study. These spiders build an irregular web between the undersurface of a leaf and the petioles of its associated leaf cluster. The spider hangs in the web just beneath the leaf surface. *T. differens* was commonly recovered in samples, but its exact habitat was not discerned. Levi (1957) reported both species on low vegetation, grasses, shrubs, and small trees. *T. murarium* was the most abundant species in New Jersey orchards (Specht and Dondale 1960), but it was not commonly collected in this study.

Kaston (1948) reported finding females of *T. differens* with 38-40 eggs per case and *T. albidum* females with 33-68 eggs per case. Overwintering sites are not known for most of these spiders, but they probably use the leaf litter below the trees.

Because of the strategic location in which their webs are placed, *Theridion* sp. exert their greatest influence on small weak flying insects such as alate aphids and small Diptera and Hymenoptera. Several alate aphids were often found in a single web. Turnbull

Figure 16. Adult female Theridion differens Emerton showing folium (A), (magnified 8X).

(1964) reported that the theridiid Achaearanea tepidariorum (C. L. Koch) selected sites for web building without regard to its prey distribution. If selected sites failed to yield an adequate supply of prey they were abandoned; if enough prey were captured the webs were maintained. This type of behavior may be similar to that of the orchard inhabiting species.

d) Anyphaenidae - This family of wandering spiders is represented by two nocturnal and one diurnal species in Virginia orchards. Wulfila saltabunda (Hentz) (Fig. 17) and Anyphaena pectorosa L. Koch are nocturnal while Aysha gracilis (Hentz) is diurnal (Platnick 1974). W. saltabunda was particularly abundant in the Moomau abandoned orchard; however, in another nearby abandoned orchard, A. pectorosa was more numerous. Dondale (1956) reported W. saltabunda and Anyphaena sp. from Nova Scotia orchards. Specht and Dondale (1960) reported Anyphaena celer (Hentz) to be the second most abundant spider in unsprayed orchards, but less abundant in commercial orchards.

Little is known about the biologies or the behavior of any of these species. Kaston (1948) reported 35 and 64 eggs per sac for W. saltabunda, 20-47 eggs per sac for Anyphaena pectorosa, and 134-196 eggs per sac for Aysha gracilis.

Night observations made June 26, 1977 indicated that the activity period for Anyphaena pectorosa commenced immediately following dusk. In fact, there was virtually no activity at 8:30 p.m. when it was just necessary to use a headlamp for observation. At 9:00 p.m. it

Figure 17. Adult female Wulfila saltabunda (Hentz), (magnified 9X).

was dark and a considerable amount of activity was observed.

By directing the main beam of light away from the spiders, it was possible to observe their movements along the limbs and leaves of the trees. Their searching behavior, like that of the salticids, appeared to be systematic. They would walk or run along a limb, tapping their long front legs in front of them. Upon encountering a leaf cluster, they would walk up the petiole of a leaf, then directly down the midvein of the upper surface to the end where they would move to the lower surface and again walk directly down the midvein in the other direction, continually tapping their legs before them. Occasionally a spider would stop at the edge of a leaf before moving to the underside and stretch out its anterior pair of legs beyond the edge of the leaf and remain in this position for a short period of time.

On one occasion during the study period, two adult females were observed to come in contact with one another while moving on the upper surface of the same leaf. Upon being contacted, the first spider immediately dropped by a silk line to a lower limb; no further confrontation was observed. Spiders were still active at 12:30 a.m. when the observations were discontinued.

e) Dictynidae - The dictynids are small sedentary spiders that spin irregular mesh webs to snare their prey (Chamberlain and Gertsch 1958). *Dictyna sublata* (Hentz) and *D. foliacea* (Hentz) were the only members of this group collected with *D. sublata* being collected more often.

D. sublata (Fig. 18) builds its web on the upper surfaces of

Figure 18. Adult female Dictyna sublata (Hentz), (magnified 12 X).

leaves. The edge of the leaf is rolled slightly inwards and held in place by the web. The spider stands on the surface of the leaf. Like the theridiids, the dictynids webs are strategically located and are most effective for the capture of small, weak flying insects such as alate aphids, thrips, Diptera, and Hymenoptera. Laboratory field observations indicate that adult spiders can capture adult tortricid moths. Few adult D. foliacea were found and its habitat was not observed.

Very little is known about the biology of dictynids. Kaston (1948) found that one female D. sublata would deposit several egg masses, often in close proximity to one another. This was also observed during this study. Kaston in one instance found 5 egg masses with 7, 12, 19, 19, and 24 eggs per mass respectively.

No Dictyna sp. were found in leaf litter samples taken in early spring and none were found beneath bark. Kaston (1948) does report that D. sublata overwinters under loose bark, litter, and dead leaves on the ground. Male D. sublata were often seen by the author, roaming the foliage early in the spring, soon after bud-break.

Some limited observations on D. sublata were made in the laboratory during 1977. A female and her recently hatched spiderlings were housed in a clear plastic, one-liter container. Various prey including Musca domestica L. and adult Platynota flavedana Clemens were placed in the cage with the spiders over a period of several days. Upon snaring the prey in her web which was built along the sides and bottom of the container, the mother spider would quickly move to the prey and bite it, often near the cervix. At about the same time, the spiderlings would also move to the prey and bite an appendage or other extremity and hold on as the prey struggled and flailed about. After the prey had been overcome, the female would move away and the spiderlings would feed. Those spiderlings that had not attached earlier would move to the prey at this time and feed. Unfortunately, other responsibilities interrupted further study at this time.

B. Commercial Orchards

1) Species: A combined total of 14 families, 38 genera, and 45 species were recorded from the sprayed orchards (Table 3). Non-web builders were represented by 22 species. Species numbers in individual orchards ranged from 18-28 and there were 16 species common to all orchards.

2) Abundance: The total number of spiders collected from the twice-monthly samples ranged from a low of 69 in the Flippin B block (Table 7) to a high of 186 spiders in the Alexander orchard (Table 4). Proportions varied from one orchard to the next, but the 6 predominant families of the unsprayed orchard still accounted for 75-92% of the total spiders collected in each sprayed orchard (Tables 4-8). Generally there were spring and summer peaks of abundance, but in some orchards (Tables 5, 8) the spring peak was not evident and may have been suppressed by the heavy pesticide use at this time.

Table 3. Spiders collected from commercial apple orchards in Virginia, April - September, 1977

Family, genus, species[a]	Orchards[b]				
	Alexander	Gerling	Flippin		
			A	B	C
Theridiidae					
Enoplagnatha marmorata Hentz	-	-	+	-	-
Euryopsis funebris (Hentz)	-	+	-	-	-
Steatoda americana (Emerton)	-	-	+	-	-
Theridion albidum Banks	+	+	+	+	+
Theridion differens Emerton	+	-	-	-	-
Theridion lyricum (Walckenaer)	-	-	-	+	-
Theridion sp.	+	+	+	+	+
Genus sp.	+	+	+	+	+
Linyphiidae					
Bathyphantes sp.	-	+	-	-	-
Lepthphantes sp.	-	-	-	+	-
Linyphia sp.	+	-	-	-	-
Micryphantidae					
Ceraticelus alticeps (Fox)	+	-	-	-	-
Erigone autumnalis (Emerton)	-	-	-	+	-
Walckenaeria sp.	+	-	-	-	-

Table 3 (continued).

Family, genus, species[a]	Orchards[b] Alexander	Gerling	Flippin A	B	C
Araneidae					
Acacesia hamata (Hentz)	-	+	+	+	-
Araneus sp.	+	+	+	+	+
Araniella displicata (Hentz)	-	-	+	+	-
Eustala anastera (Walckenaer)	-	-	+	-	-
Metapeira labyrinthea (Hentz)	-	+	-	-	-
Neoscona sp.	+	+	+	+	+
Tetragnathidae					
Tetragnatha sp.	-	-	+	-	-
Oxyopidae					
Oxyopes salticus Hentz	+	+	+	+	+
Gnaphosidae					
Genus sp.	-	+	-	-	-
Clubionidae					
Clubiona sp.	+	+	+	+	+
Anyphaenidae					
Anyphaena pectorosa L. Koch	+	+	+	-	+
Aysha gracilis (Hentz)	-	-	-	+	-
Wulfila saltabunda (Hentz)	+	+	-	-	-

Table 3 (continued).

Family, genus, species[a]	Orchards[b] Alexander	Gerling	Flippin A	B	C
Thomisidae					
Misumenoides formosipes (Walckenaer)	+	+	+	+	+
Misumenops asperatus (Hentz)	+	+	+	+	+
Misumenops oblongus (Keyserling)	+	+	+	+	+
Synema parvulum (Hentz)	-	+	-	-	-
Tmarus angulatus (Walckenaer)	+	-	-	+	-
Xysticus funestus Keyserling	-	+	-	+	-
Xysticus sp.	+	+	+	+	+
Philodromidae					
Philodromus sp.	+	+	+	+	+
Salticidae					
Eris aurantia (Lucas)	+	+	+	+	+
Hentzia sp.	+	-	+	+	+
Maevia inclemens (Walckenaer)	+	-	-	-	-
Metaphidippus galathea (Walck.)	+	+	+	+	+
Phidippus audax (Hentz)	+	+	+	+	+
Phidippus princeps Peckham	+	-	-	-	-
Phidippus sp.	+	+	+	+	+
Tutelina elegans (Hentz)	-	+	-	+	-

Table 3 (continued).

Family, genus, species[a]	Orchards[b] Alexander	Gerling	Flippin A	B	C
Dictynidae					
Dictyna sublata (Hentz)	+	+	-	-	-
Uloboridae					
Uloborus sp.	+	-	-	-	-

[a] Family names are arranged according to Kaston's (1976) Supplement to the Spiders of Connecticut; genera and species are listed alphabetically.

[b] + = Present; - = Absent.

Table 4. Summary of spider populations, Alexander commerical orchard, April - September, 1977.

	Sample Period													
	April		May		June		July		Aug.		Sept.	Total	%	Cumulative %
Family	12	29	17	30	12	27	14	27	16	26	29			
Salticidae	4	4	1	0	0	1	3	11	7	7	1	39	20.9	20.9
Philodromidae	2	0	0	0	0	2	0	3	3	2	2	14	7.5	28.4
Thomisidae	2	2	0	1	1	0	4	1	2	4	0	17	9.0	37.4
Theridiidae	0	1	1	1	1	0	0	0	2	0	0	6	3.2	40.6
Anyphaenidae	1	0	0	5	4	4	0	0	0	0	0	14	7.5	48.1
Dictynidae	0	1	0	1	2	4	13	13	16	10	21	81	43.4	91.5
Clubionidae	0	1	0	0	0	0	0	0	0	1	0	2	1.1	92.6
Araneidae	0	0	0	0	0	0	0	0	0	0	0	0	0.0	92.6
Oxyopidae	1	0	0	0	0	0	0	0	0	4	0	5	2.7	95.3
Others[a]	1	0	1	0	1	0	1	0	2	1	2	9	4.7	100.0
Total	11	8	3	8	9	11	21	28	32	29	26	186		

[a] Micryphantidae, Gnaphosidae, Uloboridae, unidentified.

Table 5. Summary of spider populations, Gerling commercial orchard, April - September, 1977.

Family	Sample Period											Total	%	Cumulative %
	April		May		June		July		Aug.		Sept.			
	14	28	17	28	11	26	13	31	17	24	22			
Salticidae	0	0	1	1	3	2	0	1	7	1	6	22	26.2	26.2
Philodromidae	2	0	0	0	0	3	0	1	4	1	8	19	22.6	48.8
Thomisidae	1	0	2	0	1	5	2	2	1	1	2	17	20.2	69.0
Theridiidae	0	0	0	0	1	0	1	0	2	1	1	6	7.1	76.1
Anyphaenidae	0	0	0	0	1	1	0	0	1	0	0	3	3.6	79.7
Dictynidae	0	1	0	0	0	0	0	0	1	0	0	2	2.4	82.1
Clubionidae	0	0	0	1	0	1	0	0	1	0	0	3	3.6	85.7
Araneidae	0	0	0	0	0	0	1	0	0	0	1	2	2.4	88.1
Oxyopidae	0	0	0	0	0	0	0	0	1	0	0	1	1.2	89.3
Others[a]	0	0	0	1	5	0	0	0	0	2	1	9	10.7	100.0
Total	3	1	3	3	11	12	4	4	18	6	19	84		

[a] Linyphiidae, Micryphantidae, Gnaphosidae, unidentified.

Table 6. Summary of spider populations, Flippin integrated block A, September, 1977.

Family	Sample Period										Total	%	Cumulative %
	April	May		June		July		Aug.		Sept.			
	27	12	31	13	30	18	29	10	23	29			
Salticidae	0	4	4	0	3	1	5	4	7	7	31	29.2	29.2
Philodromidae	0	2	2	1	0	0	3	5	4	1	23	21.7	50.9
Thomisidae	0	0	1	1	2	1	4	4	3	6	17	16.0	66.9
Theridiidae	0	3	2	2	0	0	0	2	3	0	12	11.3	78.2
Anyphaenidae	0	0	1	0	0	0	0	0	0	1	2	1.9	80.1
Dictynidae	0	0	0	0	0	0	0	0	0	0	0	0.0	80.1
Clubionidae	0	0	1	2	0	0	0	0	0	0	3	2.8	82.9
Araneidae	2	0	0	1	2	0	1	0	1	0	7	6.6	89.5
Oxyopidae	0	0	0	0	0	1	2	1	3	0	7	6.6	96.1
Others[a]	0	1	0	0	1	0	0	0	2	0	4	3.9	100.0
Total	2	10	7	7	8	3	15	16	23	15	106		

[a] Micryphantidae and Tetragnathidae

Table 7. Summary of spider populations, Flippin integrated block B, April - September, 1977.

Family	April	May		June		July		Aug.		Sept.	Total	%	Cumulative %
	27	12	31	13	30	18	29	10	23	29			
Salticidae	2	2	0	1	0	2	6	2	2	1	18	26.1	26.1
Philodromidae	0	0	0	0	0	0	1	4	2	2	9	13.0	39.1
Thomisidae	2	0	0	0	3	3	5	2	1	3	19	27.5	66.6
Theridiidae	0	0	1	0	0	2	1	2	1	0	5	7.2	73.8
Anyphaenidae	0	0	0	0	0	0	1	0	0	0	1	1.4	75.2
Dictynidae	0	0	0	0	0	0	0	0	0	0	0	0.0	75.2
Clubionidae	0	0	0	1	0	3	0	0	0	0	4	5.8	81.0
Araneidae	0	0	0	0	0	0	1	0	0	0	1	1.4	82.4
Oxyopidae	0	1	0	0	0	3	0	3	0	0	7	10.1	92.5
Others[a]	1	0	0	4	0	0	0	0	0	0	5	7.5	100.0
Total	5	3	1	6	3	13	15	11	6	6	69		

Column group: Sample Period (April through Sept.)

[a] Linyphiidae, Micryphantidae, and unidentified.

Table 8. Summary of spider populations, Flippin commercial block C, April - September, 1977.

	Sample Period												
	April	May		June		July		Aug.		Sept.	Total	%	Cumulative %
Family	27	12	31	13	30	18	29	10	23	29			
Salticidae	0	1	1	0	2	5	5	7	4	8	33	30.6	30.6
Philodromidae	0	0	0	1	1	2	9	1	9	9	32	29.6	60.2
Thomisidae	0	3	0	1	1	2	4	0	3	2	16	14.8	75.0
Theridiidae	0	1	0	0	0	1	1	1	0	0	4	3.7	78.7
Anyphaenidae	0	0	0	0	3	1	1	1	0	0	6	5.6	84.3
Dictynidae	0	0	0	0	0	0	0	0	0	0	0	0.0	84.3
Clubionidae	0	0	1	3	3	0	0	0	0	1	8	7.5	91.8
Araneidae	0	0	0	0	0	0	0	0	0	0	0	0.0	91.8
Oxyopidae	0	0	0	0	0	5	2	1	0	1	9	8.2	100.0
Others	0	0	0	0	0	0	0	0	0	0	0	0.0	
Total	0	5	2	5	10	16	22	11	16	21	108		

3) The Importance of Spiders Relative to Other Predators: Spiders generally comprised over 50% of the total predators collected in the spring and late summer (Tables 9-13). During mid-summer and spring in the case of the Flippin A block, mite and/or aphid populations increased thereby attracting more specific density-dependent predators.

4) The Importance of Spiders in the Suppression of Pest-Prey: Seasonal population assessments of pest-prey and predators are summarized in Tables 9-13. Phytophagous mites and aphids were the primary early season pests while leafroller larvae (*Platynota flavedana* (Clemens), *P. idaeusalis* Walker, and *Argyrotainea velutiana* (Walker)) were predominant in the late summer. The early populations of spiders were low, but as mentioned earlier, they often comprised a large proportion of the predators present at that time. Many spiders have been reported to feed on phytophagous mites even at densities as low as one mite per leaf (Putman, 1967). Therefore, the early spider populations may have been beneficial in suppressing mite populations before the more specific predators immigrated into the area. Late season populations of spiders also may have been important in suppressing mites at a time when they were laying overwintering eggs.

The influence of spiders on the apterous aphids was probably not significant, as most spiders usually do not feed on them (see Section 111). The alate forms, however, are readily accepted

Table 9. Seasonal populations of pests and predators monitored in the Alexander commercial orchard, April - September, 1977.

	Pests or Predators	April 12	April 29	May 17	May 30	June 12	June 27	July 14	July 27	Aug. 16	Aug. 26	Sept. 29	Total
Pests	Panonychus ulmi (Koch)[a,b]	0	0	0	0	ND[i]	0	1.9	0	0	0	0	
	Eriophyidae[c,b]	3.0	6.9	66.6	59.5	ND	323.2	66.6	25.6	9.6	0	0	
	Aphis sp.[d,e]	0	0	0	5	10	0	0	0	0	0	0	
	Dysaphis plantaginea[d,e] (Passerini)	0	2.5	7.5	17.5	5	0	0	0	0	0	0	
	Tortricidae larvae[f,g]	0	0	2	0	1	5	52	44	14	35	0	
Predators	Mite predators[h]	0	0	0	4	3	10	10	7	6	1	2	43
	Aphid predators[h]	0	1	0	0	3	10	1	4	3	1	1	24
	Total spiders[h]	11	8	3	8	9	12	21	28	32	29	26	187
	Total predators[h]	11	9	3	13	21	33	32	39	43	31	30	265
	% of predators represented by spiders	100	88.9	100	61.5	42.9	36.4	65.6	71.8	74.4	93.5	90	70.6

a Acarina: Tetranychidae

b Mites/leaf; 25 leaf sample

c Acarina

d Homoptera: Aphididae

e % infested leaf clusters: total of 40

f Lepidoptera

g Sum of 3 min. visual counts in each of 4 trees

h One tree equivalent limb-tap sample

i No data

Table 10. Seasonal populations of pests and predators monitored in the Gerling commercial orchard, April - September, 1977

	Pests or Predators	Sample Dates											Total
		April		May		June		July		Aug.		Sept.	
		14	28	17	28	11	26	13	31	17	24	22	
Pests	Tetranychus urticae Koch[a,b]	0	0	0	1.8	78.7	5.8	0	0	0.6	0	0	
	Panonychus ulmi (Koch)[a,b]	0	0.6	0	0	0.3	0.6	0	0	0	0	0	
	Eriophyidae[c,b]	0	0	0.2	1.3	21.1	49.0	4.2	44.8	7.4	3.5	0	
	Aphis sp.[d,e]	0	0	5.0	15.0	2.5	0	0	0	0	0	0	
	Dysaphis plantaginea[d,e] (Passerini)	0	0	0	0	0	0	0	0	0	0	0	
	Tortricidae larvae[f,g]	0	0	0	0	0	0	0	0	0	0	0	
Predators	Mite predators[h]	2	1	0	0	62	47	1	16	0	0	0	129
	Aphid predators[h]	1	0	0	2	2	8	0	0	1	0	0	14
	Total spiders[h]	3	1	3	3	11	12	4	4	18	6	19	84
	Total predators[h]	7	2	3	5	75	69	5	23	19	9	20	237
	% of predators represented by spiders	42.9	50.0	100.0	60.0	14.7	17.4	80.0	17.4	94.7	66.7	95.0	35.4

a Acarina: Tetranychidae
b Mites/leaf; 25 leaf sample
c Acarina
d Homoptera: Aphididae
e % infested leaf clusters: total of 40
f Lepidoptera
g Sum of 3 min. visual counts in each of 4 trees
h One tree equivalent limb-tap sample
i No data

Table 11. Seasonal populations of pests and predators monitored in the Flippin integrated block A, April - September, 1977.

	Pests or Predators	April 27	May 12	May 31	June 13	June 30	July 18	July 29	Aug. 10	Aug. 23	Sept. 29	Total
Pests	*Panonychus ulmi* (Koch)[a,b]	0.5	3.5	6.7	4.2	0.6	0.3	0	0.3	0	ND[i]	
	Eriophyidae[c,b]	0.3	5.0	7.7	6.4	4.8	4.2	2.6	10.9	1.3	ND	
	Aphis sp.[d,e]	0	5.0	47.5	22.5	5.0	0	0	0	5.0	0	
	Dysaphis plantaginea[d,e] (Passerini)	0	0	0	0	0	0	0	0	0	0	
	Tortricidae larvae[f,g]	0	1	0	0	0	16	16	19	23	23	
Predators	Mite predators[h]	21	32	25	53	51	17	48	62	0	1	310
	Aphid predators[h]	1	9	43	47	30	8	6	11	4	0	159
	Total spiders[h]	2	10	7	7	8	3	15	46	23	15	106
	Total predators[h]	24	51	75	107	89	28	69	89	27	16	575
	% of predators represented by spiders	8.3	19.6	9.3	6.5	9.0	10.7	21.7	18.0	85.2	93.8	18.4

[a] Acarina: Tetranychidae
[b] Mites/leaf; 25 leaf sample
[c] Acarina
[d] Homoptera: Aphididae
[e] % infested leaf clusters; total of 40
[f] Lepidoptera
[g] Sum of 3 min. visual counts for each of 4 trees
[h] One tree equivalent limb-tap sample
[i] No data

Table 12. Seasonal populations of pests and predators monitored in the Flippin integrated block B, April - September, 1977

	Pests or Predators	Sample Period: April 27	May 12	May 31	June 13	June 30	July 18	July 29	Aug. 10	Aug. 23	Sept. 29	Total
Pests	*Panonychus ulmi* (Koch)[a,b]	0	0	1.0	3.2	0	0	0	0	0	0	
	Eriophyidae[c,b]	5.3	66.1	295.0	182.1	85.1	11.2	7.4	2.2	4.8	0	
	Aphis sp.[d,e]	0	7.5	37.5	27.5	0	0	0	0	5	0	
	Dysaphis plantaginea[d,e] (Passerini)	0	5.0	0	0	0	0	0	0	0	0	
	Tortricidae larvae[f,g]	0	0	1	0	5	10	16	11	16	21	
Predators	Mite predators[h]	5	0	2	37	143	28	40	9	0	0	264
	Aphid predators[h]	0	1	2	5	31	3	0	7	5	0	54
	Total spiders[h]	5	3	1	6	3	13	15	11	6	6	69
	Total predators[h]	10	4	6	48	177	44	56	30	11	6	392
	% of predators represented by spiders	50.0	75.0	16.7	12.5	1.7	29.5	26.8	36.7	54.5	100.0	17.6

[a] Acarina: Tetranychidae

[b] Mites/leaf; 25 leaf sample

[c] Acarina

[d] Homoptera: Aphididae

[e] % infested leaf clusters: total of 40

[f] Lepidoptera

[g] Sum of 3 min. visual counts in each of 4 trees

[h] One tree equivalent limp-tap sample

[i] No data

Table 13. Seasonal populations of pests and predators monitored in the Flippin commercial block C, April - September, 1977.

	Pests or Predators	April 27	May 12	May 31	June 13	June 30	July 18	July 29	Aug. 10	Aug. 23	Sept. 29	Total
Pests	<u>Panonychus ulmi</u> (Koch)[a,b]	0	0.6	0.2	3.8	0.3	0	0	0	0.3	ND[i]	
	Eriophyidae[c,b]	2.6	31.0	93.0	78.4	114.9	14.1	16.0	4.8	5.4	ND	
	<u>Aphis</u> sp.[d,e]	0	0	ND	35.0	15.0	2.5	0	0	0	0	
	<u>Dysaphis plantaginea</u>[d,e] (Passerini)	17.5	2.5	ND	0	0	0	0	0	0	0	
	Tortricidae larvae[f,g]	0	0	0	0	11	43	32	34	24	40	
Predators	Mite predators[h]	6	1	1	40	89	42	20	6	1	0	206
	Aphid predators[h]	1	0	1	4	10	7	7	6	1	0	37
	Total spiders[h]	0	5	2	5	10	16	22	11	16	21	108
	Total predators[h]	7	6	4	49	109	65	49	24	18	21	351
	% of predators represented by spiders	0	83.3	50.0	10.2	9.2	24.6	44.9	45.8	88.9	100.0	30.7

a Acarina: Tetranychidae
b Mites/leaf; 25 leaf sample
c Acarina
d Homoptera: Aphididae
e % infested leaf clusters: total of 40
f Lepidoptera
g Sum of 3 min. visual counts in each of 4 trees
h One tree equivalent limb-tap sample
i No data

by almost all spiders and this is probably of considerable importance, since these forms will eventually disperse to other parts of the orchard and initiate new colonies. This would be an important suppressive factor on the spring generations of *Dysaphis plantaginea* (Passerini) and could play an important regulatory role in the fall when the alate forms return to the trees to lay overwintering eggs.

Leafroller larvae and adults were preyed upon by many species of spiders during both spring and summer generations. Of particular interest was the effective predation on larvae and adults by various salticids, notably *Metaphidippus galathea* and *Phidippus audax*. *M. galathea* matured in the spring and probably exerted its greatest influence at that time. Late instars of *P. audax* moved up into the trees in late summer when leafroller populations were at their height and when they were most damaging to the fruit.

Spearman correlation coefficients (Barr et al. 1976; Sokal and Rohlf 1969) were calculated for the seasonal associations of various prey and spider groups and are summarized in Tables 14-18. A significant correlation does not necessarily indicate a cause and effect relationship, but merely indicates the mutual presence and seasonal fluctuations of specific spider groups and pest-prey. Also, a non-significant correlation does not rule out the possibility of the occurrence of prey and spiders at some important time during the season.

Significant ($p < 0.05$) correlation coefficients were obtained

Table 14. Spearman correlation coefficients for spiders vs. pest-prey and other predators, Alexander commerical orchard, April - September, 1977.

Prey	Spider Groups							
	Salticidae	Philodromidae	Thomisidae	Theridiidae	Anyphaenidae	Dictynidae	Oxyopidae	Total
Panonychus ulmi (Koch)[a]	.00	-.32	.47	-.28	-.23	.25	-.15	.10
Eriophyidae[b]	-.19	-.05	-.42	-.14	-.04	.05	-.51	-.17
Aphis sp.[c]	-.68*	-.48	-.15	.42	.72*	-.25	-.22	-.40
Dysaphis plantagenia[c] (Passerini)	-.64*	-.75*	-.30	.65*	.40	-.63*	-.34	-.83*
Tortricidae larvae[d]	.39	.45	-.09	-.41	-.59	.84*	-.19	.72*
Mite predators	.00	.26	-.03	-.21	.17	.59*	-.44	.44
Aphid predators	.25	.50	-.13	-.12	-.03	.57*	-.34	.53
Other predators	-.43	-.01	-.19	.56	.62*	.06	-.34	.00

[a] Acarina: Tetranychidae
[b] Acarina
[c] Homoptera: Aphididae
[d] Lepidoptera
* $p < 0.05$

Table 15. Spearman correlation coefficients for spiders vs. pest-prey and other predators, Gerling commercial orchard, April - September, 1977

Prey	Spider Groups							
	Salticidae	Philodromidae	Thomisidae	Theridiidae	Anyphaenidae	Dictynidae	Oxyopidae	Total
Tetranychus urticae Koch[a]	.55	-.02	-.10	.12	.82*	.00	.23	.35
Panonychus ulmi (Koch)[a]	.02	-.16	-.05	-.24	.49	.29	-.19	.04
Eriophyidae[b]	.38	-.06	.41	.15	.65*	-.15	.20	.44
Aphis sp.[c]	.09	-.60*	-.27	-.24	.00	-.28	-.19	-.32
Dysaphis plantaginea[c] (Passerini)	.00	.00	.00	.00	.00	.00	.00	.00
Tortricidae larvae[d]	.00	.00	.00	.00	.00	.00	.00	.00
Mite predators	-.13	-.11	.24	-.27	.41	-.20	-.32	.00
Aphid predators	.35	.11	-.11	-.10	.71*	-.08	-.16	.21
Other predators	.04	.54	.40	-.15	-.14	-.41	-.27	.28

[a] Acarina: Tetranychidae
[b] Acarina
[c] Homoptera: Aphididae
[d] Lepidoptera
* $p < 0.05$

Table 16. Spearman correlation coefficients for spiders vs. pest-prey and other predators, Flippin integrated block A, April - September, 1977.

Prey	Spider Groups							
	Salticidae	Philodromidae	Thomisidae	Theridiidae	Anyphaenidae	Dictynidae	Oxyopidae	Total
Panonychus ulmi (Koch)[a]	-.81*	-.53	-.51	.29	.09	.00	-.70*	.59
Eriophyidae[b]	-.42	-.06	.17	.46	-.09	.00	-.12	-.02
Aphis sp.[c]	-.37	-.17	-.18	.59	.19	.00	-.36	-.11
Dysaphis plantagenia[c] (Passerini)	.00	.00	.00	.00	.00	.00	.00	.00
Tortricidae larvae[d]	.87*	.77*	.45	.12	.09	.00	.65*	.76*
Mite predators	-.32	-.11	.30	.05	-.35	.00	-.18	.00
Aphid predators	-.57	-.31	.08	.33	-.01	.00	-.28	-.21
Other predators	.00	.00	.00	.00	.00	.00	.00	.00

[a] Acarina: Tetranychidae

[b] Acarina

[c] Homoptera: Aphididae

[d] Lepidoptera

* $p < 0.05$

Table 17. Spearman correlation coefficients for spiders vs. pest-prey and other predators, Flippin integrated block B, April - September, 1977.

Prey	Spider Groups							
	Salticidae	Philodromidae	Thomisidae	Theridiidae	Anyphaenidae	Dictynidae	Oxyopidae	Total
Panonychus ulmi (Koch)[a]	-.54	-.39	-.62*	.00	-.17	.00	-.32	-.31
Eriophyidae[b]	-.48	-.82*	-.44	.14	-.06	.00	-.16	-.50
Aphis sp.[c]	-.37	-.35	-.88*	.08	-.26	.00	-.20	-.53
Dysaphis plantaginea[c] (Passerini)	.19	-.26	-.42	-.27	-.11	.00	.36	-.35
Tortricidae larvae[d]	.20	.81*	.59	.33	.29	.00	-.05	.54
Mite predators	-.03	-.27	.45	.04	.41	.00	-.05	.31
Aphid predators	-.36	.04	-.19	-.08	-.42	.00	.24	-.08
Other predators	.18	.42	.07	.18	.43	.00	.19	.23

[a] Acarina: Tetranychidae

[b] Acarina

[c] Homoptera: Aphididae

[d] Lepidoptera

* $p < 0.05$

Table 18. Spearman correlation coefficients for spiders vs. pest-prey and other predators, Flippin commercial block C, April - September, 1977.

	Spider Groups							
Prey	Salticidae	Philodromidae	Thomisidae	Theridiidae	Anyphaenidae	Dictynidae	Oxyopidae	Total
Panonychus ulmi (Koch)[a]	-.60	-.29	.13	-.30	-.31	.00	-.73*	-.48
Eriophyidae[b]	-.46	-.35	-.01	-.07	.25	.00	-.39	-.27
Aphis sp.[c]	-.09	.22	.05	-.08	.38	.00	.09	-.05
Dysaphis plantaginea[c] (Passerini)	-.29	-.26	.14	.16	-.20	.00	-.15	-.41
Tortricidae larvae[d]	.92*	.75*	.29	.40	.50	.00	.87*	.84*
Mite predators	-.18	-.09	-.15	.22	.72*	.00	.21	-.11
Aphid predators	.14	.22	-.05	.25	.89*	.00	.36	.25
Other predators	.35	.27	-.04	.10	.05	.00	.00	.22

[a] Acarina: Tetranychidae
[b] Acarina
[c] Homoptera: Aphididae
[d] Lepidoptera
* $p < 0.05$

for leafroller larvae and salticids in two orchards. A 0.87 and 0.92 value was calculated for the Flippin A block (Table 16) and the Flippin C block (Table 18) respectively.

The dictynid, Dictyna sublata was not well represented except in the Alexander orchard where it accounted for ca. 30% of the total predator complex. The seasonal correlation coefficient of this spider to leafroller larvae was also high (0.84, $p < 0.05$), but the biological significance of this association is difficult to assess. The late summer population of D. sublata was represented primarily by early to mid-instar spiderlings, but at this time the leafroller larvae were of the later instars. Because D. sublata is a web builder, it may have been able to capture larger prey. Further observations are needed to confirm or refute this supposition. Adults of D. sublata can capture both larvae and adults of the leafroller and may have exerted some influence on the early pest generations.

Significant, but less important correlations include those of the philodromids and the leafroller populations and the oxyopids and the leafroller populations. At first glance, they appear important, but what is really represented is the coincidence of newly hatched and other early stage spiderlings being present at times when leafroller larvae were probably too large to be effectively preyed upon.

There were significant correlations between spiders and other predators. In the Alexander orchard (Table 14) D. sublata and aphid and mite predators were correlated. The mite predator Leptothrips mali (Fitch) was often found in D. sublata webs. The influence of such interference may be important and deserves further study.

The Anyphaenidae were often correlated with aphid and mite predators. The significance of this is also difficult to assess, because so little is known about these spiders. Generally, their populations were low and they probably exerted little pressure on the other predators.

C. Comparison of the Abandoned and Commercial Orchard Studies: Although the abandoned and commercial orchard studies were undertaken at different times and with different sampling intensities, it is obvious that there were considerably more species and spider numbers in the unsprayed abandoned orchard than any of the commercial orchards studied. Chant (1956), Specht and Dondale (1960), and Legner and Oatman (1964) reported similar findings. Besides the direct toxicity of insecticides, other factors including mechanical disturbance, such as might be induced by the air-blast sprayers, may be important in keeping spider populations low in commercial orchards. There were differences in total spider numbers from one commercial orchard to the next, but because of the differences in tree size, age, and the cultural methods employed by the growers, no attempt will be made at this time to make detailed comparisons of the effects of chemicals on spider populations. Further studies utilizing adequate controls would be necessary to make any conclusive statements regarding this important consideration.

III. EVALUATION OF THE EFFICIENCY OF THE LIMB-BEATING SAMPLING TECHNIQUE FOR ESTIMATING SPIDER POPULATION FROM APPLE TREES.

1. Introduction

Sampling spider populations in trees is difficult. The irregular branching of trees and the diverse habits and habitats of spiders are only a few of the obstacles encountered. The conventional sampling method entails beating tree limbs with a stick over a cloth covered tray. Dislodged spiders are then collected and placed in a preservative. It is generally recognized that this sampling method is inadequate for absolute or basic population estimates of spiders, but few studies have indicated to what extent it is deficient or the factors influencing its efficiency. With this in mind, studies were undertaken to determine: 1) the seasonal efficiency of the limb-beating technique for sampling spiders and 2) the effects of time of sampling on the population estimates of spiders obtained using this technique.

2. Literature Review

Morris (1955) discussed the use of the limb-beating technique for estimating populations of the spruce budworm (*Choristoneura fumiferana* (Clem.)). His major criticism was that the actual proportion of the insects removed from the limbs was not known. Although there have been no definitive studies on the efficiency of the limb-beating sampling method for estimating spider populations from trees, indications of differential susceptability of spiders to capture have been reported.

Putman (1967) found that when sampling spiders from peach trees, free-living species such as the thomisids and salticids were easily dislodged, as were most of the web-building araneids and tetragnathids. The theridiids and dictynids were less efficiently removed and repeated tapping of the limbs often removed additional specimens. Putman also indicated that the efficiency of the sampling technique varied seasonally.

The effects of time of day on the efficiency of the limb-beating sample method have not been studied directly; however, Turnbull (1960) concluded from his study of spider populations associated with oak trees in England that the beating method was biased towards those spiders that were active in the area at the time the samples were taken; resting and hiding areas were not satisfactorily sampled by the beating method. Harris et al. (1972) found that environmental factors such as rain, sky conditions, and temperature could markedly affect the sampling of two insect forest defoliators, Acleris gloverana (Walsingham)(Lepidoptera: Tortricidae) and Melanolophia imitata (Walker)(Lepidoptera: Geometridae,) often differently for each species.

Other methods of sampling arthropods from trees have been investigated with the hope of circumventing the many problems associated with the limb-beating technique. Unfortunately, they too have their deficiencies. Lord (1965, 1968, 1972) considered the leaf cluster as a sample unit common to both predators and prey on apple trees. The active nature of many spiders and the large webs of others prohibits the use of this sample method. There are some small web-builders such as the theridiids and dictynids that are associated with leaves and leaf clusters which may be candidates for this sample unit.

Menzies and Hagley (1977) have described a trap which can be placed on a limb and upon closing will enclose a portion of the limb. Immediately after closure, pyrethrums are sprayed into the trap, the branch and foliage shaken, and the trapped insects removed. This trap would probably impede the movement of many spiders along the limb and there are indications that it may not be efficient for sampling spiders. During their preliminary studies all trapped spiders were not recovered from the traps.

Visual timed counting is another sample method commonly employed in the orchard ecosystem. Spiders tend to be cryptic in their habitat and therefore this sample method is of limited value.

3. Methods and Materials

A. The Seasonal Efficiency of the Limb-beating Technique for Sampling Spiders.

This study was conducted in the Moomau abandoned orchard during the period May to August, 1977. Twice monthly samples were taken using the peripheral linear meter of limb arising from the center of a tree as a sample unit (Lord 1965, 1968). Random samples of two treatments were taken from paired Golden Delicious apple trees as follows:

1) Eight trees, 3 limbs/tree were sampled by the conventional limb-beating technique; each limb received 5 sharp taps with a rubber covered beating stick. Spiders and insects were collected. Immediately after being tapped the limbs were enclosed in a 8.38 cm X 120 cm (211 liter) black plastic bag, cut from the tree, and subsequently examined in the laboratory for any arthropods that may not have been dislodged by the limb beating.
2) Eight trees, 3 limbs/tree were sampled by enclosing each in a 8.38 cm X 120 cm (211 liter) black plastic bag. Each limb was then cut from the tree, examined in the laboratory, and all insects and spiders collected.

In case the limb beating sampling method varied with the person sampling, all limbs were tapped by the same person throughout the study.

To reduce the effects of inter-tree variance (Morris 1955), the same trees were used throughout the study. If limb removal was noticeably affecting the integrity of the trees, an adjacent pair were used in their place.

The total number of leaf clusters were counted for each limb and an average number of leaves per cluster was calculated from 50 randomly selected clusters; 5 clusters from each of 10 limbs. Spiders were identified to the family taxonomic level.

The percent efficiency of capture of the limb-beating technique was calculated for selected spider groups and total spiders. Paired t-tests (Sokal and Rohlf 1969) were used to determine if the number of spiders collected by limb-beating was significantly different from the spider numbers collected by the enclosure or absolute method. All data were subjected to a Kolmogorov-Smirnov test of goodness of fit (Gold 1977; Sokal and Rohlf 1969) to determine if the assumption of normality were met.

Spearman non-parametric correlation coefficients (Barr et al. 1976; Sokal and Rohlf 1969) were determined for the relationship of foliage density (number of leaf clusters/linear meter of limb) and spiders numbers for sampled limbs.

B. The Effects of the Time of Sampling on Spider Population Estimates.

This study was also conducted in the Moomau abandoned orchard. The sample consisted of the spiders dislodged by beating the peripheral linear meter of 50 limbs; 10 limbs each from 5 randomly selected trees of the Jonathan or Stayman cultivar. The limbs were at chest height (1.5 m) and were selected for uniformity while moving around each tree. Samples were taken at 3 h intervals for a 24 h period July 23-24, and August 21-22, 1977. Spiders were identified to the family taxonomic level. At the time of the study, philodromids were still considered part of the Thomisidae and therefore are included under this family grouping. All data were subjected to a Kolmogorov-Smirnov test of normality (Gold 1977; Sokal and Rohlf 1969) prior to statistical analysis. Temperature and relative humidity were recorded at the Shenandoah Valley Research Station ca. 9.6 km south of the study orchard.

4. Results and Discussion

A. The Seasonal Efficiency of the Limb-Beating Technique for Sampling Spiders.

It was the original intent of this study to 1) determine the efficiency of capture of the limb-beating technique and 2) determine if there was a significant difference between the limb-beat population estimate and the enclosure or absolute population estimate. The first objective was completed and will be discussed in more detail later. Completion of the second objective was hampered by several unforeseen problems. First, during the conception of the study, it was assumed that there was a positive relationship between foliage density (the number of leaf clusters/ linear meter of limb) and spider numbers. If this was true, then a correction could be made that would compensate for differences in cluster numbers on limbs, i.e., spiders could be represented as numbers per 100 clusters. Once corrected for foliage density, spider numbers from two limbs could be compared; in this case the spiders dislodged by beating one limb could be compared to a paired limb which was enclosed to represent total capture. However, the Spearman correlation coefficients calculated for leaf cluster numbers and spider numbers from sampled limbs at each sample date were not significant ($p < 0.05$). Since the positive relationship of spider numbers to foliage density could not be conclusively substantiated, compensation of spider numbers for foliage density was questionable. To circumvent this dilemma, it was assumed that the sum of the number of spiders dislodged from a limb by beating and the number remaining on that limb represented total capture of spiders. Since the spiders were collected from the same limb, the cluster numbers would not be relevant.

The second problem encountered was that when the data were considered as spider numbers per limb per sample date, the assumption of normality could not be met. Log and square root transformations of the data did not correct this. Generally, spider numbers were low and there were many limbs with no or few spiders. It was thought that by summing the limb totals per tree that the data would meet the assumption of normality and this proved to be true. Unfortunately, this reduced the degrees of freedom for a paired comparison test from 23 when considering limb totals to 7 when considering tree totals. This in turn reduced the ability of the test to distinguish significant statistical differences between treatments.

The seasonal efficiency of the limb-beating technique was determined for the Salticidae, Philodromidae, and total spiders. The Salticidae was represented early in the season primarily by subadult and adult Metaphidippus galathea, mid-instars of Hentzia sp., early instars of Eris aurantia, and late instars of E. marginata. Mid-season populations were represented by early instar M. galathea, subadult, adult, and early instar Hentzia sp., mid-instar E. aurantia, and early instar E. marginata. Late season populations were composed of mid-instar M. galathea, adult and early instar Hentzia sp., subadult and adult E. aurantia, mid-instar E. marginata, and some late instar Phidippus sp. The seasonal efficiency of the limb-beating method is summarized in Table 19. There were no significant differences ($p < 0.05$) between the limb-beating and the total capture population estimates. High efficiencies of capture were associated with the limb-beating technique throughout the season; the seasonal average was 89%.

The Philodromidae was represented by a complex of possibly five species of Philodromus. Early season populations were represented by mid-instar immatures; mid-season populations were represented by subadult, adult, and some early instar immatures; finally, late season populations were represented by adult, early instar, and some mid-instar immatures. There were no significant differences ($p < 0.05$) between the limb-beating estimate and the total capture estimate of spider populations at any sample date. Except for one sample date, there were high per cent efficiencies of capture associated with the limb-beating technique (Table 20). On July 12, 15 recently hatched spiderlings were found associated with one limb subsequent to beating. They were still closely associated with the silken egg case and had not yet dispersed to other parts of the limb. These plus a few other spiderlings remaining on other limbs reduced the efficiency of capture to 50%. The mean number of spiders per tree for the total capture estimate was twice that of the limb-beating estimate, but the variance

Table 19. Seasonal efficiency of the limb beating sampling method for estimating salticid populations on Golden Delicious apple trees, May - August, 1977.

Date	Mean (± SD) No. Spiders/Tree[a]		% Efficiency Of Capture for The Limb-beat Technique (N)[b]
	Limb-beat Estimate	Total Capture	
May 19	0.50 ± 0.53	0.75 ± 0.46	67 (6)
June 2	0.63 ± 0.52	0.75 ± 0.46	83 (6)
June 21	0.50 ± 0.53	0.63 ± 0.74	80 (5)
July 12	2.88 ± 1.96	3.38 ± 2.33	85 (27)
July 28	3.63 ± 5.71	3.88 ± 6.01	93 (31)
August 16	1.25 ± 0.46	1.25 ± 0.46	100 (10)
August 22	2.00 ± 1.07	2.13 ± 1.25	95 (17)
			$\bar{X}$ = 89 (102)

[a] 8 trees; 3 limb/tree sampled each sample date.

[b] N = Total number of spiders captured from 24 limbs each sample date.

Table 20. Seasonal efficiency of the limb beating sampling method for estimating philodromid populations on Golden Delicious apple trees, May - August, 1977.

Date	Mean ($\pm$ SD) No. Spiders/Tree[a]		% Efficiency Of Capture for The Limb-beat Technique (N)[b]
	Limb-beat Estimate	Total Capture	
May 19	0.50 $\pm$ 1.07	0.63 $\pm$ 1.19	80 (5)
June 2	0.50 $\pm$ 1.07	0.50 $\pm$ 1.07	100 (4)
June 21	0.63 $\pm$ 0.74	0.88 $\pm$ 0.83	71 (7)
July 12	2.50 $\pm$ 2.45	5.00 $\pm$ 5.55	50 (40)
July 28	2.63 $\pm$ 0.74	2.75 $\pm$ 0.89	95 (22)
August 16	3.00 $\pm$ 2.07	3.00 $\pm$ 2.07	100 (24)
August 22	3.00 $\pm$ 1.85	4.00 $\pm$ 2.39	75 (32)
			$\bar{X}$ = 76 (134)

[a] 8 trees; 3 limbs/tree sampled each sample date.

[b] N = Total number of spiders captured from 24 limbs each sample date.

factor was also doubled. This probably accounts for the inability to conclude significant differences between the two population estimates. The average seasonal efficiency of the limb-beating method was 76%.

The seasonal efficiency of the limb-beating sampling method for estimating total spider populations is summarized in Table 21. The predominant family groups represented include the Salticidae, Philodromidae, Thomisidae, Theridiidae, Anyphaenidae, Dictynidae, Clubionidae, Araneidae, and the Oxyopidae. No significant differences ($p < 0.05$) were found between the limb-beating or total capture population estimates. High efficiencies of capture were generally associated with the limb-beating technique. In this case the average seasonal efficiency was 85%.

B. The Effects of the Time of Sampling on Spider Population Estimates.

The effects of time of sampling on population estimates obtained by the limb-beating sampling technique were determined for the Salticidae, Thomisidae, and total spiders and the results are summarized in Table 22. The salticids were represented mostly by early instar spiderlings, but some late instars of *Eris aurantia* and *Phidippus* sp. were present. There were significant differences ($p < 0.05$) in spider numbers between sample periods in July, but not during the normal sampling hours of 6 a.m. - 6 p.m. No significant differences were found between sample periods in August. The thomisids were represented by *Philodromus* sp. (adults and early

Table 21. Seasonal efficiency of the limb beating sampling method for estimating total spider populations on Golden Delicious apple trees, May - August, 1977.

Date	Mean (± SD) No. Spiders/Tree[a]		% Efficiency Of Capture for The Limb-beat Technique (N)[b]
	Limb-beat Estimate	Total Capture	
May 19	2.63 ± 1.51	3.25 ± 2.31	81 (26)
June 2	2.63 ± 2.00	2.75 ± 1.91	95 (22)
June 21	2.63 ± 1.60	3.13 ± 2.17	84 (25)
July 12	7.63 ± 3.81	11.13 ± 7.12	69 (89)
July 28	8.50 ± 6.55	9.00 ± 6.74	94 (72)
August 16	6.38 ± 3.58	6.63 ± 3.96	96 (53)
August 22	6.63 ± 2.50	7.75 ± 2.05	84 (62)
			$\bar{X}$ = 85 (349)

[a] 8 trees; 3 limbs/tree sampled each sample date.

[b] N = Total number of spiders captured from 24 limbs each sample date.

Table 22. Effects of the time of sampling on limb-beat population estimates of spiders on apple trees

Time	Mean No. Salticidae/Tree[a]		Mean No. Thomisidae[b]/Tree		Mean No. Total Spiders/Tree	
	July 23-24	August 21-22	July 23-24	August 21-22	July 23-24	August 21-22
12:00 Noon	7.80[c] a	4.00 a	8.40 a	7.20 a	20.60 a	15.40 a
3:00 P.M.	5.60 ab	4.60 a	10.40 a	5.80 a	22.00 a	14.80 a
6:00 P.M.	5.80 a	3.20 a	7.20 a	4.60 a	17.80 ab	12.40 a
9:00 P.M.	1.00 d	2.60 a	4.80 a	3.60 a	8.60 c	9.00 a
12:00 Midn.	2.20 bcd	1.60 a	4.00 a	4.80 a	9.40 bc	8.60 a
3:00 A.M.	1.80 cd	2.00 a	4.60 a	2.20 a	10.80 bc	7.20 a
6:00 A.M.	3.40 abcd	3.40 a	6.40 a	5.20 a	14.60 abc	13.00 a
9:00 A.M.	4.60 ab	4.40 a	10.40 a	10.00 a	21.60 a	20.40 a

[a] 5 trees; 10 limbs/tree each time period.

[b] Includes Philodromidae

[c] Means followed by the same letter in the same column do not differ significantly ($P < .05$), Duncan's Multiple Range Test.

instars), Misumenops oblongus (adults and early instars), M. asperatus (late instars and adults), Misumenoides formosipes (late instars), and Xysticus sp. (late instars and adults). Significant differences ($p < 0.05$) of spider numbers between sample periods were not found on the July or August sample dates. The category total spiders consists primarily of the Salticidae, Thomisidae, Theridiidae, Anyphaenidae, Dictynidae, Clubionidae, Araneidae, and Oxyopidae. There were significant differences ($p < 0.05$) between sample periods during the July sample date, but as with the Salticidae, no differences were found during the normal sampling hours of 6 a.m. - 6 p.m. No significant differences ($p < 0.05$) were found between any sample periods during the August sample date.

The results of this study indicate that the time of sampling by the limb-beating method has little effect on the population estimates obtained during normal sampling periods. It should be mentioned that this study considered species groups and not individual species. Therefore, the compensatory action of one species to another may mask any true differences in spider activity and the efficiency of the sampling method. Also, the results reflect the activity of only those life stages of the species sampled and do not necessarily reflect that which might be found at different development stages and times. Furthermore, the study was conducted under a limited range of environmental conditions (Table 23) and should be considered within these limitations.

Table 23. Weather data recorded July 23-24 and August 21-22, 1977

	Time (EDT)	Sky Conditions	Temperature (^{o}C)	Relative Humidity (%)
July 23-24	12:00 Noon	Clear	25	34
	3:00 P.M.	Clear	26	36
	6:00 P.M.	Clear	27	30
	9:00 P.M.	Clear	23	50
	12:00 Midn.	Clear	16	70
	3:00 A.M.	Clear	17	60
	6:00 A.M.	Clear	15	70
	9:00 A.M.	Clear	20	50
Aug. 21-22	12:00 Noon	Clear	23	50
	3:00 P.M.	Clear	24	50
	6:00 P.M.	Clear	23	74
	9:00 P.M.	Partly-Clear	18	90
	12:00 Midn.	Overcast	18	90
	3:00 A.M.	Partly-Clear[a]	17	90
	6:00 A.M.	Partly-Clear	18	80
	9:00 A.M.	Clear	18	75

[a] A brief rain shower occurred at ca. 2:00 a.m.; the foliage was only slightly wet.

IV. SPIDER FEEDING STUDIES

1. Introduction

These studies were involved specifically with the determination of acceptable pest-prey of the predominant spider species found in Virginia apple orchards. Feeding by spiders on beneficial insect predators was also investigated.

2. Literature Review

Spiders as a group have in the past been considered indiscriminate, general predators (Comstock 1912; Savory 1928; Gertsch 1949; Kaston 1948). Recent studies, however, have indicated that a spider's size, microhabitat, and behavior dictates what prey will be encountered and effectively captured, thereby allowing for temporal and spatial segregation of a habitat by several spider species (Enders 1975, 1976; Kajak 1965; Turnbull 1960a, 1960b; Waldorf 1976). Whitcomb (1974) has further stated that in agroecosystems, complementary spider niches within a habitat may allow for one pest species to be preyed on in several different ways, by several different spider species. This type of situation has been discussed by MacLellan (1973) in his study of the predators of the light brown apple moth (*Epiphyas postivittana* (Walker)) in Australian apple orchards. Spiders were common and were found throughout the entire apple tree. Many species occupied strategic locations from which to prey on the moth larvae as they moved to feeding sites. Chant (1956) and Putman (1967) also indicated the importance of the complex of spider species preying on phytophagous orchard mites in England and Ontario, Canada respectively.

Other than the aforementioned studies, few investigations have been directed towards understanding spider pest-prey interactions in the orchard environment. Most prey records of orchard spiders have been obtained in conjunction with other studies. Chant (1956) tested insect prey for acceptability to several orchard spiders.

He found that most spiders tested (Theridiidae, Linyphiidae, Erigonidae, and others) fed readily on members of the Homoptera and Hemiptera, including Aphis pomi (DeGeer), Psylla mali (Schmidberger) and Anthocoris nemorum L. As Chant states, the feeding of spiders on Aphis pomi is at variance with Bristowe (1939) who reported that spiders generally rejected aphids as prey. Chant also found that the larger species of spiders fed on insect predators of orchard pests. This was not found to be reciprocated, as no predacious insects were observed to feed on spiders during these studies.

Dondale (1956) reported several spider prey records from Nova Scotian orchards. He found Araniella displicata and Philodromus rufus feeding on Homoptera; Coriarachne lenta (Walckenaer), Misumena vatia (Clerck), Tmarus angulatus (Walckenaer), and Metaphidippus galathea were observed feeding on eye-spotted bud moth larvae (Spilonota ocellana (D & S)); Philodromus cespiticolis was observed to feed on Homoptera and Miridae; and Paraphidippus marginatus was often seen feeding on larvae of Lepidoptera, and on Miridae, Homoptera, and small spiders. Stultz (1955) reported that Agelenopsis sp., Coriarachne versicolor Keyserling, Dictyna sp., Misumena calycina (L.) also fed on the eye-spotted bud moth in Nova Scotian orchards.

Schoene (1932) reported that spiders, including Theridion sp., may have been responsible for reducing caged nymphal populations of the white apple leafhopper (Typhlocyba pomaria McAtee). Schoene also stated that no predacious insects were observed attacking the leafhoppers in Virginia apple orchards. Trammel (1974) categorized spiders as important predators of the white apple leafhopper in in New York orchards.

Smulyan (1920) found alate rosy apple aphids (*Dysaphis plantaginea* (Passerini)) caught in spider webs among the branches and twigs of apple trees in Virginia orchards. He also observed spiders associated with apterous aphids within curled leaves, but he did not find any evidence of feeding by the spiders.

3. Methods and Materials

Laboratory feeding studies were conducted with eight spider species. The methods used were similar to those of Howell and Pienkowski (1971). A single spider was placed in a chamber consisting of a small plastic petri dish (6 x 2 cm) that had small holes drilled in the cover for ventilation. Individual test prey were placed in the chamber. The test spiders were adult females unless otherwise noted and included the following species: *Theridion albidum*, *Anyphaena pectorosa*, *Philodromus placidus*, *Misumenops oblongus*, *Hentzia palmarum*, *Metaphidippus galathea*, *Phidippus audax*, and *Dictyna sublata*. The following prey were offered to each spider species: alate and apterous forms of *Aphis* sp. and *Dysaphis plantaginea*; adult and larvae of the tortricid moth, *Platynota flavedana*; adult leafhoppers (Typhlocybinae); adults of the predacious thrips *Leptothrips mali*; adults of the predacious coccinelid *Stethorus punctum* (Le Conte); and larval *Chrysopa* sp. The potential prey was allowed to remain in the chamber for 48 h. If no feeding was observed within the first test period, it was repeated up to three times with different individual prey. If no feeding occurred it was assumed the insect was not a prey species. Test spiders and prey were obtained from apple trees in abandoned or commercial orchards.

4. Results and Discussion

Alate forms of both aphid species were accepted by all spiders tested (Table 24), often within minutes after being introduced into the test chamber. The apterous forms were not accepted by most spiders. Theridion albidum, Dictyna sublata, and Metaphidippus galathea did capture and feed on the apterous forms, but the two former species fed much more readily than the latter.

Leafroller (Platynota flavedana) adults and larvae were accepted by all spiders except T. albidum and Anyphaena pectorosa. The mid-late instar larvae and adult moths may have been too large for T. albidum to effectively capture. Also, the leafroller larvae, if not disturbed during the first day, would build silken retreats along the sides of the test chamber. This may have reduced the chance for the prey to come in contact with the web of T. albidum and it may have been a barrier to the attack of the nocturnal hunter A. pectorosa.

Leafhopper adults were readily accepted by all test spiders. This test prey species was quite numerous in an abandoned apple orchard where it was observed to be preyed on by several spider species.

The predacious thrips, Leptothrips mali was captured and fed on by T. albidum, M. galathea, and D. sublata. The thrips was often found in the webs of D. sublata in the field. Immatures of several spider species were also tested and found to feed on the thrips. These included Philodromus placidus, Misumenops oblongus,

Table 24. Spider feeding test on pests and beneficial insects associated with apple trees in Virginia orchards.

Spiders	Prey Species[a]: Homoptera: Aphidae *Aphis* sp. - alate	*Aphis* sp. - apterous	*Dysaphis plantaginea* - alate	*Dysaphis plantaginea* - apterous	Lepidoptera: Tortricidae *Platynota flavedana* - adult	*Platynota flavedana* - larvae	Homoptera: Cicadellidae Leafhopper - adults	Thysanoptera: Phlaethripidae *Leptothrips mali* - adults	Coleoptera: Coccinellidae *Stethorus punctum* - adult	Neuroptera: Chrysopidae *Chrysopa* sp. larvae
Theridiidae										
Theridion albidum	X	X	X	X	0	0	X	X	X	0
Anyphaenidae										
Anyphaena pectorosa	X	0	X	0	0	0	X	0	0	0
Philodromidae										
Philodromus placidus	X	0	X	0	X	X	X	I	0	0
Thomisidae										
Misumenops oblongus	X	0	X	0	X	X	X	I	0	0
Salticidae										
Hentzia palmarum	X	0	X	0	X	X	X	I	0	0
Metaphidippus galathea	X	X	X	0	X	X	X	X	0	0
Phidippus audax	X	0	X	0	X	X	X	I	0	0
Dictynidae										
Dictyna sublata	X	X	X	0	X	X	X	X	X	0

[a] X = fed on by adult spiders; 0 = not fed on by adult spiders; I = fed on by immature spiders.

Hentzia palmarum, M. galathea, and Phidippus audax. These findings may be of considerable importance because immature spiders are often quite numerous in orchards, especially during mid and late summer.

Only the web builders T. albidum and D. sublata captured the adult coccinelid Stethorus punctum. It could not be ascertained if feeding did take place, but the beetles were dead before the end of the 48 h test period.

The predacious Chrysopa sp. larvae were not fed on by any of the spiders tested; however, one large larvae fed on two adult M. galathea during the study.

The results of these studies do not necessarily reflect the true range of predation by the spiders species tested. The restricted environment of the test chamber in no way simulates the orchard environment where the rate of successful capture or even encounter of a prey species may be low. These studies merely indicate that a given spider will or will not feed on the particular prey offered. The feeding studies do provide considerable insight into the spider pest-prey and spider insect predator interactions associated with the orchard ecosystem. Further studies with other spider species and prey from the orchard could provide additional useful data for incorporation in pest management programs and should be a fruitful area for future study.

LITERATURE CITED

Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A user's guide to SAS. SAS Institute Inc., Raleigh, N. C. 329 p.

Bristowe, W. S. 1939. The comity of spiders. Vol. I. The Ray Society, London. 228 p.

Chamberlain, R. V., and W. I. Gertsch. 1958. The spider family Dictynidae in America north of Mexico. Bull. Amer. Mus. Nat. Hist. 116: 1-152.

Chant, D. A. 1956. Predacious spiders in orchards in southeastern England. J. Hort. Sci. 31: 35-46.

Comstock, J. H. 1912. The spider book. Doubleday and Co., New York, 721 p.

Croft, B. A. 1975. Tree fruit pest management. Pages 471-507 in R. L. Metcalf and W. Luckman, eds. Introduction to insect pest management. John Wiley & Sons, New York.

Dondale, C. D. 1956. Annotated lists of spiders (Araneae) from apple trees in Nova Scotia. Can. Entomol. 88: 697-700.

Dondale, C. D. 1958. Notes on population densities of spiders (Araneae) in Nova Scotia apple orchards. Can. Entomol. 90: 111-113.

Dondale, C. D. 1961a. Revision of the *aureolus* group of the genus *Philodromus* in North America. Can. Entomol. 93: 199-222.

Dondale, C. D. 1961b. Life histories of some common spiders from trees and shrubs in Nova Scotia. Can. J. Zool. 39: 777-787.

Dondale, C. D. 1966. The spider fauna (Araneida) of deciduous orchards in the Australian Capitol Territory. Aust. J. Zool. 14: 1157-92.

Dondale, C. D., and J. H. Redner. 1968. The *imbecillus* and *rufus* groups of the spider genus *Philodromus* in North America (Araneida: Thomisidae). Mem. Entomol. Soc. Can. 55: 1-78.

Dondale, C. D., and J. H. Redner. 1976. A review of the spider genus *Philodromus* in the Americas (Araneida: Philodromidae). Can. Entomol. 108: 127-157.

Edwards, R. J. 1958. The spider subfamily Clubioninae of the United States, Canada and Alaska. Bull Mus. Comp. Zool. 118: 364-436.

Enders, F. 1975. The influence of hunting on prey size, particularly in spiders with long attack distances (Araneidae, Linyphiidae, and Salticidae). Amer. Natur. 109: 737-763.

Enders, F. 1976. Size, food-finding, and Dyar's Constant. Environ. Entomol. 5: 1-10.

Gertsch, W. J. 1939. A revision of the typical crab-spiders (Misumeninae) of America north of Mexico. Bull Amer. Mus. Nat. Hist. 76: 277-442.

Gertsch, W. J. 1949. American spiders. D. Van Nostrand Co., New York. 285 p.

Gold, H. J. 1977. The KSLTEST procedure. Pages 101-103 in J. T. Helwig, ed. SAS supplemental library user's guide. SAS Institute Inc. Raleigh, N. C.

Hagley, E.A.C. 1974. The arthropod fauna in unsprayed apple orchards in Ontario II. Some predacious species. Proc. Entomol. Soc. Ontario. 105: 28-40.

Harris, J. W. E., D. G. Collis, and K. M. Magar. 1972. Evaluation of the tree-beating method for sampling defoliating forest insects. Can. Ent. 104: 723-729.

Hauschild, K. I., and B. L. Parker. 1976. Seasonal development of the tarnished plant bug on apple in Vermont. Environ Entomol. 5(4): 675-679.

Haynes, D. L., and P. Sisojevic. 1966. Predatory behavior of Philodromus rufus Walckenaer (Araneae: Thomisidae). Can. Entomol. 98: 113-133.

Horner, N. V. 1972. Metaphidippus galathea as a possible biological control agent. J. Kans. Entomol. Soc. 45(3): 324-327.

Horner, N. V., and K. J. Starks. 1972. Bionomics of the jumping spider Metaphidippus galathea. Ann. Entomol. Soc. Amer. 65(3): 602-607.

Howell, J. O., and R. L. Pienkowski. 1971. Spider populations in alfalfa, with notes on spider prey and effects of harvest. J. Econ. Entomol. 64: 163-168.

Hoyt, S. C. 1967. Population studies of five mite species on apple in Washington. Proc. 2nd Internat. Congr. Acarol. 117-133.

Hukusima, S. 1961. Studies of the insect association in crop field XXI. Notes on spiders in apple orchards. Jap. J. Appl. Entomol. Zool. 5: 270-272.

Jennings, D. T. 1972. An overwintering aggregation of spiders (Araneae) on cottonwood in New Mexico. Entomol. News. 83: 61-67.

Jennings, D. T. 1976. Spiders on black walnut. Amer. Midl. Natur. 95(1): 111-119.

Kajak, A. 1965. An analysis of food relations between the spiders Araneus cornutus Clerck and Araneus quadratus Clerck and their prey in meadows. Ekol. Polska Ser. A. 13: 717-764.

Kaston, B. J. 1948. Spiders of Connecticut. Bull. Conn. Geol. Nat. Hist. Surv. 70: 1-874.

Kaston, B. J. 1972. How to know the spiders. 2nd ed. Wm. C. Brown Co., Dubuque, Iowa.

Kaston, B. J. 1976. Supplement to the Spiders of Connecticut. J. Arachnol. 4: 1-72.

Legner, E. F., and E. R. Oatman. 1964. Spiders on apple in Wisconsin and their abundance in natural and two artificial environments. Can. Entomol. 96: 1202-1207.

Levi, H. W. 1957. The spider genera Enoplagnata, Theridion, and Paidisca in America north of Mexico. Bull. Amer. Mus. Nat. Hist. 112: 5-123.

Levi, H. W. 1973. Small orb-weavers of the genus Araneus north of Mexico. Bull. Mus. Comp. Zool. 145: 473-552.

Levi, H. W., and D. E. Randolph. 1975. A key and checklist of American spiders of the family Theridiidae north of Mexico (Araneae). J. Arachnol. 3: 31-51.

Lord, F. T. 1965. Sampling predator populations on apple trees in Nova Scotia. Can. Entomol. 97: 287-298.

Lord, F. T. 1968. An appraisal of methods of sampling apple trees and results of some tests using a sample unit common to insect predators and their prey. Can. Entomol. 100: 23-33.

Lord, F. T. 1972. Comparisons of the abundance of the species composing the foliage inhabiting fauna of apple trees. Can. Entomol. 104: 731-749.

MacLellan, C. R. 1973. Natural enemies of the light brown apple moth Epiphyas postvittana in the Australian Capitol Territory. Can. Entomol. 105: 681-700.

Menzies, D. R., and E.A.C. Hagley. 1977. A mechanical trap for sampling populations of small, active insects. Can. Entomol. 109: 1405-1407.

Morris, R. F. 1955. The development of sampling technique for insect defoliators, with particular reference to the spruce budworm. Can. J. Zool.

Muma, M. H. 1975. Spiders in Florida citrus groves. Florida Entomol. 58(2): 83-90.

Muniappan, R., and H. L. Chada. 1970a. Biological control of the greenbug by the spider Phidippus audax. J. Econ. Entomol. 63: 1712.

Muniappan, R., and H. L. Chada. 1970b. Biology of the crab spider, Misumenops celer. Ann. Entomol. Soc. Amer. 63: 1718:1722.

Platnick, N. 1974. The spider family Anyphaenidae in America north of Mexico. Bull. Mus. Comp. Zool. 146: 205-266.

Putman, W. L. 1967a. Prevalence of spiders and their importance in Ontario peach orchards. Can. Entomol. 99: 160-170.

Putman, W. L. 1967b. Life histories and habits of two species of Philodromus (Araneida: Thomisidae) in Ontario. Can. Entomol. 99: 622-631.

Riechert, S. E. 1974. Thoughts on the ecological significance of spiders. BioSci. 24: 352-356.

Savory, T. H. 1928. The biology of spiders. The Macmillian Co., New York. 376 p.

Schone, W. J. 1932. Leafhoppers injurious to apple trees. Va. Agric. Exp. Sta. Bull. 283. 34 p.

Smulyan, M. T. 1920. The rosy apple aphis. Pages 38-64 in Va. Agric. Exp. Sta. annual report for period ending 1919.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman, San Francisco. 776 p.

Specht, H. B., and C. D. Dondale. 1960. Spider populations in New Jersey apple orchards. J. Econ. Entomol. 53: 810-814.

Stultz, H. T. 1955. The influence of spray programs on the fauna of apple orchards in Nova Scotia. VIII. Natural enemies of the eye-spotted bud moth, Spilonota ocellana (D & S) (Lepidoptera: Olethreutidae). Can. Entomol. 87: 79-85.

Trammel, K. 1974. The white apple leafhopper in New York--Insecticide resistance and current control status. Search Agriculture 4: 1-10.

Turnbull, A. L. 1960a. The spider population of a stand of oak (Quercus robus L.) in Wytham Wood, Berks., England. Can. Entomol. 92: 110-24.

Turnbull, A. L. 1960b. The prey of the spider Linyphia triangularis (Clerck) (Araneae, Linyphiidae) Can. J. Zool. 38: 859-873.

Turnbull., A. L. 1964. The search for prey by a web-building spider Achaearanea tepidariorum (C. L. Koch)(Araneae, Theridiidae). Can. Entomol. 96: 568-579.

Turnbull, A. L. 1973. Ecology of the true spiders (Araneomorphae) Ann. Rev. Entomol. 18. 305-348.

Turnbull, A. L., C. D. Dondale, and J. H. Redner. 1965. The spider genus Xysticus C. L. Koch. in Canada. Can. Entomol. 97: 1233-1280.

Waldorf, E. S. 1976. Spider size, microhabitat selection, and use of food. Amer. Midl. Nat. 96: 76-87.

Whitcomb, W. H. 1974. Natural populations of entomophagous arthropods and their effect on the agroecosystem. Pages 150-163 in F. G. Maxwell and F. A. Harris, eds. Proc. Summer Instit. on Biol. Contr. Plant insects and diseases. University Press Mississippi, Jackson. 647 p.

Appendix 1. Seasonal chemical spray record, Alexander orchard, 1977.

Date	Material	AMT/Hectare
March 30	Dodine 65W	1.68 kg
April 5	Thiram 65W	6.72 kg
April 11	Captan 50W	5.04 kg
	Thiram 65W	1.68 kg
	Phosphamidon 8EC	0.53 litre
May 18; June 7	Dikar 76W®	6.72 kg
	Phosmet 50W	3.36 kg
June 24	Dikar 76W®	6.72 kg
	Phosmet 50W	3.36 kg
	Phosphamidon 8EC	0.53 litre
July 15; Aug. 10	Dikar 76W®	6.72 kg
	Phosmet 50W	3.36 kg
September 5	Captan 50W	6.72 kg
	Zineb 80W	6.72 kg
	Phosmet 50W	6.72 kg

Appendix 2. Seasonal chemical spray record, Gerling orchard, 1977.

Date	Material	AMT/Hectare
March 15	Superior oil 70 sec.	56.12 litre
	Polyram 80W	5.04 kg
March 30	Azinphosmethyl 50W	1.68 kg
	Demeton 6EC	0.44 litre
	Polyram 80W	5.04 kg
April 1	Barium polysulfide	3.36 kg
	Polyram 80W	5.04 kg
April 19	Phosalone 3EC	3.51 litre
	Demeton 6EC	0.44 litre
	Polyram 80W	5.04 kg
May 4	Phosalone 3EC	3.51 litre
	Polyram 80W	5.04 kg.
May 27	Phosalone 3EC	3.51 litre
	Superior oil 70 sec.	7.02 litre
	Benomyl 50W	0.42 kg
June 27	Phesalone 3EC	3.51 litre
	Superior oil 70 sec	7.02 litre
	Tricyclohexylhydroxytin 50W	0.05 kg
	Benomyl 50W	0.42 kg
August 5	Phosalcne 3EC	3.51 litre
	Captan 50W	5.04 kg

Appendix 3A. Seasonal chemical spray record, Flippin orchard - integrated block A, 1977.

Date	Material	AMT/Hectare
March 17	Dodine 65W	1.12 kg
March 25, 30; April 6, 13	Dikar 76W®	2.80 kg
April 20, 27; May 5, 12, 19, 26	Dikar 76W®	2.80 kg
	Phosalone 25W	1.12 kg
June 3, 13, 27; July 8	Dikar 76W®	2.80 kg
	<u>Bacillus thuringiensis</u> Berliner (Thuricide HPC)®	7.02 litre
July 27	Dikar 76W®	2.80 kg
August 9	Dikar 76W®	2.80 kg
	Phosalone 25W	1.12 kg
August 18	Dikar 76W®	280 kg

Appendix 3B. Seasonal chemical spray record, Flippin orchard - integrated block B, 1977

Date	Material	AMT/Hectare
March 17	Dodine 65W	1.12 kg
	Superior oil 70 sec.	37.42 litre
March 25, 30	Benomyl 50W	0.28 kg
	Sup. oil 70 sec.	2.33 litre
April 6, 13	Benomyl 50W	0.28 kg
	Superior oil 70 sec	2.33 litre
	Polyram 80W	1.40 kg
April 20, 29	Benomyl 50W	0.28 kg
	Azinphosmethyl 50W	0.28 kg
June 3	Benomyl 50W	0.28 kg
	Bacillus thuringiensis Berliner (Dipel®)	0.56 kg
	Phosphomidon 8EC	0.29 litre
June 13, 27; July 18	Benomyl 50W	0.28 kg
	Bacillus thuringiensis Berliner (Dipel®)	0.52 kg
July 27	Benomyl 50W	0.28 kg
August 5	Benomyl 50W	0.28 kg
	Phosmet 50W	1.12 kg
August 18	Benomyl 50W	0.28 kg

Appendix 3B. Seasonal chemical spray record, Flippin orchard - commercial block C, 1977

Date	Material	AMT/Hectare
March 15	Captan 50W	1.17 kg
	Thiram 65W	1.17 kg
March 28; April 8	Captan 50W	2.33 kg
	Ferbam 76W	0.70 kg
April 19	Polyram 80W	2.80 kg
April 25	Captan 50W	2.33 kg
	Thiram 65W	0.70 kg
	Azinphosmethyl 50W	0.58 kg
May 2	Captan 50W	2.33 kg
	Thiram 65W	0.70 kg
	Azinphosmethyl 50W	0.58 kg
	Demeton 6EC	0.18 litre

VITA

The author was born April 7, 1951 to Esther and Joseph McCaffrey in Providence, Rhode Island. In 1969 he graduated from Pilgrim High School in Warwick, Rhode Island and entered the Chem Tech program at Rhode Island Junior College. Following his graduation in 1971 with an A.S. degree in Applied Science, the author entered the University of Rhode Island. In 1974 he was awarded a B.A. degree in Biology from that institution. From 1974-1975 he was employed as a developmental research technician for Central Research, Pfizer Inc., Groton, Connecticut. In 1975 he commenced the M.S. degree program in the department of Entomology at VPI & SU.

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SPIDERS ASSOCIATED WITH APPLE TREES IN VIRGINIA WITH NOTES ON THEIR IMPORTANCE IN CONTROLLING ORCHARD INSECT PESTS

by

Joseph Peter McCaffrey

(ABSTRACT)

The species complex and population dynamics of spiders were studied in an abandoned and several commercial apple orchards in Virginia. There were 68 and 45 species found in the abandoned and combined commercial orchards respectively. Species numbers in individual commercial orchards ranged from 18-28. There were 16 species common to all sprayed orchards. Members of the Salticidae, Philodromidae, Thomisidae, Theridiidae, Anyphaenidae, and Dictynidae, together comprised about 90% of the total spiders collected in the abandoned orchard during a one year study. Results from commercial orchards reflected similar findings. Two peaks of spider abundance were usually observed in all orchards; a small one in the spring and a larger one in the late summer-fall. Spiders often represented over 50% of the total predators collected in commercial orchards during the spring and fall. Studies of the association of spiders and various pest-prey indicate that spiders may be important suppressive or regulatory agents especially with regards to aphid and tortricid leafroller populations.

Results of an evaluation of the seasonal efficiency of the limb beating sampling technique indicated that the sampling method was

acceptable for quantitative spider population estimates. The time of sampling did not effect the population estimates of spiders during the normal sampling periods of 6 a.m. - 6 p.m.

Spider feeding tests on insect pests-prey and beneficials showed that one pest species could be preyed upon by a complex of spider species. Beneficial insects such as *Lepthothrips mali* (Fitch) also were susceptable to capture by several spider species.